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Interregional bio-physical connections—A 'footprint family' analysis of Israel's beef supply system

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ABSTRACT

The need to advance bio-physical accounting as a base for sustainability assessment has been acknowledged and advanced in recent years. One approach highly relevant to the 21st century global reality is the 'Footprint'—Ecological, Land, Water and Carbon. While each has merits and limitations, the potential to bring all together under the title of the 'Footprint Family' is emerging. This paper embraces a footprint family approach to analyze beef consumption in the state of Israel over a decade (1999–2010) and explore some tradeoffs between different biophysical components. The research results reveal that on average a tonne of beef consumed in Israel, reflecting a mixture of sources of supply from all over the world requires 9.5 ha of land and 10,000 m^3 of water, mostly for grazing in Latin America (in Brazil and Argentina) but also for growing feed in the U.S and the E.U. Enteric fermentation, manure management, farm operations, shipping and slaughtering generate approximately 19.7 t of CO_2e and the above can be integrated into an ecological footprint figure of approximately 6 global hectares. The paper also demonstrates the utility of inter-regional biophysical accounting at the detailed commodity level. Inter-regional accounting identifies the geographic locations that contribute resources to, and are affected by, the production of specific consumption products. Comprehensive interregional biophysical accounting can be used to generate a better understanding of the complex ecological impacts associated with most consumption products, and the implications of the relationship between these impacts for sustainability.

1. Introduction

A growing public and political awareness of domestic and global environmental issues, of sustainable development as a concept, and the importance of assessing current conditions as well as the effectiveness of existing and emerging measures, has advanced the development of several bio-physical/sustainability accounting approaches. One approach that is receiving increased attention and that is highly relevant to the 21st century global reality, is the 'Footprint'—ecological, land, water and carbon. While each footprint metric has merits and limitations, when brought together they become a powerful tool under the title of the 'Footprint Family' (Galli et al., 2012; Fang et al., 2013, 2014; Ridoutt and Pfister, 2013).

The footprint family has been described as: "a set of indicators—characterized by a consumption-based perspective—able to track human pressures on the surrounding environment, where pressure is defined as appropriation of biological natural resources and CO_2 uptake, emission of GHG's, and consumption and pollution of global freshwater resources" (Galli et al., 2012; page 103). It can be used to identify and assess environmental loads associated with a process, product or system, and this assessment allows for examination of potential bio-physical tradeoffs from proposed policy and other measures (Galli et al., 2012; Giljum et al., 2011; Steen-Olsen et al., 2012).

However, despite recent acknowledgment of the advantages of using the footprint family, most empirical studies have used a single type of footprint accounting. Only a few have attempted to integrate more than a single indicator (for a comprehensive list of studies see Fang et al., 2013). Further, existing studies using any or all of the footprint family members indicators have several characteristics that need to be highlighted in the context of the study presented in this manuscript: (a) while all footprint studies acknowledge any entity's dependence and impact on the local and global environment, only a few studies have separated the footprint into its domestic and global components (e.g., Steen-Olsen et al., 2012; Kastner et al., 2014; Stossel et al., 2014), traced the footprint to specific external geographic locations (e.g., Steen-Olsen et al., 2012; Kissinger and Rees 2009), or quantified the footprint of individual life cycle stages along the commodity chain of a product

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or entity (e.g., production, processing, packing, shipping etc.); (b) most studies provide a snapshot of the footprint in a single year and do not follow processes over a period of time; and (c) most footprint studies have focused on macro and meso geographic scales analyzing the overall footprint of nations or cities, rather than commodities (It is important though to acknowledge that in many cases those studies had to integrate various data on different specific commodities).

We argue here that the significant progress in the development of different bio-physical accounting tools (e.g., Materials Flow Analysis (MFA); Life Cycle Assessment (LCA)), and access to growing quantities of information from new and established national and international data bases, make it possible to advance a full comprehensive footprint family approach, to trace and quantify globally dispersed footprints related to individual consumed commodities and to use that analysis to examine tradeoffs between different components as a means to reduce the overall bio-physical burden embedded in consuming the studied commodity.

One commodity sector that has been completely reshaped through the expansion of global commodity chains is the livestock production system (and subsequently, the role of meat in the diet). The global meat supply system demands the highest inputs of natural resources compared to all other food types, and emits the most greenhouse gases as widely acknowledged in recent years (e.g., Pathak et al., 2010; Mogensen et al., 2009; Steinfeld et al., 2006; Fiala, 2008; Moss et al., 2000). Beef in particular requires the highest quantities of land area and water volume per unit of production compared to other meat products (Weber and Matthews, 2008; Mogensen, et al., 2009; Gerbens-Leenes and Nonhebel, 2002).

This paper embraces a footprint family approach to analyze beef consumption in the state of Israel over a decade. It demonstrates the utility of detailed, comprehensive, commodity level footprint family analysis, and illustrates its potential for use in development of more sustainable consumption. Despite the growing acknowledgment of the beef sector environmental impacts and the growing number of studies analyzing various bio-physical aspects of that commodity, to date very few studies have attempted to examine the footprint of this commodity from a consumption perspective i.e. to analyze the footprint of beef consumed in one region in a way that will capture the unique circumstances of each supplying/exporting region (e.g., climatic condition, availability of land, capital and technology, regulation and management, etc.) and the overall footprint as a mixture of different sources of supply and footprints along several commodity chains.

The case of Israel, and specifically the case of beef supply, illustrates an extreme and rapidly increasing level of reliance on natural capital from external, global sources. The analysis extends beyond the geographic boundaries of Israel to identify and account for natural capital used in different parts of the world to support Israel's demand for beef products. The study illuminates some of the limitations of footprint approaches and the emerging possibilities for overcoming most of them, so that they can be used to generate a better understanding of the complex bio-physical impacts associated with the consumption of most products, and the implications for sustainability.

2. Background

In recent decades continuous processes of population and economic growth, in conjunction with increasing globalization, have resulted in a historically unprecedented extension and thickening of the web of inter-regional and local-global tele-coupled connections (Liu et al., 2007; Kissinger et al., 2011). It is widely being acknowledged that human wellbeing and sustainability depend on the sustainability of ecological systems and on conservation of natural capital (Daly, 1997; Costanza, 1996). In an era in which the world economy is global, local human lifestyles are linked to the natural capital and ecological services of multiple geographic scales: local, regional and global (Stossel et al., 2015; Koellner and van der Sleen, 2011; Giljum and Eisenmenger, 2004).

At present however, while economic integration implies greater 'connectivity' within the global village, the spatial separation of material production (including resource extraction) from consumption, keeps many signals of negative feedback from supporting eco-systems from reaching governments that should be verifying resource flows (e.g., for food security), producers who use raw materials, and from individual consumers (Princen et al., 2002; Dauvergne 2005; Galli et al., 2014). Furthermore, the prevailing system of costs, prices, and market incentives fails to reflect critical ecological scarcity or the appropriate levels of natural capital stocks of different regions (Daly 1997; Rees 1995; Norgaard and Xuemei, 2007).

2.1. Measuring biophysical resources using the footprint family methodology

Footprint studies of all types rely on data from one or more national and international data bases such as those maintained by the FAO, IEA UNFCC, and others. They also rely on tools such as Life cycle assessment (LCA), and Environmental input output analysis (EIOA). In the current footprint literature, the indicators ranked as most important include ecological, carbon, and water footprints (Fang et al., 2014; Galli et al., 2012). Other suggestions for a set of 4 footprint indicators included material, land, water and carbon footprints (European Commission, 2011; Tukker et al., 2014).

One member of this set, the carbon footprint, comprised of the different types of GHG's emissions, namely, carbon dioxide, nitrous oxide, methane, and several fluorinated gases (Pachauri and Reisinger, 2007). The sum of the gases is presented in terms of CO_2 equivalent (CO_2e), also called Global Warming Potential (GWP) (USEPA, 2011).

Next, the ecological footprint (EF, created by Rees (1992) and Wackernagel and Rees (1996), calculates the area of biologically productive land that is needed to produce resources for human consumption and the long term sequestration of population's CO_2 emissions (Galli et al., 2007; Fang et al., 2013). EF aggregates multiple components into a single number that is representative of equivalent land area, called global hectares. Critics of the EF typically challenge the fact that there is no specific geographic dimension to the tool (it does not indicate where this land is actually being used), and that the reduction of multiple criteria to a single number can cause one to lose important details (Kissinger and Gottlieb, 2010).

The land footprint is a variation of the ecological footprint focusing only on its land component. Some have discussed land footprint in terms of global hectares (e.g., Weinzettel et al., 2013). Other calculated the actual land required all over (e.g., Erb, 2004; Kastner et al., 2014) or a place-oriented approach as described in Kissinger and Gottlieb, 2010 and Kissinger, 2013 which calculates the real land (in hectares) used in each country to sustain a product or process.

Finally, the water footprint, introduced by Chapagain and Hoekstra (2004) and Hoekstra and Chapagain (2007), is defined as "the total volume of freshwater that is used to produce the goods and services consumed by the individual or community" (Hoekstra, 2009). Units are expressed in volume of freshwater per year, usually in cubic meters, Under the categories of blue green and grey water.

As highlighted above, several footprint studies rely on data from Environmental Input Output Analysis models (EIOA) and in recent years similar to the approach suggested in this manuscript on