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Analysis

On sustainability interpretations of the Ecological Footprint

Miroslav Syrovátka

Palacký University Olomouc, Faculty of Science, Department of Development & Environmental Studies, 17. listopadu 12, 771 46 Olomouc, Czech Republic

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ABSTRACT

This paper focuses on using the Ecological Footprint concept for sustainability assessment. The Ecological Footprint is a popular indicator of human use of environmental resources and is commonly presented at the country level by comparing the consumption footprint with territorial biocapacity, with a negative balance implying unsustainability. This constrains a country's consumption by its biocapacity but allows its stock of resources to be depleted if they are not associated with domestic consumption. This paper argues that this approach is legitimate but should not automatically constitute a default framework for interpretation. Two perspectives on entitlements to environmental resources are analyzed and, based on them, a novel approach to sustainability assessment is proposed. The paper further discusses the links between national sustainability and the related issues of self-sufficiency, consumption, and responsibility.

1. Introduction

The Ecological Footprint (EF) is a popular indicator of human use of environmental resources, widely used for sustainability assessments. This paper analyzes two alternative sustainability interpretations of the EF concept (Section 3) and proposes an assessment which combines the two perspectives (Section 4). This assessment provides a richer perspective on country sustainability that may be used beyond the EF. The paper contributes to the discussion on defining sustainable and fair management of local and global environmental resources, and is therefore relevant to the fields of ecological economics and sustainability economics (see Baumgärtner and Quaas, 2010) and, more specifically, for measuring environmental sustainability (see Moldan et al., 2012).

2. The Ecological Footprint concept

The EF is one of the tools which attempt to quantify human pressure on the environment. It builds on the older concept of carrying capacity applied to the human population (see, e.g. Ehrlich and Holdren, 1972; Catton, 1980; Vitousek et al., 1986). More specifically, it is based on the first sustainability principle of Daly (1990), i.e. that harvests of renewable resources should not exceed their regeneration. Rees (1992) used the term "appropriated carrying capacity" for measuring the sustainability of a society in a certain territory, which was later renamed by Wackernagel and Rees (1996) as the Ecological Footprint. The EF measures the area of biologically productive land and water needed to produce renewable resources consumed by a human population and to assimilate its waste. It is an aggregate indicator which translates different types of resource use to a single spatial unit—a global hectare, i.e. a hectare with the world average biocapacity. While the metric is appealing as a communication tool for showing human impact on the environment, its methodology and usefulness have also been challenged.[1] This paper does not reflect on the methodological critique of the EF except in direct relation to the aims of the paper.

Though the concept has multiple applications,[2] the most common applications are on a national and global level. As for the former, the most widely used methodology and results are the National Footprint Accounts (NFA). The methodology has evolved over time (see Borucke et al., 2013; Lin et al., 2018, for recent methodology) under the think tank Global Footprint Network (GFN), founded in 2003 by Mathis Wackernagel, Susan Burns and Steve Goldfinger (GFN, 2019a). According to the creators of the EF concept (Rees and Wackernagel, 2013,

E-mail address: miroslav.syrovatka@upol.cz.

[1] The discussion between proponents and critics has been recently extensively covered by three journals: *PLOS Biology* (Blomqvist et al., 2013a; Rees and Wackernagel, 2013; Blomqvist et al., 2013b), *Journal of Industrial Ecology* (van den Bergh and Grazi, 2014a; Wackernagel, 2014; van den Bergh and Grazi, 2014b), and *Ecological Indicators* (Giampietro and Saltelli, 2014a; Goldfinger et al., 2014; Giampietro and Saltelli, 2014b; van den Bergh and Grazi, 2015; Lin et al., 2015; Galli et al., 2016). *Ecological Economics* has covered the topic from its inception, with critical views provided especially by van den Bergh and Verbruggen (1999) and Fiala (2008), and a response to the latter paper by Kitzes et al. (2009).

[2] The indicator has been applied on various levels, such as for a particular person (e.g. GFN, 2019b), for a city or region (e.g. Baabou et al., 2017; Moore et al., 2013; Hopton and White, 2012), for a product, service or activity (e.g. Huijbregts et al., 2008; Mancini et al., 2018), and for an organization (e.g. Bagliani and Martini, 2012; Nunes et al., 2013).

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p. 1, emphasis original) the NFA "constitute *the most comprehensive assessments of the ecological status of nations available.*" Though one can calculate countries' EFs based on one's own methodology, most of the applications (including this paper) use the NFA as they provide consistent data for most of the world's countries. The GFN and its staff also present and interpret the results. Given the position of the organization, these perspectives may serve as a default option for other users and they are also discussed in this paper.

There are two main applications of the EF concept on national and global levels. The first approach looks at the EF as a measure of the human use of (renewable) environmental resources. On a global level, humanity consumes 20.6 bil gha of bioproductive resources. The EF can also be calculated for countries and interpreted in terms of between-country inequality in the use of environmental resources. For example, the population of the Netherlands/India consumes 100 mil/1450 mil gha of bioproductive resources. When converted to per capita (pc) terms, the results are 5.9 and 1.1 gha for the average Netherlander and Indian respectively. The second approach uses the EF indicator together with biocapacity indicator (i.e. the area of biologically productive land and water) for sustainability assessments. Biocapacity represents the environmental limits and the EF represents the extent towards which humanity reaches or exceeds these limits. By comparing the EF with biocapacity, one can assess whether a given population lives within the carrying capacity of the environment (the EF is lower than the biocapacity) or not (the EF exceeds the biocapacity). The results show that on a global level the EF is larger than biocapacity (20.6 versus 12.2 bil gha) and therefore, humanity has exceeded the planet's aggregate regenerative and assimilative capacity. In this respect, the EF is used as an indicator of one dimension of environmental sustainability.[3]

There are other approaches which attempt to quantify global environmental limits and corresponding human pressures. One well-known concept is that of planetary boundaries for "the safe operating space for humanity" (Rockström et al., 2009), but there are also footprints for various environmental issues such as the water footprint and chemical footprint (for the link between planetary boundaries and footprints, see Fang et al., 2015). These approaches are less aggregate than the EF, but they also show that humanity has exceeded some of the environmental limits (Steffen et al., 2015; Hoekstra and Wiedmann, 2014).

When assessing the sustainability of human impact on the environment, the planet as a whole is not the only relevant level of analysis. As the ability to act mostly pertains to countries, it is necessary to search for relevant limits and pressures at a national level. The following two sections are about the difficulties of defining what limits are relevant for the population and the implications for the EF concept as a tool for sustainability assessment at a country level. Section 3 discusses two sustainability perspectives in relation to national self-sufficiency, rights for environmental resources, and consumer versus producer responsibility. It is argued that the most common sustainability presentation of the EF concept is built on a combination of the political principle of control over territory, the ecological principle of carrying capacity and implied self-sufficiency, and the moral principle of consumer responsibility. These principles are legitimate, but they do not constitute the only framework for interpretation and lead to certain implications. Section 4 presents an integrated assessment that combines the two perspectives discussed in the preceding section.

3. Sustainability perspectives

3.1. Two models of bioeconomy

Imagine a castaway on an island. The island has certain renewable resources that the castaway may use. He may cut trees to make fire or build a dwelling. If the castaway harvests less wood than provided by the natural growth of the forest, he lives within the regenerative capacity of the island's forests. In other words, his EF (here limited to wood products) is within the island's biocapacity. If he harvests more wood than the natural growth, he directly diminishes the island's biocapacity. We implicitly assume that the castaway's island is here for his use. That is, he can use *all* the island's resources, but also *only* the island's resources; it is a closed autarkic economy. This fully trade-autarkic economy is the strictest version of the *self-sufficient local bioeconomy* (SLB) model. There is also a less strict version that allows for some trade. The castaway may exchange products of biocapacity with a castaway on another island and this would still be sustainable as long as his total EF stays within the aggregate biocapacity of the island.

The SLB model can be analogically applied to human society: to be sustainable, a society must use no more resources (the EF) than those available on its territory (biocapacity). The less strict version of the SLB model is the most common sustainability interpretation of the EF concept by the GFN (see below). According to this view, countries should live within the respective aggregate biocapacity of their territories measured in global hectares (when applied on a national level, "local" should be interpreted as "national"). For example, the Netherlands' EF (5.9 gha pc) is higher than its biocapacity (0.9 gha pc), resulting in a negative balance (a deficit of −5.1 gha pc). Canada's EF (8.0 gha pc) is well below its biocapacity (15.2 gha pc), constituting a large positive balance (a reserve of 7.2 gha pc). For this view of sustainability, a high consumption lifestyle is not a sign of unsustainability as long as it is supported by the regenerative capacity of a given political territory. Indeed, it would be difficult for Canada *not* to live within its large biocapacity.

An alternative interpretation of sustainability is based on equal per capita entitlements—let us call it the *egalitarian global bioeconomy* (EGB) model. Suppose all people in the world, notwithstanding their countries of origin, have the same entitlement to the planet's natural resources. Then it makes sense to calculate the average global biocapacity per capita (1.7 gha) and compare it with the respective national EFs per capita.[4] In this perspective, both Canada and the Netherlands are unsustainable (with Canada having a larger ecological deficit), but for some other countries the two perspectives lead to a reversed sustainability assessment. Moving to the Global South, the EF of Rwanda amounts to 0.8 gha pc and that of Namibia 2.1 gha pc. Under the SLB standard, Rwanda is unsustainable (a deficit of −0.3 gha pc) and Namibia sustainable (a reserve of 4.4 gha pc). With the EGB standard, Rwanda is sustainable (a reserve of 0.9 gha pc) and Namibia unsustainable (a deficit of −0.4 gha pc). For these two countries, their sustainability assessment depends fundamentally on the applied sustainability benchmark. It may seem odd that with the same tool we can make two opposite sustainability conclusions. If so much depends only on the choice of a perspective, their respective legitimacy should be considered.

3.2. National self-sufficiency

Before I discuss the legitimacy of the two sustainability perspectives, it is necessary to substantiate the above mentioned claim that SLB is currently the most common interpretation of the EF concept by the GFN. In one of the papers responding to the EF's critics, the group of GFN directors and scientists (Goldfinger et al., 2014, p. 629) state:

> "As any science-based metric built on a research question, it describes what exists and then leaves it up to the user to decide how to use this information, and what values to apply to it. … Footprint

[3] As the EF does not include all types of environmental degradation, notably the depletion of non-renewable resources and pollution (except CO_2 emissions), it cannot be used as a comprehensive indicator of environmental sustainability.

[4] The most relevant comparison in this respect is that of the average global biocapacity with *individual* EF.

accounts do not tell you if a Footprint is too big or too small, or if it is fair that the per capita Footprint of one country is larger than that of another. Similarly, a measure of weight is a description: whether something is too heavy or too light is an interpretation, which depends on the context, on other variables and on value systems. Metrics enable judgments, sometimes contradictory ones, but in and of themselves are not judgments."

The excerpt compares the EF metric to a measure of weight and distinguishes between description and interpretation. Numerical results *alone* are hardly useful in providing substantive information about the world; for understanding we need an interpretation. Using the weight analogy, the numerical description of one's weight is useless without context which can be provided by a benchmark such as other people's weight or a threshold for being overweight and underweight. The same goes for environmental issues: atmospheric concentrations of CO_2 are of little use without a benchmark to which they can be compared.

What benchmark is most often provided by the GFN community? The organization publishes the EF methodology and dataset (NFA) as well as other materials on its website; other documents are published by the authors affiliated with the GFN. As the NFA include both footprints and biocapacities, it suggests that the GFN considers these two metrics to be jointly relevant, i.e. country's biocapacity as a benchmark to which the country's footprint should be compared. By 2016, the main NFA data table (excel sheet) showed ecological balances (deficits or reserves) explicitly; in more recent editions, these are no longer in the data file. The newest edition of the NFA nevertheless shows these results graphically. The *Open Data Platform* section of the GFN webpage (2019c) opens with a large map depicting the ecological balance of the world's countries: countries in red show an ecological deficit and are called "biocapacity debtors;" countries in green show an ecological reserve and are called "biocapacity creditors" (see Fig. A.1 in Appendix).

This type of presentation does not clarify where the GFN draws a line between description and interpretation. It is not clear whether the term "biocapacity debtor" is still within the descriptive footprint accounts and shows an ecological debt which should be paid (but then, how and to whom?), or whether it is outside the accounts and is an interpretation of the results with an implicit value judgment that "biocapacity debtors" consume more than they should (but then, why is the interpretation in the data section?). The same map (without the creditor/debtor labels) is shown in the results section of the most recent journal article on the EF methods and results (Lin et al., 2018). While most of the official GFN materials do not provide direct implications in terms of sustainability, a senior GFN scientist (Galli, 2015, p. 212) in an article *on the rationale and policy usefulness* of the EF accounting states:

"At a national level, when a country's Ecological Footprint is greater than its biocapacity, a biocapacity deficit occurs. When a country's Ecological Footprint is smaller than its biocapacity, it is said to have a biocapacity reserve. This does not determine whether the country is sustainable … but it describes an essential minimum condition for sustainability."

Reasonable people may disagree whether the construction of the benchmark, the use of the benchmark, or only the explicit narrative interpretation embrace values and go beyond description. What is clear from most GFN materials is that the most relevant use of countries' footprints is to compare them with countries' biocapacities; that ecological deficits are viewed negatively, and either explicitly (as in the quotation above) or implicitly (as in most other GFN materials) interpreted as a mark of unsustainability. This view of sustainability reflects a version of the SLB model described above, i.e. living within the aggregate territorial biocapacity.[5]

This leads us to the question: What is an appropriate spatial scale? Rees and Wackernagel (2013, p. 1) claim that EF assessments at national and regional (as opposed to global) levels, by which they implicitly mean comparison with domestic biocapacity, have "the highest policy utility" and "they correspond to levels of government that have authority to act." Indeed, countries are the main administrative units that control "their" territories. If the world is composed of fully trade-autarkic units (countries), these would naturally have to respect the production capacity of their territories, otherwise it would diminish with future implications on the population it can sustain. For example, the British charity Population Matters (2016) uses the EF data to calculate the sustainable population and the overshoot population for each country: the Netherlands exceeds its sustainable population of 4 mil by an overshoot population of 13 mil. In the world of autarkic national economies, the Netherlands could run an ecological deficit only in the short term. In the long term, without technological progress, the population and/or its consumption would decrease as the IPAT equation suggests (see Ehrlich and Holdren, 1972).

The perspective of a world composed of self-sufficient local bioeconomies is not necessarily a good model of global sustainability. Global sustainability does not require that all units must be self-sufficient as the units (regions however defined) are not closed systems as the planet. By applying the concept of carrying capacity on regions, Vanderheiden (2008, p. 442) argues, one commits "the fallacy of assuming that a rule which applies to the whole applies equally to each part." It is one thing to argue that the world should not exceed regeneration and assimilation capacities of its ecosystems, and another to require that this principle should be met at a national (i.e. from the ecological point of view irrelevant) level. Trade allows for the export and import of biocapacity. Without trade, countries' prosperity would be limited by their respective biocapacities. The prevailing sustainability interpretation of the EF concept allows for some trade in biocapacity, but domestic consumption (i.e. production plus net imports) is fundamentally limited by domestic biocapacity. To be sustainable, a biocapacity-rich country may consume (either by import or by drawing on its own biocapacity) a lot of biocapacity-intensive products, but a biocapacity-poor country cannot and this applies even if the imports do not contribute to the overuse of biocapacity in the exporting country.[6] That is why some authors noted that comparing national EFs with national biocapacities brings anti-trade sentiments (see van den Bergh and

[5] The NFA measure countries' footprints and biocapacities in global hectares, i.e. hectares with world average biocapacity. The SLB model may benefit from using actual productivity of (consumption's country) land measured in local hectares, i.e. hectares with national average biocapacity. A more general point was raised by Giampietro and Saltelli (2014a). They argued that the EF is measured in virtual global hectares without an external referent, which is not useful for analysis and policy. They suggested that to calculate "ghost land" of imported biomass, one should use either land productivity of a consumption country or of countries from which the biomass was imported.

[6] Practically speaking, the EFs of rich countries do not come mainly from biocapacity-intensive products as intuitively understood, such as food and wood. The majority (60% in 2014) constitutes carbon footprint for which the EF methodology requires forest area. That is, by consuming carbon-intensive goods, country B arguably pursues an implicit import of biocapacity from biocapacity-rich countries. As this is practically not a trade where two agents agree with the transaction, it cannot be regulated by the "exporting" country. While there are international declarations where countries are bounded by "responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction" (Rio Declaration on Environment and Development; UNCED, 1992), "exporting" countries can hardly appeal to this principle in this context. The climate change problem is commonly understood as a global commons problem (overuse of the global atmosphere) rather than a negative externality whose victims are biocapacity-rich countries. When it is conceptualized as a negative externality, the victims are usually understood to be countries most affected by climate change.

Grazi, 2015; van den Bergh and Verbruggen, 1999).

Self-sufficiency within territorial environmental resources is difficult for areas with a high population density. According to one estimate (Chambers et al., 2002), the EF of London is more than 40 times higher than its biocapacity (6.63 versus 0.16 gha pc). If London is forced to reduce its EF below its biocapacity, a large share of its people would starve or migrate elsewhere (both would increase per capita biocapacity for the remaining population). The creators of the EF (Rees and Wackernagel, 1996, pp. 236 and 241, emphasis original) were well aware of the difficulty of applying their sustainability standard on urban regions: "Perhaps the most important insight from this result is that *no city or urban region can achieve sustainability on its own*." Though the authors argued for "greater regional self-reliance," they acknowledged that "self-sufficiency is not in the cards for most modern urban regions."

To what extent can we justify the application of the SLB model of sustainability on countries that resemble cities or urban regions? Van den Bergh and Verbruggen (1999, p. 66) argue that national boundaries are geo-political and "have no environmental meaning." According to the authors, it is meaningless to compare large and small countries, and to expect the populations of small, densely populated regions and countries to live within the carrying capacities of their territories as smaller territories necessarily show greater trade dependency. Some countries have a high population density in low-productive areas which leads to low biocapacity per capita and ecological deficit (like the Netherlands and Singapore), others have a sparse population in high-productive areas which leads to high biocapacity per capita and ecological surplus (like Canada and Finland). From the SLB perspective, a country like the Netherlands "can only operate by draining other regions ecologically" (Wackernagel and Silverstein, 2000, p. 393), but from an economic perspective this "can be seen as part of a normal situation where trade is mutually beneficial, rather than an indicator of non-sustainability" (Stiglitz et al., 2009, p. 71). Note also that the export of biocapacity (with the exception of carbon emissions) can be regulated by the exporting country if deemed detrimental.

3.3. Rights for environmental resources

The discussion of sustainability cannot avoid the issue of moral rights for environmental resources. The example that opened this section depicted a castaway on an island. We assumed that he can use all the island's resources, but this was not laid out in terms of rights as we thought of it in isolation. The concept of rights becomes relevant once other people and societies are considered. The world is more complex, consisting of states which occupy certain territories and have sovereignty over resources in those territories. This is mostly accepted by other states and supported by international law and declarations.[7] Proponents of the SLB model can refer to this framework when justifying rights to territorial resources (though not the self-sufficiency idea). Yet, a legal perspective is not the only legitimate view.

Think about a world where all people are born equal and have the same rights and entitlements. It is a legitimate perspective built on a strong moral argument irrespective of the fact that none of them are in effect granted in today's world. When Rawls (1971) developed his theory of justice as fairness, he argued that just principles can be created only behind "a veil of ignorance" where people do not know their position in a society. Such a just society provides equal rights and opportunities to its members and allows for inequality only insofar as it works for the benefit of its worst-off members. Though Rawls argued that these principles are applicable only to national societies, an argument can be raised as to whether a moral theory should be confined within borders.[8] If being born to poor parents is an "accident of birth" which matters for justice, why is being born in a poor country not endowed with natural resources not? Countries have control over natural resources in their territories, but the distribution of natural resources among countries' territories is arbitrary and national borders have been established by coercion and violence.

This led to the development of cosmopolitan (egalitarian) theories of global justice. Beitz (1975, p. 370) extended Rawls' argument, claiming that deliberation among states over a fair arrangement would lead to a similar result as one among people within a country: "Not knowing the resource endowments of their own societies, the parties would agree on a resource redistribution principle which would give each national society a fair chance to develop just political institutions and an economy capable of satisfying its members' basic needs." Global egalitarians view the planet's natural resources and spaces as collectively owned by the global population, and therefore, current arbitrary and unequal distribution as unjust. For example, one global egalitarian (Hayward, 2006, p. 368) has argued that the world community should recognize a basic norm of "a globally equal per capita right to ecological space." Based on such arguments, global egalitarians propose institutions and policies for global justice, mostly those that concern redistribution (see Casal, 2011a; Casal, 2011b; Pogge, 2011; Steiner, 2011; Risse, 2012). For example, Thomas Pogge proposed a Global Resources Dividend which would tax the extraction of natural resources and distribute the revenues to poor people in the world. A more radical approach is advocated by Hillel Steiner; a Global Fund would collect revenues from rents based on competitive bidding for renting each location in the world, which would be distributed to all people in the form of basic income.

There is an interesting link between such policies and international migration. Consider the treatment of migration in the SLB model: the consumption of the average Netherlander is unsustainable in the Netherlands but would be sustainable by moving to Canada. In the EGB framework, migration would not help increase one's quota as the rights are individual rather than national. The redistribution and migration policies work as substitutes. If the world is open to migration as some propose,[9] it effectively means the same as the right to equal biocapacity as people can migrate from biocapacity-poor countries to biocapacity-rich countries.

Cosmopolitan theories and their policy recommendations have been challenged (see, e.g. Rawls, 1999; Miller, 2007) either in principle or as politically unfeasible. Individual entitlement rights are not recognized by international law and there is no global authority which could set and enforce them. Countries with a large biocapacity (or any other territorial resource to be globally shared for that matter) would hardly agree with this redistribution. Arguments against cosmopolitan theories do not rest only on countries' territorial sovereignty. Equal entitlements may also be undeserved if different countries or individuals have contributed little to the creation of their value. Biocapacity is not purely nature's endowment, but also an artefact of human ingenuity (e.g. the invention of more productive agricultural techniques leading to both higher yield and higher biocapacity) and social institutions (different institutional arrangements may support or hinder the inventions and their use), and there is less legitimacy in entitlements to the outcomes of human work such as to a certain share of global GDP or biocapacity.

Yet, outcomes cannot be fully ascribed to the current generation:

[7] Principle 2 of Rio Declaration on Environment and Development (UNCED, 1992): "States have … the sovereign right to exploit their own resources."

[8] Rawls (1999) later developed principles for international justice that were very different from those suggested for nation states. This gave rise to criticism for incoherence (see Pogge, 2004).

[9] See Carens (1987) for philosophical arguments for open borders. Caplan (2012) provides both theoretical and empirical arguments against immigration restrictions, especially related to US immigration. According to Risse (2016, p. 40, emphasis original), countries should not restrict immigration as long as they *"underuse their share of collectively owned resources and spaces."*

while one might have contributed to her country's GDP, the current per capita level has also been affected by her ancestors, for which she cannot claim credit. Additionally, it is difficult to reject global equal rights as morally wrong for global commons such as the global atmosphere. Note that the EF's methodology translates *atmospheric* emissions into *land* area, a hypothetical area of forests required to sequester anthropogenic carbon emissions not absorbed by the oceans. The critics have challenged this conversion as arbitrary (Blomqvist et al., 2013a, p. 2): “What exists in reality is a certain amount of emitted carbon that is absorbed neither by forests nor oceans.” As the global ecological deficit is comprised practically from carbon emissions not directly depleting territorial resources, the argument of territorial rights—and the SLB model based on them—is not so convincing.

For carbon emissions, the Contraction & Convergence model, i.e. reducing global emissions and gradual convergence towards equal per capita allocation, has been promoted by the Global Commons Institute and has received some acceptance over time (see Global Commons Institute, not dated). Interestingly, the originators of the EF concept were supportive of this view—and not just for global emissions—especially in the early years after the EF was developed. In the first book on the EF, Wackernagel and Rees (1996, p. 54) mentioned the comparison of individual or average EFs with “fair Earthshare,” i.e. with an average global biocapacity. Wackernagel and Yount (1998, p. 517) argued that 1.7 ha per capita, i.e. the average global biocapacity after some deduction for biodiversity protection, “become the ecological benchmark for comparing ecological footprints” and called it “a reference point for sustainability.” Over time, however, the dominant view of the GFN has become that of SLB. It is true that even nowadays, the EGB view of sustainability is not completely ignored by the organization, but it is rather on the margin.[10]

At the same time, most authors that have recently downscaled planetary boundaries to national levels have chosen equal per capita allocations (see Häyhä et al., 2016). These studies were made for South Africa (Cole et al., 2014), Sweden (Nykvist et al., 2013), Switzerland (Dao et al., 2018), European Union countries (Hoff et al., 2014), and for up to 150 countries with available data (O'Neill et al., 2018). Most of these authors acknowledge that these allocations may not be appropriate for all cases (e.g. for geographically and temporally bounded resources such as freshwater use) and more factors are legitimate for downscaling the boundaries (such as responsibility). However, it is notable that when the authors decided to apply downscaling, for most of them (all except for the first study) the first choice was that of equal per capita allocations. As one of the teams noted, “any broadly accepted way of going beyond the ‘equal share per capita’ is currently lacking” (Dao et al., 2018, p. 52).

3.4. Consumption versus production

There is still one remaining issue important for the current framing of the EF concept: the EF relates to consumption.[11] This is based on a premise that the consumer is responsible for the environmental aspects of a product's life cycle wherever the product was sourced from. To what extent is this justified? Imagine country A that drills oil which is then exported to country B where it is used for production that is exported to country C. The consumer is the driving force of the entire process and as such should bear some, perhaps most, of the responsibility. Yet, other links in the chain also benefited from the process and therefore some responsibility should be borne by them. It is not intuitively clear how this responsibility should be shared among the links of the whole production-consumption chain (for proposals see, e.g. Lenzen et al., 2007; Marques et al., 2012). The most common sustainability interpretation of the EF concept (i.e. consumption footprint combined with territorial biocapacity) implies that overusing your biocapacity (by, for example, cutting more wood than natural growth) is sustainable as long as it is not for your consumption but for export. On the other hand, if your ecological deficit is covered by using (i.e. “importing”) other countries' biocapacity, instead of and above your own, you are unsustainable despite the fact that your biocapacity is maintained. By implication, the EF concept assesses whether a country could maintain its current consumption standard in the long term only from aggregate domestic biocapacity.

The concepts of sustainability and responsibility are intertwined. It may seem odd that a country which has completely deforested its territory is considered sustainable as long as the timber was exported. But this is a necessary implication of the consumption approach. A different sustainability perspective would require a country to maintain its stock of resources (biocapacity) to preserve their services. This is better served by the production approach: though consumption may be the driving force, what physically depletes domestic resources is domestic primary production (plus some external emissions). From the perspective of a national sustainability policy, it is safer to saturate domestic consumption with foreign biocapacity. It is also more feasible to regulate the rates of harvest and waste emission on the production side (i.e. where firms are extracting resources and releasing emissions) than on the consumption side. When sustainability is viewed from a narrow national perspective, the maintenance of non-declining territorial (national) stock of resources is a reasonable rule.[12] The prevailing use of the EF does not serve well for this purpose. The combination of the territorial approach to biocapacity with a non-territorial consumption approach to the EF constrains a country's consumption by its biocapacity but allows a country's stock of resources to be depleted if they are not destined for domestic consumption.

It has been suggested by the originators of the EF concept (Rees and Wackernagel, 2013) that the EF may serve to assess a degree of risk a country faces when running an ecological deficit. This risk could stem from a large disruption of global trade induced by export restrictions on the side of countries with biocapacity-intensive export. While this is possible and would significantly affect human well-being in countries with biocapacity-intensive import, it is rather unlikely. Moreover, this risk relates only to trade in non-carbon biocapacity; carbon deficit bears little risk of *this* type as forest-rich countries are not able to hinder the sequestration of CO_2 on their territories wherever emitted for deficit-country consumption. Also, when countries draw on other countries' biocapacity, it does not automatically follow that they would show the same resource throughput leading to the depletion of their own biocapacity when faced with a new situation of limited (or zero) biocapacity import.

3.5. Summary

To summarize, the most common presentation of the EF concept

[10] Sustainable Development section of the GFN webpages (2019c) shows a figure depicting HDI on the horizontal axis with a line through 0.7 (a cut-off for high human development) and the EF on the vertical axis with a line through 1.68 gha (pc world biocapacity). The explanatory text follows: “Combining these two indicators provides clear minimum conditions for global sustainable human development.” Yet, no detailed explanation or discussion follows, and neither data nor figures for countries' individual ecological balances are provided (though one can easily compute the data). The same applies for the journal article by Lin et al. (2018).

[11] The glossary on the GFN webpages (2019d) states: “Without further specification, Ecological Footprint generally refers to the Ecological Footprint of consumption” which is also the “most commonly reported type of Ecological Footprint.” While the EF is usually presented in its consumption version, it should be acknowledged that the recent NFA also include production footprints.

[12] The Adjusted Net Saving indicator produced by the World Bank is built on a similar approach. For a country to be sustainable, its overall wealth should not decline. For methodology of the ANS, see Lange et al. (2018); for a comparison of the EF and the ANS, see Syrovátka and Harmáček (2016).

shows for each country the biocapacity of its territory, the EF of its consumption, and the resulting ecological balance; a negative balance is interpreted as a sign of unsustainability. I have shown that this is one perspective how to view sustainability and that the complementary perspective of equal entitlements is legitimate, at least for global commons. I have argued that sustainability is about responsibility, but there is a difference between responsibility for maintaining domestic resources and responsibility for the external effects of one's own consumption; the latter approach does not ensure national sustainability. The current framing of the EF provides one perspective on sustainability with some peculiar implications.

The GFN claims that their measure is descriptive and value-free, but the results are presented in a way that goes beyond description. Yet, in a very relativist sense, no indicator is value-free. By choosing what and how to calculate, how to present the results and relate them to one another, one is already setting an agenda and suggesting an interpretation. It should also be acknowledged that for the sake of making an easy presentation, one sometimes must choose one interpretation over another and the choices of the GFN are not unreasonable (at least not each of them independently). But, given how complex the issue of assessing a country's sustainability is, it would be useful if the EF developers provided a framework of spatial sustainability and described how the EF fits into this, and/or broadened its view beyond the nation-self-sufficient and consumption-centered perspectives. The GFN has recently made an important step towards the latter by also publishing production footprints. The following section provides further extension of this agenda.

4. Sustainability quadrants

Given the legitimate arguments for both sustainability perspectives outlined in the previous section, in this section I suggest an assessment which takes both perspectives into account. Fig. 1 illustrates this assessment. It is based on data from the NFA (GFN, 2018), keeping the prevailing consumption approach and global hectare as the measurement unit.

Fig. 1 is divided into four quadrants based on two criteria: local

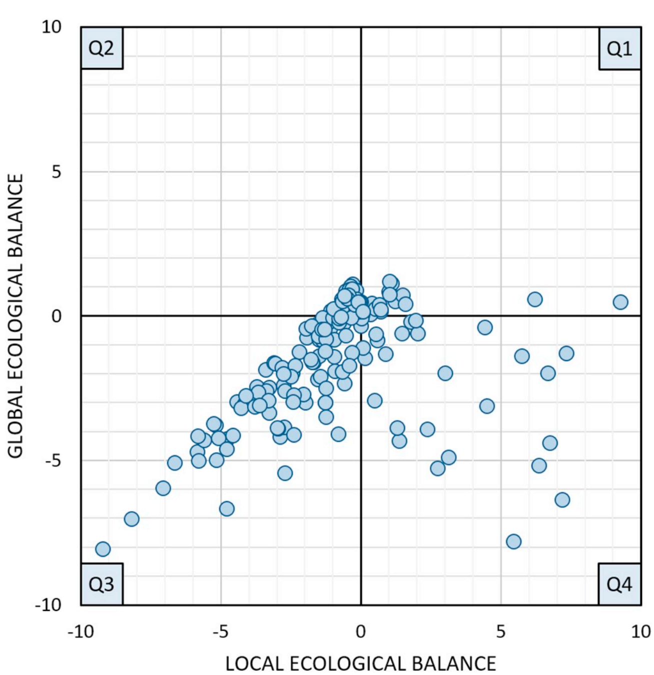

Fig. 1. Sustainability quadrants.
Notes: The figure shows 175 countries out of 182 countries with EF data; 7 countries are outside the displayed area. The balances are per capita.
Source: Author based on data from GFN (2018).

ecological balance (country's biocapacity minus country's EF) and global ecological balance (world average biocapacity minus country's EF), both expressed in per capita terms. Each quadrant represents one specific type of environmental sustainability. The distribution is asymmetric (65 countries have a global ecological balance lower than −2, but no country has this value higher than 2), but by design the quadrants are the same size and therefore do not display 7 countries. The first quadrant (Q1) shows fully sustainable countries. This is the strictest sustainability requirement as the country's population must live both within the biocapacity of its territory and within the global average biocapacity. The opposite quadrant (Q3) shows fully unsustainable countries. Their consumption can be supported neither by their domestic biocapacity nor by the global average biocapacity. The remaining two quadrants show the combinations of global sustainability and local unsustainability (Q2), and of local sustainability and global unsustainability (Q4).

According to the EF metric, the world as a whole is unsustainable as the global EF (2.84 gha pc) is higher than global biocapacity (1.68 gha pc). This is also suggested by Fig. 1, where most countries are fully unsustainable (53%; Q3), while a small minority are fully sustainable (11%; Q1). To get a comprehensive picture, one should look beyond the unweighted and overall results. Fig. A.2 (Appendix) shows a population-weighted distribution which better reflects each country's contribution to global unsustainability. Additionally, as more than half of the global EF is constituted by carbon emissions, whose conversion to land area has been challenged, one may be interested in results which do not include the carbon footprint. For this purpose, the carbon footprint was deducted from the EF, while forest biocapacity was maintained as it supports another type of footprint (wood). Not surprisingly, the non-carbon global EF (1.13 gha pc) is well below the global biocapacity (1.68 gha pc). Fig. A.3 (Appendix) shows the sustainability quadrants based on non-carbon EF. Only a minority of countries are now fully unsustainable (8%; Q3) and more than a third are fully sustainable (38%; Q1).

Table 1 shows the distribution of countries in the four quadrants based on their income level. The country sustainability assessment shows a clear pattern with respect to income. Almost four fifths (78%) of high-income countries are fully unsustainable and none are fully sustainable. For low-income countries, only one (3%) is fully unsustainable, while more than a third (38%) are fully sustainable. The clearest division is along the line of the global ecological balance: positive balance (Q1 and Q2) show all but one low-income country, but no high-income countries. As a country's domestic biocapacity is not relevant for the global ecological balance, this type of unsustainability can only arise from the size of the EF. Indeed, there is a strong association between countries' Gross National Income (GNI) per capita and their EF per capita—the Pearson correlation coefficient is 0.84 (see also Fig. A.4 in Appendix). This suggests that when aiming for global

Table 1
Sustainability and income.
Source: Author based on data from GFN (2018) and World Bank (2018a).

Country classification	Sustainable	Partly sustainable		Unsustainable
	Q1	Q2	Q4	Q3
Low income	11 (38%)	17 (59%)	0 (0%)	1 (3%)
Lower middle income	8 (17%)	15 (32%)	6 (13%)	18 (38%)
Upper middle income	1 (2%)	1 (2%)	13 (28%)	31 (67%)
High income	0 (0%)	0 (0%)	12 (22%)	42 (78%)
World	20 (11%)	33 (19%)	31 (18%)	92 (52%)

Notes: Countries are classified by the World Bank based on per capita GNI for 2014. The table shows 176 countries out of 182 countries with EF data; the 6 countries without income status are not included. The percentages relate to country income groups, not to quadrants; they add up to 100% in lines (except where not due to rounding), not in columns.

sustainability through the reduction of global EF (rather than through an increase in global biocapacity), global economic activity must decline and/or its efficiency (the EF per unit of economic activity) must increase.[13]

The proposed assessment of sustainability combines two important and legitimate sustainability perspectives. It is based on the idea that an understanding of a complex problem requires the consideration of different perspectives and choosing those most relevant. For many issues, there are two (or few more) complementary views which provide a much richer picture than a single view. Take this analogy with responsibility for climate change: developing countries highlight the high per capita emissions of developed countries; developed countries point to developing countries' emissions that are inefficient (per unit of economic activity as opposed to per capita) and increasing (the rate of change as opposed to the level). Each problem requires different conceptualization and a two-dimensional figure can only capture two perspectives at a time. The picture provided by Fig. 1 is simple, yet informative. It gives the same weight to SLB and EGB views of sustainability, providing more legitimacy than each of them independently. It shows whether a country overuses (in an aggregate sense) its domestic biocapacity, an equal share of global biocapacity, both, or neither.

The richer picture provided by this assessment brings some difficulties in terms of interpretation. First, a country's performance cannot be expressed in a single number. Aggregate indicators, such as the Gross Domestic Product or the Human Development Index, are popular because they are (more or less successfully) able to compress a rich reality into one number which can be easily compared over time and with other countries. The two-dimensional figure, though still easier to interpret than a set of indicators, will be used less than a crude, single-number indicator. Second, because the approach uses two sustainability thresholds, it does not provide an unambiguous sustainability assessment. Fig. 1 clearly shows that countries in Q1 are sustainable and countries in Q3 are unsustainable. But how to assess the sustainability of countries in Q2 and Q4? While it is possible to sum the two balances and argue that the total balance must be positive for a country to be sustainable, this approach lacks theoretical justification. Perhaps, a case can be made that all countries should meet at least one sustainability threshold (i.e. being anywhere except in Q3), though such a liberal approach does not ensure global sustainability. Asking countries position themselves only in Q1 is a sure path to global sustainability, but it is very strict for countries with low per capita biocapacity.

Note that what is presented here is a concept which builds on certain interpretations of moral rights. One may too easily reject the EGB model on the grounds of political unfeasibility. But, there is nothing wrong in thinking about normative concepts without considering their political feasibility. The EF is not a legal tool which can force countries to pass on their resources to a common pool for global redistribution. Moreover, the application of the SLB model (i.e. requiring countries to live within their respective aggregate biocapacities) is equally unfeasible, as positive local ecological balance cannot be enforced on other countries. Even under a complete embargo applied on imports from Q2 and Q3 countries (a very unlikely scenario), these countries could still produce for domestic consumption with the resulting emissions of CO_2. On the other hand, the global ecological deficit can be eliminated by reducing the EFs of countries in all four quadrants, including those that are fully sustainable (Q1).

5. Concluding remarks

The EF concept is appealing as a communication tool for showing human impact on the environment and is widely used for sustainability assessments. Though the metric was challenged, the critics have mainly focused on the methodology of the indicator, neglecting its interpretation. In this paper I have shown that the EF metric is presented at the country level mostly by comparing the consumption footprint with territorial biocapacity, with a negative balance (by means of imports from other countries and/or by depleting a country's own biocapacity) implying unsustainability. I have argued that this approach is legitimate, but should not automatically constitute the default framework for interpretation. Two views on the entitlements to environmental resources were discussed and compared. The first regards the SLB wherein a country can only live within the aggregate bioresources provided by its territory; the second is that of the EGB where a country is entitled to an amount of the world's bioresources proportionate to its population. Based on these perspectives, I have suggested how countries' sustainability may be assessed using the two sustainability thresholds. The resulting matrix provides a richer framework for sustainability interpretation and assessment that may be used by the EF and, more importantly, beyond it.

The analysis revealed two interrelated questions for sustainability indicators more generally: (a) whether a country whose consumption goes beyond its biocapacity is necessarily unsustainable; (b) whether a country whose consumption draws on the resources of other countries rather than its own, whether or not its consumption exceeds its biocapacity, is more or less sustainable. The current framing of the EF concept answers the first question positively and is ambivalent towards the second question. The idea of self-sufficiency has different meanings in closed and open systems; the approach most commonly used by the GFN treats countries more like closed units and therefore constrains them by their biocapacity. One can ponder whether countries constrained by their biocapacities should also be constrained by their levels of human capital and what bioresource-rich otherwise-poor countries can offer to bioresource-poor otherwise-rich countries in exchange for products of human capital. The consumption approach of the EF concept holds countries responsible for the effects of their consumption but does not hold them responsible for maintaining the resources on their territories. A different sustainability perspective would require a country to preserve its resources for its descendants. Though consumption may be the driving force, what physically depletes domestic resources is domestic primary production. In a narrow national sustainability perspective, it may be safer to saturate domestic consumption from foreign biocapacity and it is also more feasible to regulate primary production and emissions than consumption.

Aggregate indicators of (environmental) sustainability are challenging as they always need to deal with the questions of whether and how to aggregate arguably unsubstitutable components. But an additional difficulty relates sustainability to political borders, self-sufficiency, and responsibility. Perhaps we need at least two (sets of) measures to assess a country's performance in sustainability. The “local” one which ensures that domestic resources are not depleted and the “global” one which takes into account a country's contribution to the depletion of other resources—whether these should be understood as global commons or all external resources is another difficult question.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[13] This is a general rule derived from the IPAT equation, but its applicability is limited for the EF as currently calculated. It does not apply for those components in which the EF is directly linked with the related biocapacity.

Appendix

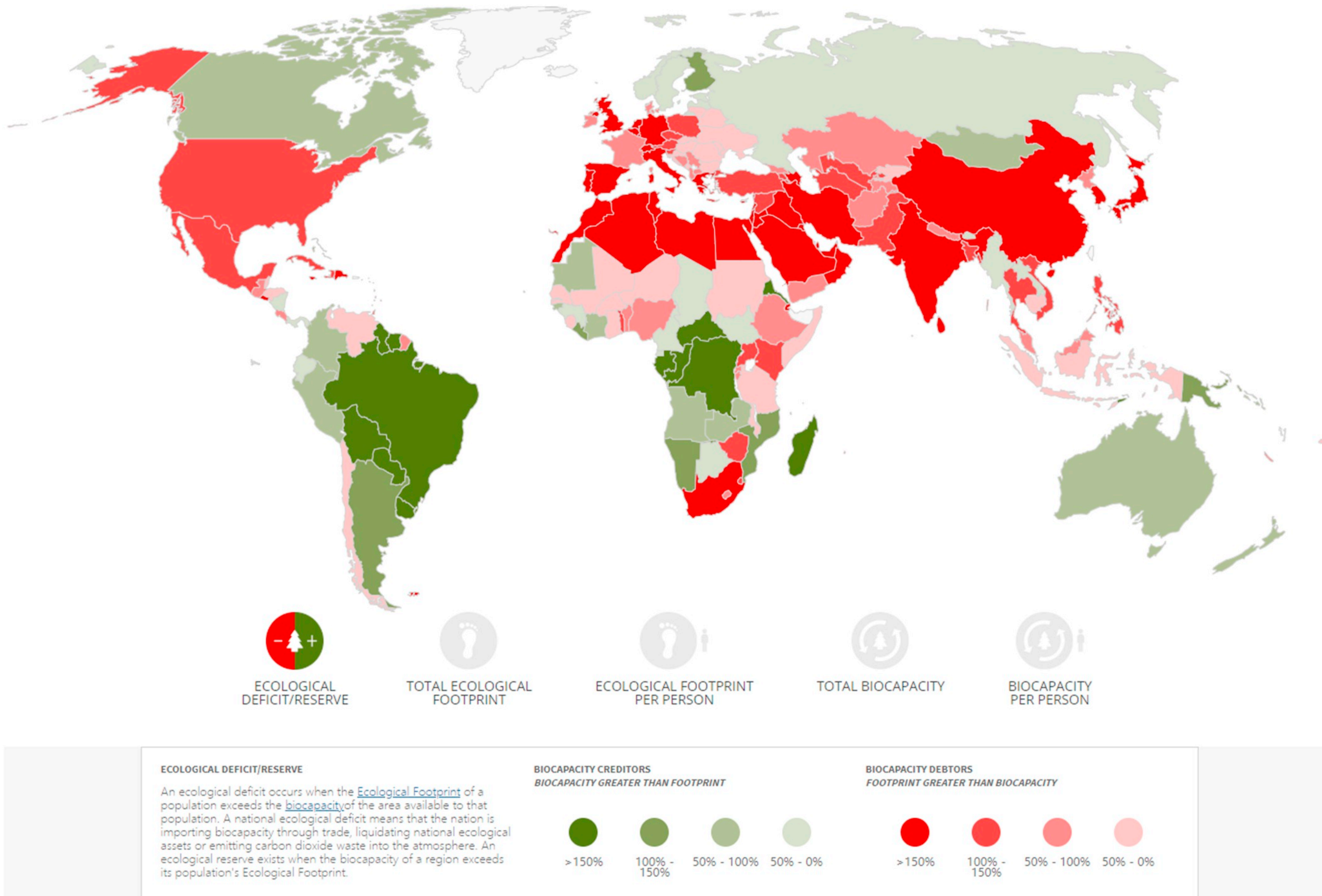

Fig. A.1. Open Data Platform.
Source: GFN (2019c).

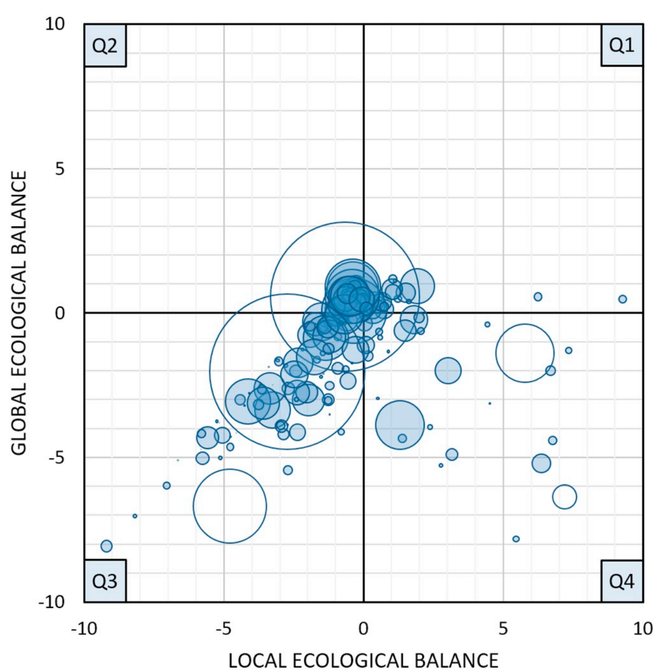

Fig. A.2. Sustainability quadrants: population-weighted distribution.
Notes: The figure shows 175 countries out of 182 countries with EF data; 7 countries are outside the displayed area. The balances are per capita. The size of the circles represents country population. Unshaded circles represent India (Q2), China and the United States (Q3), and Brazil and Canada (Q4).
Source: Author based on data from GFN (2018).

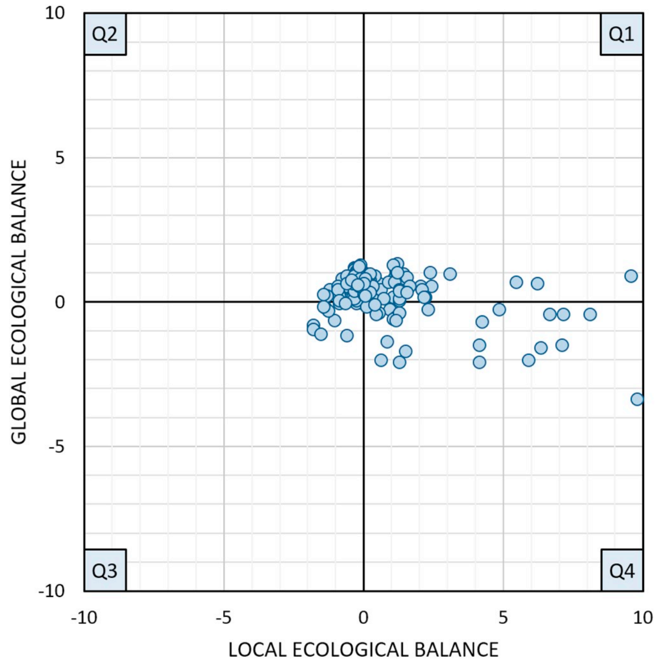

Fig. A.3. Sustainability quadrants: non-carbon EF.
Notes: The figure shows 157 countries out of 159 countries with disaggregated EF data; 2 countries are outside the displayed area. The balances are per capita. The EF excludes carbon footprint.
Source: Author based on data from GFN (2018).

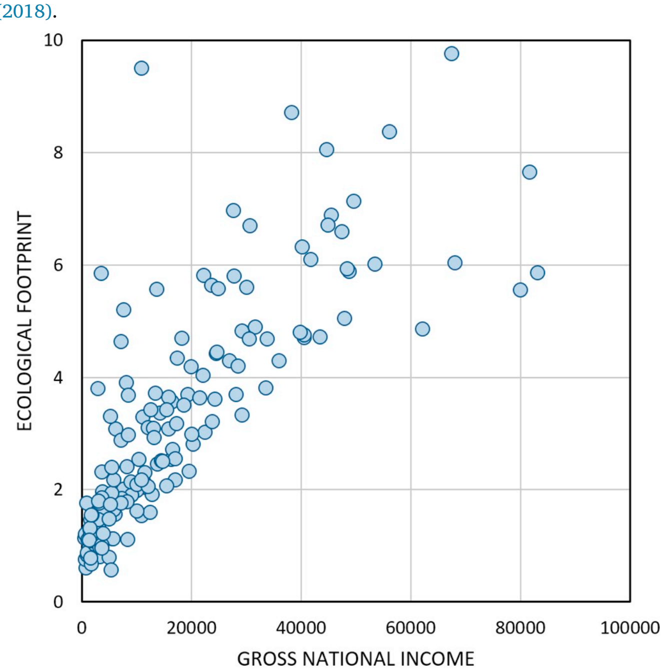

Fig. A.4. Ecological Footprint and income.
Notes: The figure shows 163 countries out of 182 countries with EF data; GNI data are not available for 16 countries and 3 countries are outside the displayed area. GNI is measured in purchasing power parity (rather than in market exchange rates used for World Bank country classification) to better reflect relative differences in countries' incomes. GNI and EF are per capita.
Source: Author based on data from GFN (2018) and World Bank (2018b).

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