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Integrating Ecological, Carbon and Water footprint into a "Footprint Family" of indicators: Definition and role in tracking human pressure on the planet

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ABSTRACT

In recent years, attempts have been made to develop an integrated Footprint approach for the assessment of the environmental impacts of production and consumption. In this paper, we provide for the first time a definition of the "Footprint Family" as a suite of indicators to track human pressure on the planet and under different angles. This work has been developed under the 7th Framework Programme in the European Commission (EC) funded One Planet Economy Network: Europe (OPEN:EU) project. It builds on the premise that no single indicator per se is able to comprehensively monitor human impact on the environment, but indicators rather need to be used and interpreted jointly. A description of the research question, rationale and methodology of the Ecological, Carbon and Water Footprint is first provided. Similarities and differences among the three indicators are then highlighted to show how these indicators overlap, interact, and complement each other. The paper concludes by defining the "Footprint Family" of indicators and outlining its appropriate policy use for the European Union (EU). We believe this paper can be of high interest for both policy makers and researchers in the field of ecological indicators, as it brings clarity on most of the misconceptions and misunderstanding around Footprint indicators, their accounting frameworks, messages, and range of application.

1. Introduction

1.1. Global environmental changes: an overview

In the last four decades, countries around the world have experienced economic growth, poverty reduction and improved welfare (UNDP, 2006; UNEP, 2007). These changes have been reached at the expense of the planet's ecosystem preconditions and ability to sustain life (Goudie, 1981; Haberl, 2006; Nelson et al., 2006; Rockström et al., 2009). Over the last century, the world population has quadrupled and global resource consumption and waste emissions have grown to a point where humanity now consumes at a faster pace than the Earth can regenerate (Haberl et al., 2007; Hoekstra, 2009; Wackernagel et al., 2002; WWF, 2010).

Forests, particularly in tropical zones, are cut faster than they can regrow (130,000 km^2 of forest have been destroyed per year for the last 15 years) and fishes are caught faster than they can restock (15% of ocean stocks were depleted in the same period) (UNEP, 2007). World average per capita food and services consumption has grown during the last four decades (Turner, 2008); global extraction of natural resources (e.g., biomass, fossil fuels, metal ores, and other minerals) has increased by nearly 45% in the last 25 years (Behrens et al., 2007; Giljum et al., 2009a; Krausmann et al., 2009). Many countries in arid and semi-arid regions of the world (e.g., Central and West Asia, North Africa) are already close to or below the threshold for water scarcity of 1000 m^3 capita^{-1} year^{-1} (Falkenmark, 1989). Greenhouse gas (GHG) emissions are accumulating in the atmosphere (IPCC, 2007a) causing climatic changes and potential negative feedback on the health of ecosystems (Butchart et al., 2010; Haberl, 2006; UNEP, 2007).

The distribution of human-induced pressures is uneven in both its nature (Behrens et al., 2007; Haberl, 2006; Krausmann et al., 2009) and geographic location (Erb et al., 2009; Foley et al., 2005; Giljum et al., 2009a; Haberl et al., 2007; Halpern et al., 2008; Hertwich and Peters, 2009; Hoekstra and Chapagain, 2007; Kitzes et al., 2008a; Niccolucci et al., this issue; Ramankutty and Foley, 1999; Ramankutty et al., 2002; Sutton et al., this issue). On a per capita basis, people in high income countries consume more resources than those in lower income countries. The transition from biomass-driven (agricultural) to fossil-fuel-driven (industrial) soci-

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eties experienced by high income countries (Haberl, 2006; Galli et al., 2011a) has determined a shift in the ecosystem compartments that are now under the highest human-induced pressure.

As scenarios illustrate, these trends will likely continue in the future if measures are not taken. In a business-as-usual scenario, global extraction of natural resources could further grow by more than 50% by 2030 compared to today's situation (Lutz and Giljum, 2009), and humanity's demand on ecological assets (in Ecological Footprint terms) could equal two Earths worth of resources slightly after 2030 (Moore et al., this issue). Up to two-thirds of the world population could experience water scarcity over the next few decades (Alcamo et al., 2000; Vörösmarty et al., 2000) and approximately one billion people could face absolute water scarcity (less than 500 m^3 $capita^{-1}$ $year^{-1}$) by 2025 (Rosegrant et al., 2002).

Empirical measurements have thus to be sought to understand the driving forces behind these impacts and find ways to reduce them while maintaining economic and societal well-being. The EC funded One Planet Economy Network: Europe (OPEN:EU) project, under which this work has been performed, originates from the willingness to enable policy makers to address the objectives of the EU Sustainable Development Strategy (SDS) and other policy strategies to help transform the EU into a One Planet Economy by 2050 (http://www.oneplaneteconomynetwork.org/index.html).

1.2. The need for a set of indicators

Managing the planet's ecological assets is becoming a central issue for decision makers around the world (Best et al., 2008). Integrated ecosystem approaches can potentially best inform decision makers as they enable tackling multiple issues concurrently and help avoid additional costs and/or inadvertently undoing progress in one sector by not accounting for direct and indirect implications of actions in other sectors (Robinson et al., 2006; Turner, 2008). The way human activities are linked to each other and affect different compartments of the planet has to be understood (Vörösmarty et al., 2000; Weisz and Lucht, 2009).

Climate change, for example, is currently seen as the most impending environmental issue deterring societies from sustainability. Unfortunately, in the search for sustainability, decision makers have approached sustainable development through the climate change lens (Robinson et al., 2006), with a smaller focus upon other impacts caused by humanity. Looking at carbon in isolation – rather than a symptom of humanity's overall metabolism of resources – has made us blind to other dangers. The world's appetite for water, food, timber, marine, and many other resources is also relevant with respect to resource limits (Ewing et al., 2010; Fischer-Kowalski and Haberl, 2007; Giljum et al., 2009b; Krausmann et al., 2009; WWF, 2010).

1.3. The need for a consumer approach

If we lived in a world where countries produced and consumed all goods and services within their borders, the distinction between consumption-based and production-based accounting would be unnecessary. But we live in a highly globalized world, where economies of scale and comparative advantage in many areas exist, rendering trade and commerce highly valuable and "responsibility" over impacts much more complex. For instance, given the existing global environmental policy framework (e.g., Kyoto protocol) holding producers rather than final consumers responsible for human impact, a perverse incentive exists for industrialized countries to outsource high-impacting activities to transition economies, where such activities are usually carried out in a cheaper but less eco-efficient way. This is likely to cause an increase in the overall environmental pressure associated with consumption activities as countries tend to import environmentally-inefficient goods and services to sustain their consumption patterns.

After years of debate (i.e., Bastianoni et al., 2004; Lenzen et al., 2007; Peters, 2008), consumption-based accounting (CBA) is becoming increasingly relevant as it provides several opportunities for policy and decision making processes. As highlighted by Wiedmann (2009), CBA is useful in complementing territorial-based approaches by including all driving forces for demands on ecological assets associated with consumption activities. CBA can provide complementary information for the formulation of international environmental policy frameworks, where the participation of developing countries could be favored through the alleviation of competitiveness concerns, thus facilitating international cooperation among developing and developed countries. Finally, CBA can be used to monitor decoupling and design strategies on sustainable consumption and production policies at the national, regional and local levels.

Ecological, Carbon and Water Footprints are able to complement traditional analyses of human demand by coupling producer and consumer perspectives. These indicators present a quantifiable and rational basis on which to begin discussions and develop answers regarding the efficiency of production processes, the limits of resource consumption, the international distribution of the world's natural resources, and how to address the sustainability of the use of ecological assets across the globe (Senbel et al., 2003).

By bringing together Ecological, Carbon and Water Footprints into a single conceptual framework, the aim of this paper is to provide analysts and decision makers with a robust and ready-to-use suite of indicators enabling them to take the first step towards a multidisciplinary sustainability assessment; however, it is not the scope of this paper to create a new indicator. While the analysis performed in this study may highlight areas for potential modifications and improvements of the selected indicators (see Section 4.4), implementing such modifications goes beyond the scope of the OPEN:EU project and this paper.

The remainder of the paper is thus structured as follow: Section 2 provides a description of the 'traditional' Ecological, Carbon and Water Footprint methodologies; Section 3 summarizes their complementary and overlapping properties and defines the "Footprint Family" suite of indicators as in use in the OPEN:EU project; Section 4 gives insight on the potential role of the Footprint Family in the EU policy context and provides information on the limitations and potential future improvements. Final remarks are provided in the conclusion section.

2. Methods

Three indicators have been selected to be included in the Footprint Family for use in the OPEN:EU project: Ecological, Carbon and Water Footprint. Beyond the similarity in name, these three methods were selected because of their scope and research question.

2.1. Ecological Footprint

The Ecological Footprint is a resource and emission[1] accounting tool designed to track human demand on the biosphere's regenerative capacity (Wackernagel et al., 1999a, 2002). It documents both direct and indirect human demands for renewable resource production and CO_2 assimilation and compares them with the planet's ecological assets (biocapacity) (Monfreda et al., 2004; Wackernagel et al., 1999b). In doing so, Ecological Footprint and biocapacity

[1] CO_2 is the only greenhouse gas accounted by the Ecological Footprint method.