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The ecological footprint: Useful science or politics?

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1. Introduction

In their quest for measures that could be understood by any advanced civilization, alien or otherwise, physicists found to their chagrin that measurement is at best a relative exercise—"all our measurements are relative" (Planck 1949, p.47 as quoted by Mirowski 1992). The history of science indicates that the "naturalness" of natural numbers depends as much on the cultural milieu as on "science," which itself is affected by culture (Mirowski 1992). What is true for the physical sciences is certainly truer for the biological and social sciences—measures are grounded on one's perspective, with a metric accepted by some rejected by others. Wackernagel and Rees' (1996) ecological footprint (hereafter EF) certainly falls in this category. It is less a scientific measure than one designed to raise public awareness and influence politics. In this regard, it must be considered a success.

2. Measurement issues

The EF originates with an ecological view of sustainability that is both neo–Malthusian and anti monetary valuation (Rees and Wackernagel 1998; see also van Kooten and Bulte 2000, Chapter 8). Proponents of the EF oppose the aggregation and substitutability inherent in a monetary metric, they are against discounting, and they reject marginal in favor of absolute (average) valuation. Our contention is that, in the construction of the EF metric, the very same measurement issues (aggregation, substitutability, discounting, valuation) have not been dealt with in a meaningful way. Due to this imperfection, the EF is useless for policy analysis where tradeoffs at each moment in time and over time are essential. Unfortunately, EF proponents smooth over crucial measurement problems with rhetoric.[2]

The EF rejects (neoclassical) economics. Yet, economics has a long history developing and constructing various money metrics, because economists needed such metrics for public policy analysis. Economists have faced up to problems of aggregating various forms of capital—recall the "two–Cambridge" controversy dealing with substitutability among various forms of capital (Ferguson 1979, pp.252–66)—, aggregation across individual agents, efficiency versus equity, discounting (and intergenerational transfers), and, more recently, the problem of nonmarket measurement. Admittedly, not all of these issues have been satisfactorily resolved, but this should only serve to make one leery of claims about the ability of any one measure to address sustainability questions. The EF has failed to learn from economics the lessons of metrology—the rigor required to build useful metrics.

W&R define the ecological footprint in different ways: it is either "… the 'load' imposed by a given population on nature" (p.5) or "… an accounting tool that enables us to estimate the resource consumption and waste assimilation requirements of a defined human population or economy in terms of a corresponding productive land area" (p.9). W & others (p.377) employ the latter definition but add that the EF shows how much nature a nation uses—"the amount of nature [humans] occupy in order to live" (p.376). Nowhere is nature defined. Nowhere is there a clear and scientifically rigorous definition of the EF. One can only conclude that the EF is a convenient means of organizing globally available data on population, income, resource use and resource availability into a single metric that permits comparisons across nations—an accounting tool. There are problems with this accounting tool.

First, data are aggregated to demonstrate that global society, and most well–to–do countries, are living beyond their (ecological) means, or beyond their carrying capacity (see below). The purported evidence for this is the depletion of natural capital observed today—a strong sustainability point of view. The EF is chosen because of its apparent "ease" at aggregating sustainable development data (especially compared to monetary measures); resource and waste flows are easy to measure, it is claimed, as is the conversion of such flows to "productive" land area. Nothing could be further from the truth. We know little about what happens to wastes when they enter ecosystems (e.g., how they are broken down, how long they reside in ecosystems, potential damages they cause), and we know even less about how to convert resource and waste flows into a productive land area—the aggregation problem.

The EF depends on assumptions about how one substitutes between various forms of nature and how they are aggregated. Thus, for example, land needed for carbon uptake is rated the same as productive cropland, or forestland, or "degraded" land (which supports activities that might well enhance productivity of other land categories), which clearly cannot be the case. This is addressed in part by assuming different yield factors for different land uses in different countries, presumably based on some measure of actual output. For Italy, pasture is given a yield factor of 6.5 while arable land has a yield factor of 1.49 (W & others). These indicate that output in Italy is that much higher than the global average—Italian land (nature?) is that much "better." Although yield factors address differences in land quality among regions, economic factors are not taken into account. In less developed countries, economic incentives lead to low output levels, while subsidies in North America and Europe have resulted in higher agricultural output than would otherwise be the case. By using yield factors, the proponents of the EF are making judgements about the substitutability between various kinds of natural capital, and about the correctness of distorting economic incentives. As a result, solutions to environmental problems that depend on substitution cannot be studied using the EF tool.

Further, despite the strong sustainability stance of its proponents, the EF requires implicit judgements about the substitutability between natural capital and other forms of capital. The reason is that, in addition to the yield factors, various "weights" are used to convert human investment activities into land area. For example, in determining how much land is needed to cover a country's demand for wood products (say for construction), the footprint uses average annual growth rates of 2.0 m^3 ha^{-1} for Italy (W & others) and 2.3 m^3 ha^{-1} for Canada (W&R). The EF overestimates the land area required to provide human capital, in the form of housing say, because countries could use timber from forests in regions that yield 40 m^3 ha^{-1} per year or more. This requires an increase in trade, but it will reduce the globe's EF. The alternative is for countries to rely on timber harvests from primary and other less productive forests or on wood substitutes, such as cement and aluminum, which are much less environmentally friendly.

The point is that other ways of aggregating the same data, and other assumptions about substitution possibilities, can lead to opposite conclusions about local, regional and global sustainability. The EF is a metric that depends on how aggregation occurs.

Finally, discounting is avoided because the EF is a static measure—a snapshot of the extant situation with respect to sustainability. However, it is not possible to talk about soil erosion, carbon fluxes and "overshooting" of ecological capacity, topics considered briefly below, without taking into account dynamics, and that requires explicit or implicit assumptions about how one views (discounts) the future.

To conclude this discussion, we note that the EF is an attempt to replace extant measures of sustainability, both monetary (see Pearce and Atkinson 1995; Hueting 1989) and biophysical (Rennings and Wiggering 1997), with a single one. This is much like replacing measures of humidity, temperature and air pressure as indicators of weather with a single measure, altitude, since each of the former are (perhaps imperfectly) correlated with the latter.[3] Clearly, this would lead to a much less useful indicator, just as the EF is a much less useful indicator of sustainability than the indicators its proponents wish to discard. Further, claims that the EF avoids problems of aggregation and substitutability (and even discounting) are empty ones that simply do not hold up under careful metrological scrutiny.

3. Where the footprint fails: Sustainability and land use

Soil erosion

Soil erosion certainly relates to sustainability and is something that has been studied by agricultural scientists for over 100 years. Yet, we are uncertain about the effect of soil loss on crop yields and have great difficulty measuring it, much less the associated damages. Problems relate not only to plant biology and rates of soil renewal, but to a host of economic factors that include the impact of government agricultural incentive and subsidy programs, technological change, crop rotations (viz., green manuring), and farmer's attitudes towards stewardship and risk (see van Kooten 1993 for a review). Soil erosion can only be studied over time. It depends not only on the agronomic system applied to a particular field at a particular point in time, but also on the management of adjacent (and more distant) fields, past agronomic practices and investments in conservation, which might require use of other natural resources, thereby implying tradeoffs. The EF cannot address soil erosion issues because they deal with tradeoffs among natural and human–made capital, monetary variables and discounting. Nonetheless, one would expect a land–based measure of sustainability to be able to say something about this important topic.

Carbon uptake and climate change

Carbon (C) uptake plays a large role in the EF construct, accounting for some 50% of required land. The presumption is that warming leads to unsustainable outcomes and that it can somehow be mitigated. On both counts the underlying notion is misguided, as least in terms of primary outputs.

Global warming is not unbounded due to feedback mechanisms, including CO_2 fertilization. Excluding technological advance, researchers project a rise in global agricultural output as a result of climate change, even absent a CO_2–fertilization effect (see van Kooten and Folmer 1997 for a review). In addition, climate change will not only increase the supply of commercial timber, but also the globe's wilderness (biodiversity) area (Sohngen et al. 1999). Meanwhile, existing management technologies can address fears related to increased pest and disease incidents in agriculture and forestry.

By seeking of offset C release from all fossil fuel consumption, the EF ignores real economic constraints. It has been shown that the costs of terrestrial C uptake increase dramatically beyond about 10% of what needs to be sequestered annually. In order to calculate these costs (necessary if the land option is to be compared with other strategies for removing atmospheric CO_2), past and present management activities and biological dynamics need to be taken into account, and discounting cannot be avoided (see Stennes 1999; van Kooten et al. 1999). The EF is not up to the measurement task. But the bigger problem is that society will never accept the high costs of terrestrial–based CO_2 strategies, especially as these costs include lost environmental amenities (e.g., scenic agricultural landscapes, reduced biodiversity from monocultures). Clearly, society would not wish to eliminate or "cover" all CO_2 emissions—it is both physically impossible and too expensive. Here the EF not only ignores political reality, but the nuances of environmental interdependencies.

Finally, reliance on the EF as a policy tool for dealing with C uptake could potentially lead to perverse environmental incentives if the EF is used to judge governments' sustainability efforts in the international arena. Since C uptake due to fossil fuel consumption dominates the EF, the best way for a country to lower its EF is to reduce its consumption of fossil fuels by shifting to hydroelectric and/or nuclear power. Potential damage to the ecosystems from dam building and disposal of nuclear wastes are not included in EF accounting.

Overshooting ecological capacity

EF analysis concludes that humans have exceeded the globe's ecological or human carrying capacity (CC). While the footprint concept is used to estimate an ecological CC, global CC itself is little more than a heuristic.[4] The EF indicates that we have exceeded CC, with the world as a whole running an ecological deficit. Is this necessarily bad? The answer is that this disparity (EF>CC), known as "overshooting," may well be optimal in the sense of increasing overall well being. That is, overshooting may be a characteristic of sustainable development along an optimal path, consistent with dis–investment in natural capital in favor of alternative investments. For example, it may be beneficial to convert some forests to agriculture because doing so leads to greater agricultural output. Likewise, some primary forest can be harvested and replaced by more productive plantation forests, thereby reducing pressure on remaining primary forests.

The point is that overshooting ecological CC may be optimal, even in the absence of anticipated future technological change and even on a sustainable development path. While the EF relies on the ad hoc assumption that the current stock of natural capital is somehow optimal, there is no reason why depleting some of it may not be optimal. In that case, one would advocate a (temporary) large footprint.

4. Discussion

W&R and W & others emphasize an important policy role for the EF. EF analysis can "… assist in the development of appropriate policy responses in a wide range of contexts from technology, policy and environmental assessment, through local, regional, and national planning, to the design of international treaties (W&R, p.150). However, there is a big difference between EF analysis and public policy. The EF seeks to measure human impact on nature, but public policy requires much more. It requires an understanding of human behavior and motivation, and the role of institutions, economic incentives and politics. The EF is ill–equipped to address any of these issues, so its claim is largely an empty one.

As noted in the introduction, the main purpose of the EF is to raise public awareness and call people to effective political action (e.g., W&R, p.15). Beyond rhetoric to limit consumption, which is a naïve and politically unacceptable notion, there is no policy prescription.[5] What can be done to bring about sustainable development? This is left unanswered because there is no policy evaluation in the footprint. Yet, policy issues and recommendations matter, perhaps even overriding all other concerns, because wrong–headed policies could lead society down an unsustainable path where it was on a sustainable one previously.

For those concerned with sustainable development, therefore, indicators of sustainability must be realistic in what they seek to accomplish, and what they can say about the paths we are on. In this regard, the EF may prove anathema to those who are concerned about the environment and sustainable development, but wish to rely upon indicators that are rooted in solid metrology, are not susceptible to the vagaries of the assumptions that go into their construct, and lead to realistic policy analysis.

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Notes

[1] Subject to the usual qualifier, the authors wish to thank Jeroen van den Bergh for helpful comments and suggestions.

[2] This is particularly evident upon reading Wackernagel and Rees (1996, hereafter W&R) and Wackernagel et al. (1999, hereafter W & others). While one expects careful mathematical analysis of the EF measure and regression analysis, one gets illustrations that are designed more to convince than to enlighten. Hence, our observation that the EF is not about measurement but about raising public awareness and pursuit of a political agenda.

[3] We are indebted to H. Verbruggen for this analogy. Of course, other indicators of sustainability can be used in conjunction with the EF (W & others, p.389), but these are limited to social indicators of quality of life (and implicitly not monetary ones).

[4] Additional insights are offered by comparing Pickover's (1997) history of carrying capacity and population crash (pp. 60–69) with that of W&R (pp.48–49).

[5] An exception, perhaps, is the policy to slow (stop or even reverse) the trend to globalization because it "… accelerates the depletion of the planet's natural assets" (W&R, p.21). This is addressed by van den Bergh and Verbruggen (1999) in their fine critique of the EF.