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Letter to the Editor

Footworking in circles

Reply to Goldfinger et al. (2014) "Footprint Facts and Fallacies: A Response to Giampietro and Saltelli (2014) Footprints to nowhere"

With eleven sections plus an introduction and a conclusion, Goldfinger et al. (2014) thoroughly dispose of our case on the inadequacy of the ecological footprint (Giampietro and Saltelli, 2014) published on this journal. We identify circularity and contradiction in the argument of Goldfinger et al. (2014) and consolidate our case on the lack in coherence between the EF ambition to quantification and its evanescent architecture. We find confirmation of the non-relevance and counter productivity of this measure for policy consumption.

1. Introduction

The 'Letter to the Editor' of Goldfinger et al. (2014) devotes eleven sections plus an introduction and a conclusion to defend the merit of the ecological footprint (EF) against our criticism (Giampietro and Saltelli, 2014) published on this journal after one round of revision. Reading this long letter, the question is legitimate of what happened of the review process if so many misunderstandings of the EF seeped into the final version of our work. In fact a careful analysis of the EF defense reveals circularity and contradiction.

To an external reader – to a user of the EF, the situation might seem around an academic debate between different schools. There was a critique of the EF to which the EF proponents thoroughly replied. At the bottom-line, one might conclude, some skeptics do not like the EF but this is part of normal scientific and academic controversy. The EF can be retained as one among others measures partly contributing to the debate on sustainability.

In the present text we try to dispel this conclusion by insisting in the lack on coherence between the EF ambition to quantification and its evanescent accounting style. The EF produces numbers which, rather than being affected by uncertainty, are devoid of an external reference, and consequently of no descriptive value. We conclude on the non-relevance and counter productivity of this measure for policy consumption. Table 1 offers an itemized reply to the thirteen sections of Goldfinger et al. (2014).

1.1. The EF is inconsistent with its stated purpose of measuring demand on ecosystems

According to Goldfinger and co-authors of the Global Footprint Network (GFN), the EF research question has been misunderstood – this is detailed in pages 1–5, then again in the conclusions. We learn that the EF is not meant for sustainability, nor to measure alteration to the ecosystem. Instead '*it documents current demand and compares it with current supply* '.

Goldfinger et al.'s letter appears conflicting in different assertions: first it states "*it is shown that the Footprint reflects the productivity of actual rather than hypothetical ecosystems . . .* " (page 1), and afterwards that "*Tracking impacts on ecosystem productivity is certainly relevant for sustainability assessments, but Ecological Footprint accounts are not designed to measure this aspect*" (page 5). This exemplifies GFN's contradiction: how is it possible to construct a system in which virtual land is designed to absorb gas emissions without somehow considering the impact that different hypothetical ecosystem productivities would have on it?

It is said that "*By providing measures that are directly observable, results become more robust and are subject to empirical verification*" (page 8). What part of the EF can be empirically verified if the measure of captured CO_2 is estimated on the base of virtual land?

Arguments put forward to defend the EF construct help to deconstruct it, e.g., "*sequestration rates are calculated from average forest sequestration capacity [. . .], because reliable data is not available on carbon sequestration other than forest*" (page 12). Does this assumption take into account that only 31% of the Earth's surface actually possesses the necessary characteristics (and then status) of a forest, and that net sequestration rates vary significantly from zone to zone? The EF number could be made to oscillate over several orders of magnitude either way from its reported value by plausible (within the developers' framework) variation of its input assumption.

1.2. The EF depends mostly from a dimensionally flawed energy emissions assessment

Confronted with the critique of Giampietro and Saltelli (2014) that one cannot offset a flow with a stock (an area in fact), in their rebuttal the GFN team produces a new formula whereby the area becomes an average sequestration rate per area:

$$\mathrm{EFc} = \frac{\text{annual amount emitted}}{\text{sequesteration rate per area}} = [\mathrm{ha}] \quad (1)$$

There is no mention of this formula in the official guidebook, where EFc is instead calculated through the following:

$$\mathrm{EFc} = \mathrm{EFp} + \mathrm{EFi} - \mathrm{EFe} \quad (2)$$

where EFi and EFe are the footprints embodied in imported and exported commodity flows, respectively and the EFp,the ecological footprint of production written as:

$$\mathrm{EFp} = \frac{\mathrm{P}}{\mathrm{Yn}} \times \mathrm{YF} \times \mathrm{EQF} = \frac{[\mathrm{kg/year}]}{[\mathrm{kg/ha}]} = \left[\frac{\mathrm{ha}}{\mathrm{year}}\right] \quad (3)$$

in this last case, rightly, the quantitative assessment of EF is actually a function of time.

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Table 1
Answer to the GFN's itemized comments:

GFN Point	Our reply
1. Introduction This section anticipates the materials contained in the subsequent points.	
2. What is the research question addressed by footprint accounting? The EF measures the actual biosphere's capacity humans are using, expressed in gha.	At the global level the EF is a measure of the requirement of carbon absorptive capacity only. Several other aspects are not addressed at all, such as land degradation, shortage of minerals and fossil resources, accumulation of pollutants in the atmosphere (7 million deaths per year according to the WHO, 2014) and a relevant number of others.
3. Is the ecological footprint overly aggregate? The EF brings together demands competing for regenerative capacity: provision of food, hosting infrastructure, sequestering carbon emission.	The indicator is overly aggregated in the sense that no single number by itself can capture in details a complex phenomenon, especially if it comes without any consideration on the underlying uncertainties.
4. Is measuring actual or estimating "natural" biocapacity more useful? Biocapacity is calculated measuring the actual productivity of the relative ecosystem.	Since the idea behind the EF assessment is to confront the use of human natural resources (demand) over the biosphere's regenerative capacity (supply), we should not consider the supply characterized by input flows without stock depletion nor accumulation of waste in the ecosystem. This assessment is necessarily based on a hypothetical situation. The GFN's argument is not epistemologically valid.
5. Are global hectares (gha) a measure of actual or hypothetical productive area? Gha is a virtual unit based on actual and measured flows. The number of gha is equal to the number of biologically productive hectares on the planet for the reference year.	The problem is ill posed. If the system capacity per hectare per year refers to empirical measures, why would a virtual unit be needed? How could one determine the amount of virtual land capable of fixing a certain amount of carbon dioxide if not by assuming a hypothetical situation? (see Section 1 above).
6. Is the carbon component of the ecological footprint misleading? The EF accounts for carbon emissions, because it is demand for sequestration of emissions, rather than energy use per se, which competes with other demands on biocapacity. In planning for long-term sustainability, constraints on the availability of biocapacity for carbon sequestration are likely to be a far more limiting factor than the depletion of fossil fuel stocks found in the lithosphere.	In the EF the global overshoot is made to depend only on the capacity of the biosphere to capture carbon emission (potentially fixable with various methods of carbon sequestration). Leaving aside the conceptual inconsistency of neglecting the problem of how to generate liquid fuels in case of depletion of non-renewable fossil fuel resources, one still wanders why the planet's vulnerability should be seen as a mere function of its capacity to absorb carbon, against the spectrum of threats faced by the planet due to man's activity.
7. Units mismatch: does the carbon footprint compare flows with stocks, or flows with flows? Flows are compared to flows and measured in gha (area of resource regeneration). The demand side is instead based on the number of tonnes of CO_2 emitted per unit-time.	The conceptual terms of what is measured are not always clear. More than one version of the accounting equations has been provided (see Section 2 above).
8. Does ecological footprint accounting assume perpetual forest? Is it based on virtual forest area? The value of the carbon component of the EF is calculated using the measured global average carbon sequestration rate of a forest, and thus indicates the amount of actual forest area needed to sequester a given annual carbon emissions flow.	Yes to both questions above. The amount of CO_2 absorbed each year refers to is a transitional process, valid only in a specific time, while anthropogenic emissions are expected constant in time (see Section 2 above). The authors do not reply to this logical impasse.
9. Will the ecological footprint of carbon change as technological solutions to the storage of CO_2 develop? Yes if biochar, ocean deposition, carbon capture and storage or any other technology is deployed that successfully reduces anthropogenic carbon emissions, less sequestration capacity would then be required to absorb the remaining emissions, and the carbon Footprint would decline accordingly.	This point shows the lack of logic of the chosen protocol. If the demand of sequestration capacity depends on the specific performance of the growing forests of the planet this year and/or on new technologies to be implemented in the future and/or on unknown effects of ocean deposition that may be discovered in the future, why do we calculate it in the first place?
10. Should carbon and non-carbon ecological footprint components be aggregated? Demand for food, fiber and timber resources and demand for carbon sequestration directly compete for the mutually exclusive use of bioproductive areas. Tradeoffs among these demands can be aggregated within a single accounting framework and expressed in the same units.	No, they should not. Why should grams of fish eaten in the Galapagos islands be transformed in grams of beef equivalent raised in the pasture of Ireland and then summed to virtual global hectares of ever-growing forest? It is difficult for us to associate a value expressed in "virtual global hectares" to the concept of empirically measured grams of fish.
11. Do ecological footprint results reflect directly measureable properties of the world? Yes they do.	As repeated in a number of points before, the question is epistemologically ill posed. Equivalent hectares of land are a way, if at all, of modeling rather than measuring nature.
12. 13. Is the ecological footprint useful for policymakers, or is its use counterproductive? Conclusions Ecological footprint accounting provides effective, easily communicated and policy relevant measures of a key aspect of sustainability.	Policy makers need to be informed that the EF can be misleading in the light of assumptions and simplifications used for its construction.

Furthermore, if Goldfinger and co-authors want to prove that the equation is dimensionally correct, they confirm our criticism that the EF method is assuming the existence of virtual forests that grow forever. In our view the problem here is determined by a lack of conceptualization of what is measured by the quantities indicated in this equation. The amount of CO_2 emitted per year (the numerator) is a flow coming from a process that can be considered as in steady-state (a fund-flow in the jargon introduced by Georgescu-Roegen, 1971). This implies that this flow will be emitted every year in the future, since this "quantity/year" is associated with the reproduction of human societies. On the contrary, the amount of captured CO_2 (the denominator) is a flow coming from a transitional process. The flow can be sustained for a limited period by the filling of a stock. Put in another way, a flow of carbon can be absorbed by a growing forest providing a given sink capacity "per hectare and per year" only once. Therefore, this value is valid only for a specific year (it changes in time) since it refers to a transitional state. This means that the sequestration rate per area will decrease in time reaching zero. An accounting method relevant for sustainability should decide how to deal with the fact that the emissions of CO_2 from the society are expected also in the next years, whereas the area already used to stock carbon cannot be used again. In this situation, either we have to add new hectares every year (the stocks used to absorb the flow has to be increased in time), or we have to assume that the hectare of forest considered in the first assessment will continue to fix the same amount of carbon per hectare per year forever (the given area of forest should be able to keep absorbing the flow forever). The latter assumption cannot reflect real dynamics. If the GFN adopts an accounting scheme based on the quantity of hectares of forests that happen to be in a transitional period on the planet Earth at each given year, then the GFN must necessarily refer to the characteristics of actual hectares (empirical measurement) that are in a special situation. It is those hectares' special situation that makes it possible for them to absorb important quantities of carbon. Then if this quantitative assessment is used to offset a steady-state flow of carbon, they should hypothesize the continuous generation of a quantity of actual hectares of growing forest in time [ha = f(t)]. Moreover, this also implies that the hectares in the denominator should no longer be accounted as "virtual global hectares" in a protocol used for sustainability accounting because of the fact that – as stated by Goldifinger and co-authors – the measured characteristics of sink capacity per hectare per year refer to empirical measures of actual growing forests. This implies that these assessments refer to a special situation experienced at the moment by the planet Earth and that therefore are useless as an accounting system as this situation is bound to change in the future.

In our opinion the GFN's reply to our 'stock versus flow' criticism reveals a certain tendency to make the EF a moving target. Each criticism 'arrives late' as in the meantime the EF has been or is being improved. We behaved ecologists should help the EF to improve instead of criticizing it.

1.3. The EF is optimistic at the global scale and policy-misleading at the local one

Let us look of at an example of the quality of the GFN's accounting method. In the report "*Japan ecological footprint report 2012*", the Fukushima nuclear disaster is estimated having a relevant impact of the country's biocapacity. "[. . .] *the estimation is conducted by applying a tougher criterion: Areas where the level of radiation exposure is expected to be greater than the Japanese legal level of allowable radiation exposure for ordinary citizens in normal settings. According to this law, radiation exposure must be equal or lower than 1 milli Sv/year. The measure of biocapacity affected using this criterion was estimated to be 6,554,200 gha*" (page 40). We have difficulties with both style and substance of this account. On one hand it is ludicrous to offer five digit precision on this number; on the other hand we are none the wiser after correcting Japan's biocapacity by a number which depends upon a (Japanese) law on radiation exposure. We find this another example of the ad-hoc style of the EF accounting system based on a semantically void formalism.

In rebutting the criticism of the anti-trade bias of the EF accounting the GFN notes (page 20): "*Ecological Footprint accounting can track biocapacity flows between countries, and the extent to which a country's demand exceeds its capacity to meet that demand, but nowhere does it state that this is desirable or undesirable, good or bad.*"

This is disingenuous. All EF maps vividly depict e.g., biocapacity debtors in red and biocapacity creditors in green, the latter being often countries with lower population density. Again we find this accounting futile (why should one use it) and misleading (no useful policy prescription can be derived from it).

"*Furthermore, while Ecological Footprint accounts assess only one dimension of sustainability, the size of a country's biocapacity deficit (or reserve) is a key parameter in determining a country's overall sustainability profile*" (ibidem). This argument is repeated several times in the GFN rebuttal and yet again what is the use of a partial, purportedly conservative, implausibly accurate accounting? In what respect is this a key parameter in a country's sustainability? In their conclusions the GFN states (page 21): "*Ecological Footprint accounting provides effective, easily communicated and policy relevant measures of a key aspect of sustainability—that is, whether humanity is living within the planet's limited regenerative capacity, or exceeding it.*"

As we explained at length in our paper, we firmly believe that the EF offer no realistic nor effective measure of this regenerative capacity nor of countries' exceedance of this capacity, neither at the local nor at the global level. The only valid claim here is that the message is easy to communicate, but the message is wrong.

2. Conclusions

In their rebuttal of our criticism the GFN states that our work attacks a different EF than the one developed by the GFN, and that we aim to an ideal, unavailable EF based on pristine states of ecosystems. The purpose of our work – in line with of other practitioners such as Blomqvist et al. (2013) – is not to vouch for such an ideal measure, but to inform the policy debate that the existing EF is useless and misleading. One cannot accept EF's flaws on the ground that the EF has normative virtues. EF's rhetoric trivializes bio-economics and muddles the sustainability debate.

To the extent that we accept to consider the members of the Sten–Fitoussi–Stiglitz Commission as a representative team of qualified expert, these have already given their judgment:

"*Overall, this means that the Ecological Footprint could at best be an indicator of instantaneous non-sustainability at the worldwide level. EFs for countries should be used as indicators of inequality in the exploitation of natural resources and interdependencies between geographical areas. Moreover, even the worldwide ecological deficit emphasized by the EF may not convey the message it is said to. Indeed, one can show that the worldwide imbalance is mostly driven by CO_2 emissions, expressed in hectares of forest needed for storage. By definition, the worldwide demand placed on cropland, built-up land and pasture cannot exceed world biocapacity.*" (CMEPSP, 2009)

In conclusion, we agree with Goldfinger and co-authors about the key importance of producing easily communicated scientific information; this is essential to make possible an informed societal deliberation over sustainability issues. However, accounting methods need to avoid the risk of simplifications typical of reductionism.

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