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Ecological Footprint: Implications for biodiversity

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ABSTRACT

In October 2010, world leaders gathered in Nagoya, Japan, for the CBD COP10 and agreed on the adoption of new biodiversity targets and new indicators for the period 2011–2020. This represents a positive development. But given the previous failure in achieving the 2010 biodiversity targets, new approaches to implementation as well as relevant measuring and monitoring systems are needed, for this renewed effort to have lasting success in preserving biodiversity.

The need to adopt a comprehensive approach in monitoring biodiversity clearly emerged and it can be seen in the five strategic goals within which the 2020 Aichi Biodiversity targets are classified. Among them, is the strategic goal A, which aims to *address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society*. The aim of this paper is to describe the role of the Ecological Footprint in tracking human-induced pressures on biodiversity thus providing a synthesis of how the Ecological Footprint tool can contribute to the advancement of conservation science. Information is provided on the main features of the Footprint indicator and its dataset, the ongoing work to improve the methodology as well as the geographical (more than 150 countries covered) and temporal coverage (a period of almost five decades) of the Ecological Footprint accounting tool.

1. Introduction

The material well-being of our societies builds on the biosphere's natural capital including the richness of the species that inhabit the planet. However, as several studies have consistently reported, biodiversity is declining at an unprecedented rate and human pressure on ecosystems is among the contributors to this decline (BIP, 2010; Butchart et al., 2010; EEA, 2010; Ellis et al., 2010; Lenzen et al., 2012; Loh et al., 2005; SCBD, 2010; Walpole et al., 2009; Weinzettel et al., 2013).

Butchart et al. (2010) have concluded that, at global level, leaders' efforts to slow or reverse biodiversity decline have not been sufficient and the CBD 2010 biodiversity Targets (CBD, 2006; SCBD, 2003) have not been met: although responses have increased, they have not managed to counteract growing pressures. Multiple reasons have been identified for the failure to deliver on the 2010 Targets. Although the surface of protected areas and FSC certified forests is increasing, an increasing number of policies are being adopted (nationally and internationally) to tackle the issue of invasive alien species and more funding is invested by national governments and international organizations in biodiversity-related aids, clear biodiversity related targets are still lacking and many policies are improperly implemented (Butchart et al., 2010).

Biodiversity is one of the most striking aspects of our planet; nonetheless knowing how many species inhabit Earth remains enigmatic (Mora et al., 2011). Moreover, a global observation system for monitoring biodiversity changes does not exist yet (Pereira et al., 2012) and consistency is lacking at national and regional level in monitoring and sharing frameworks (Pereira et al., 2013). Acknowledging the complexity of developing a global observation system – about 100 indicators have been proposed for the 2020 Aichi Biodiversity Targets (CBD, 2010) – Pereira et al. (2013) have proposed an EBV (Essential Biodiversity Variables) process as starting point for global biodiversity monitoring programs. Undoubtedly a step in the right direction, such EBV process is still lacking a proper focus on pressures on ecosystems and threats to biodiversity as well as measures of the economic significance of biodiversity in decision-making processes. Of the five strategic goals of the 2020 Aichi Biodiversity Targets (CBD, 2010), strategic goal A – "*Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society*" – is by far the least developed one with no agreement about what to monitor and how to monitor it.

The extent of human induced pressures on ecosystems and their potentially debilitating consequences for both the planet's health and society's social and economic stability are hardly

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informing the main political and economic decisions. Trends reported in Butchart et al. (2010) for five selected parameters (Ecological Footprint, nitrogen deposition, alien species, fish stock overexploitation and climate impact) indicate that human-induced pressures have increased over the last few decades. Findings from Rockström et al. (2009) suggest that, because of such increased human pressure, mankind is likely to be already beyond safe operating limits in key planetary systems. The accumulation of human pressure is fundamental to many environmental issues and world leaders face the challenge of selecting appropriate policies and investments to prevent further detrimental effects (Bauler, 2012; Heink and Kowarik, 2010; Moldan et al., 2012).

According to a recent study (McCarthy et al., 2012), reducing the extinction risk of threatened species could cost up to $US 4.76 billion a year, while effectively managing all sites of global conservation significance would cost approximately $US 76.1 billion per year. Efforts to conserve biodiversity have been historically directed towards the protection of habitats and species. However, although fundamental in conservation efforts (Butchart et al., 2012) and potentially capable to supply more regulating services than threatened habitats (Maes et al., 2012), protected areas (PA) may no longer be sufficient in reducing the risk of species' extinction given how fast human pressure is growing. Measuring and monitoring the drivers of human pressure, and thus of biodiversity loss, is therefore necessary and efforts need to be substantially strengthened to address the loss of biodiversity at planetary level for 2020 Aichi Biodiversity Targets to come alive.

A broad range of empirical measurements exists that can be used to identify the driving forces behind impacts and select policies to reduce them while maintaining economic and societal well-being (e.g., Chapin et al., 2009). One of them is the Ecological Footprint, an accounting system for ecosystem services described in this article.

As human demands upon the Earth's ecosystems rapidly increase (Goudie, 1981; Haberl, 2006; Nelson et al., 2006; Rockström et al., 2009), the future ability of the biosphere to provide for humanity and the many other species is being degraded. Barnosky et al. (2012) have argued that a planetary-scale critical transition is approaching because of the many human pressures, and that tools are needed to detect early warning signs and forecast the consequences of such pressures on ecosystems. The Ecological Footprint (Wackernagel et al., 2002) can be one of such tools; however, it is just one of the many pressure indicators in need to be adopted and the variables it measures are just some of those one need to consider when looking at the overall pressure mankind poses on the planet's ecological assets.

The aim of this paper is thus to clearly describe the main research question and the key features of the Ecological Footprint methodology and explain how this metric links to five key mechanisms of biodiversity loss. By providing results about country trends, and giving examples of how Footprint accounts track global (or indirect) pressures on biodiversity, the paper outlines how this tool can be used to complement measures of ecosystem-specific direct impacts on biodiversity.

2. Methodology

2.1. Ecological Footprint and biocapacity: an overview

Pursuing a sustainable approach to human development – which includes avoiding habitats and species loss – requires better understanding the choices before us. For this, policy and decision makers need the knowledge and tools to manage the Earth's ecosystems and ecological assets as well as the pressure human activities pose on them. The Ecological Footprint methodology (Wackernagel et al., 2002) offers a way to measure one key aspect defining the resource dimension of sustainable development. It provides an accounting system that tracks how much of the planet's regenerative capacity humans demand to produce the resources and ecological services for their daily lives and compares that to how much regenerative capacity they have available from existing ecological assets. This accounting tool can be applied globally and at the regional and country level and gives insight on the above by means of two indicators:

- On the demand side, the *Ecological Footprint* measures the biologically productive land and sea area – the ecological assets – that a population requires to produce the renewable resources and ecological services it uses.
- On the supply side, *biocapacity* tracks the ecological assets available in countries, regions or at the global level and their capacity to produce renewable resources and ecological services.

Both Ecological Footprint and biocapacity results are expressed in a globally comparable, standardized unit called "global hectare" (gha) – a hectare of biologically productive land or sea area with world average bioproductivity in a given year (Galli et al., 2007; Monfreda et al., 2004).

Although unable to track every human-related pressure on the biosphere, the Ecological Footprint attempts to capture all demands on the biosphere that compete for space. Demand refers to usage of biologically productive land and sea areas that generate the renewable resources and ecological services that humans demand (Fig. 1). By measuring the demands that compete for biologically productive space, the biocapacity and Ecological Footprint indicators focus on the biomass-based flows of the ecosystems' provisioning services and the waste uptake of its regulating services. Examples of the services quantified by Ecological Footprint accounts and the ecosystem-types providing them include: cropland for the provision of plant-based food and fiber products; grazing land and cropland for animal products; fishing grounds (marine and inland) for fish products; forests for timber and other forest products as well as for sequestration of waste (CO_2, primarily from fossil fuel burning) thus regulating the climate. Built-up surface for shelter and other urban infrastructure is also tracked (Borucke et al., 2013).

A country's Ecological Footprint of consumption (EF_C) is derived by tracking the ecological assets demanded to absorb its waste and to generate all the commodities it produces, plus imports minus exports. It is calculated as shown in equation 1 (see Borucke et al., 2013).

$$EF_C = EF_P + EF_I - EF_E \quad (1)$$

where EF_P is the Ecological Footprint of production and EF_I and EF_E are the Footprints embodied in imported and exported commodity flows, respectively. Since Ecological Footprints are calculated in global hectares, the Ecological Footprint (EF) of each single product i, irrespective of whether it is locally produced, imported or exported, is calculated as in:

$$EF = \frac{P_i}{Y_{W,i}} \cdot EQF_i \quad (2)$$

where P is the amount of each primary product i that is harvested (or carbon dioxide emitted) in the nation; $Y_{W,i}$ is the annual world-average yield for the production of commodity i (or its carbon uptake capacity in cases where P is CO_2); and EQF_i is the equivalence factor for the land use type producing products i.

The Ecological Footprint of consumption (EF_C) indicates the demand for biocapacity by a country's inhabitants while the Ecological Footprint of production (EF_P) indicates the demand for

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