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Footprints to nowhere

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ABSTRACT

Crisp numbers make it to the headlines. However, it is unlikely that a single crisp number can capture a complex issue, such as the analysis of the sustainability of human progress both at the local and the global scale. This paper tackles this standard epistemological predicament in relation to a media-friendly model of man's impact on Nature: the Ecological Footprint (EF). The claim made by the proponents of this analytical tool is that EF makes it possible to check "how much is taken" by the economic process versus "how much could be taken" according to ecological processes. In this paper we argue that the ecological footprint assessment – purportedly useful as an argument against the idea of perpetual growth – is fraught with internal contradictions. Our critical appraisal is based on the lack of correspondence between the semantics – the claim about what the EF accounting does – and the syntax – the EF protocol of accounting that should deliver the purported output. We critically examine the various assumptions used in the approach, showing that the EF is in contradiction with its stated purposes and would lead to paradoxes if its prescriptions were used for policy making. We also contend that the laboriousness of EF computation protocols contrasts with its ultimate fragility. In fact the estimate of carbon footprint due to energy production is what determines the assessment of the planet's deficit of virtual land. We show that this estimate cannot be defended in light of the assumptions and simplifications used for its construction. Our conclusion is that the EF does not serve a meaningful discussion on the modeling of sustainability, and that the same media-friendly narrative about the Earth Overshot day is in the end reassuring and complacent when considering other aspects on man's pressure on the planet and its ecosystems.
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1. Introduction

Crisp numbers make it to the headlines. Thus a poignant way to warn against perpetual economic growth and the plundering of natural resources is by stating '*Our planet is already 50% over-exploited*'. At least, this is the claim made by the Global Footprint Network (GFN) on its website. According to its designers, the Ecological Footprint provides a useful narrative to assess man's impact on earth, be it the lifestyle of a person, the economy of a country or the state of the planet.

Stating a concept under the aegis of a number also makes good marketing, as known to authors of books such as '*29 Leadership Secrets*'. The success of the Ecological Footprint concept is likely associated to the strong social demand for such a product. The proponents of the Ecological Footprint (EF) analysis have successfully filled a gap in the market by designing a straightforward numerical indicator whose simplicity appeals to the media and general public and whose mild verdict has found ready approval with the political establishment. Unfortunately, the simplifications adopted to reach a wide audience come at the cost of the logical coherence of the proposed analytical tool. Indeed, we demonstrate in this paper that the Ecological Footprint, presented as an argument against the idea of perpetual economic growth, depicts in fact a much rosier state of affairs than an ecological analysis would warrant.

The Ecological Footprint analysis has earlier been subject to severe criticism from within the scientific community. This critique has centered on a series of specific logical inconsistencies in the EF protocol and shortcomings in the indications it provides (e.g., Bastianoni et al., 2012; Fiala, 2008; Haberl et al., 2001; Lenzen et al., 2007; Ponthiere, 2009; Tabi and Csutora, 2012; van den Bergh and Grazi, 2010; van den Bergh and Verbruggen, 1999; Wiedmann and Barrett, 2010; Wiedmann and Lenzen, 2007).

In the time window the paper was being reviewed the debate has developed and reached a new high thanks to a paper in PLOS (Blomqvist et al., 2013a). The footprint community reaction was also published (Rees and Wackernagel, 2013) as well as the authors counter conclusion to this (Blomqvist et al., 2013b).

In this paper we go a step further to the same diligent analysis of Blomqvist et and co-workers, and examine the overall weakness of the approach from an epistemological perspective, that is:

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(i) the lack of congruence between the original narrative of the Ecological Footprint and the protocol presently proposed for its quantification; (ii) the consequent incongruence of the quantitative indications provided by the EF index; and (iii) the flaws in the pre-analytical assumptions.

To this purpose, we first present in Section 2 the cultural premises in the field of theoretical ecology against which Wackernagel and Rees developed the original narrative of the EF concept in the early 90s (Rees and Wackernagel, 1994; Wackernagel and Rees, 1996). Then, in Section 3, we analyze the metric currently used in the Ecological Footprint analysis, the factors determining the requirement (human appropriation) and supply (biocapacity) for food and useful biomass, and the carbon footprint. In Section 4 we examine the conceptual flaws in the EF protocol in relation to the "non-energy related" biocapacity. In Section 5 we target the protocol for the quantification of the "energy related" biocapacity measured in the EF protocol in terms of carbon footprint. Finally, in Section 6 we place our findings in the context of the pitfalls and challenges of the production and use of quantitative science for governance and argue that in the present situation of Post-Normal Science (high stakes, urgent decisions, and large doses of uncertainty in complex societal and ecological settings) practitioners and stakeholders alike need to be vigilant that the quality of scientific work is not compromised by the high pressure from society for simple answers and straightforward numbers.

2. The original narrative used to frame the Ecological Footprint Analysis by simplifying theoretical ecology's concepts

In this section we briefly describe the scientific settings and cultural context against which Wackernagel and Rees developed their Ecological Footprint in the 1990s (Rees and Wackernagel, 1994; Wackernagel and Rees, 1996). Well before the introduction of the Ecological Footprint, many theoretical ecologists had made significant progress in the development of quantitative analyses to characterize the impact of human activity on the integrity of ecological processes. Much of this work focused on developing a quantitative representation of the interaction between complex socio-economic systems (human processes) and ecological systems (ecosystem processes). With this interaction taking places simultaneously across two different spatio-temporal scales, scientists inevitably struggled with serious epistemological problems. Not surprisingly then the quantitative approaches put forward all emphasized a careful pre-analytical and theoretical discussion of the nature of the investigated systems (e.g., Margalef, 1968; Odum, 1971, 1983, 1996; Ulanowicz, 1986, 1995, 1997) and converged toward a similar rationale: natural ecosystems are the result of autopoiesis (self-organization stabilized by informed autocatalytic loops) taking place under a set of biophysical constraints – i.e. thermodynamic laws.

This rationale allowed the definition of sets of expected characteristics for different typologies of ecosystems – a natural state for the studied typology. For example, we can now effectively talk of a trophic structure of a tropical forest, a savannah or an aquatic ecosystem. We can also define expected relations between the sizes of individual functional compartments (e.g., carnivores, herbivores) within a selected typology of ecosystem. In the same way, we can predict the volume of water evapotranspirated per unit of standing biomass in given typologies of terrestrial ecosystems. It is within the general context of non-equilibrium thermodynamics and autopoietic systems that concepts such as "ecosystem health" (Cairns et al., 1993; Schaeffer et al., 1988; Waltner-Toews et al., 2008) or "ecosystem integrity" (Kay and Schneider, 1992; Woodley et al., 1993; De Leo and Levin, 1997) become meaningful.

Indeed, the existence of expected benchmarks for typologies of *healthy* ecosystems makes it possible to detect situations of ecosystem stress and/or lack of integrity of ecological elements (i.e., elements operating outside their natural configuration). Within this common frame, various quantitative methods of formalization of indices of stress have been proposed, including:

- *Em*ergy analysis, useful to assess the degree of environmental loading –i.e. assessing the densities of flows per hectare determined by human colonization against the expected densities of flows per hectare associated with the characteristics of ecosystem typologies (Odum, 1971, 1996);
- Indicators based on network theory, such as the concept of ascendency that aims at quantitatively describing the growth and development (biocomplexity) of an ecosystem as a whole – looking at the expected sets of quantitative characteristics of the relations parts/whole (Ulanowicz, 1986, 1995, 1997);
- Extended input/output analysis (embodied analysis), studying the interface of energy and material flows between ecosystems and economies (Herendeen, 1981, 1998);
- Indicators assessing the disturbance to terrestrial ecosystems induced by agricultural production using thermodynamic analysis of water flows per unit of standing biomass (Giampietro and Pimentel, 1991).

All the above approaches share a common semantic framing: (i) they assume that it is possible to define an expected set of characteristics for known typologies of healthy (i.e., undisturbed) ecological systems; (ii) these benchmarks are then used as a yardstick against which the degree of disturbance found in specific situations (instances of disturbed ecosystems) is measured. Thus, these quantitative analyses are based on two numerical assessments of "flow" characteristics (e.g., kg of biomass of a given element per ha/year) that are associated with the identity of ecosystems. These two assessments refer to two clearly defined *external referents*: (i) the expected characteristics of natural flows in a given typology of undisturbed ecosystem (Φ_{NAT}) and (ii) the measured characteristics of actual flows in a given instance of altered ecosystem, i.e., the system to be assessed for ecological compatibility (Φ_{ACT}).

For instance, an expected flow rate of biomass in a healthy ecosystem (Φ_{NAT}) can be contrasted against a measured, actual flow rate of biomass in the system under analysis (Φ_{ACT}). In this way one can obtain a quantitative indication of the degree of alteration ("stress") by measuring the discrepancy between the actual, measured state (Φ_{ACT}) and the expected state for that typology of ecosystem (Φ_{NAT}). Or, alternatively, starting from the size of a particular element of an ecosystem, known to perform a given function, one can calculate the corresponding size of ecosystem that would be required to respect the natural pattern of organization (like estimating the body size of a pre-historic man from the size of the skull). Quantitative applications of this approach are illustrated in Box 1 and have been explained in detail elsewhere (Giampietro and Pimentel, 1991).

When first presenting their innovative approach – the ecological footprint analysis – Rees and Wackernagel relied on the scientific premises just described by referring to the concept of *natural capital* (Rees and Wackernagel, 1994). They built on the idea put forward by Ecological Economics (Daly, 1990) using the concept of *strong sustainability*: Given that manufactured capital cannot substitute for natural capital (manufactured capital and natural capital are complements of each other) anyone interested in sustainability should have a method to monitor the preservation and reproduction of natural capital in relation to the flows of natural resources

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