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**Ecological Footprint Accounts**

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<a>1.<em>Introduction – What is the question?

This chapter documents and discusses the role of Ecological Footprint accounting. It covers what the accounts attempt to do, explains the role of such accounts in sustainability and economic assessments, how the robustness and rigour of the accounts are being improved, and what the answers are to common issues raised about the Footprint in the scientific and policy literature.

Ecological Footprint accounting is driven by one key question: *How much of the biosphere’s (or any region’s) regenerative capacity does any human activity demand?* Or more specifically: How much of the planet’s (or a region’s) regenerative capacity[[1]](#endnote-1) does a defined activity – such as supporting the consumption metabolism of a particular population – demand to provide all the ecosystem services that are competing for mutually exclusive space? These services include provision of all the resources that the population consumes and absorption of all that population’s waste, using prevailing technology and management practice(Wackernagel, 1991; Rees and Wackernagel, 1994; Wackernagel and Rees, 1996; Wackernagel et al., 2002).

Accounts typically have two sides. For example, financial “profit and loss” statements track both ‘expenditure’ and ‘income’, or balance sheet document ‘assets’ and ‘liabilities’. Similarly, Footprint accounts compare demand on biocapacity (Footprint) against availability of biocapacity.

The Ecological Footprint emerged as a response to the challenge of sustainable development, which aims at securing human well-being within planetary constraints. By staying within planetary constraints, one makes sure that biocapacity, the essential ingredient for any value chain, is available now and for future generations (Rockström et al., 2009). The ambition lying behind Ecological Footprint accounts is to provide motivational, managerial and monitoring capacity for assessing and dealing with biocapacity and its biophysical constraints.

<a>2.<em>What are Ecological Footprints for and how are they measured?

When people catch more fish than fishing grounds can regenerate, fisheries eventually collapse; when people harvest more timber than forests can re-grow, they advance deforestation; when people emit more CO2 than the biosphere can absorb, CO2 accumulates in the atmosphere and contributes to global warming. The overuse of these and other renewable resources is called ‘biocapacity overshoot’. Biocapacity is shorthand for biological capacity, which is the ability of any ecosystem – hence the whole biosphere – to produce useful ecosystem services for humans. This includes regeneration of biological materials and absorption of wastes generated by humans. Biocapacity is not fixed. It represents the availability of natural, renewable resources and waste absorption services that can be used by humanity in a given year. The abundance and productivity of natural capital change each year.[[2]](#endnote-2) For instance natural disasters such as forest fires or landslides, or human-induced degradation such as deforestation, soil loss, climatic impacts or acidification can reduce biocapacity. On the other hand, careful agricultural and forestry management can also magnify biocapacity.

There is an interesting debate around biocapacity and whether it is sustainable or can ever have a maximum. As currently measured, biocapacity only captures what is being regenerated, not whether this level of bioproductivity – or ability to maintain its level of potential net primary productivity – can be maintained forever. If this level of bioproductivity cannot be maintained, we consider the biocapacity to be fragile. Within the domain of Ecological Footprint research, ‘fragility of biocapacity’ has not been researched in detail. Such research would provide deeper insight into how much of the currently assumed biocapacity may not last, for instance due to water, energy or soil constraints. However, a preliminary investigation of this aspect (Moore et al., 2012) has revealed that the world’s biocapacity could potentially rise through 2030, peaking at 12.5 billion gha (1.5 gha per capita – assuming the UN’s medium population projection) because of the effects of increased availability of land suitable for agriculture (this being a result of the initial effects of climate change). As the climate warms further and land becomes constrained, agricultural land would probably be given preference over forests in the attempt to fulfil the food requirements of a growing world population. As a result, world biocapacity could then decrease to 11.7 billion gha in 2050 (1.3 gha per capita), or less if yields drop (Challinor et al. 2014).

Biologically productive regions represent the area, both land and water, that supports significant photosynthetic activity and biomass accumulation that can be utilized by humanity. To achieve sustainable development, it is crucial to have information regarding humanity’s demand and material dependence on the biosphere as well as the complementary information: what the biosphere does provide, in any given year. Hence Ecological Footprint accounting compares the actual amount of biological resources produced and the wastes absorbed by the planet in a given year with the number of resources humans extract and how much waste is subsequently generated in that year. This accounting can be done at any scale, from the resource demand of a single activity or a single individual, to that of a city, country, or the entire world (see section 3 for more detail). Global Footprint Network’s most recent national and global accounts (Global Footprint Network, 2014) show that, in 2010, the most recent year for which data are available, humanity continued to be in [overshoot](http://www.footprintnetwork.org/overshoot),[[3]](#endnote-3) demanding over 50 per cent more than what the biosphere renewably provided in that year.

We emphasize that Footprint assessments are accounts, not an index, such as the Environmental Sustainability Index (Global Leaders of Tomorrow Environment Task Force, 2002), or the Dow Jones sustainable development index (http://www.sustainability-index.com). Accounting is systematically distinct from an index or a composite which combines various incommensurable elements into a single number. Accounts start from a clear research question. They use as their measurement a common unit. These are entities that are shared among the various things that are compared, that is, they are relatively substitutable among themselves.[[4]](#endnote-4) Examples include financial accounting, which includes GDP, where dollars are the unit, or greenhouse gas accounts, where the unit is CO2 equivalents. In the case of Ecological Footprint accounting, the unit is global hectares.[[5]](#endnote-5)

In contrast, composite indicators, such as a Mercer quality of life indicator (Mercer, 1994) which compares the liveability of cities, or the World Economic Forum competitiveness indicator (WEF, 2012) comparing national economies, or Transparency International’s corruption perceptions index (Transparency International, 2012) measuring the perceived levels of public sector corruption, are a somehow arbitrary aggregation of diverse indicators that are then averaged out according to a particular weighing framework. The upside of indices is that they can be as broad as they wish and cover various topic areas. The downside is that the results depend on the arbitrary architecture of the index, with assumed or implied trade-offs. In other words, composite indicators lack a clear, method-independent research question, a prerequisite for scientific inquiry. In spite of their limited scientific robustness, indices may still serve practical functions. For instance they can be used as alarm bells, but they cannot be used for determining trade-offs. They can also be constructed as proxies for quick or standardized assessments or diagnostics, such as those carried out in psychology or healthcare. They are helpful diagnostic short-cuts once the index is extensively tested in statistically valid ways against measureable outcomes. Indices in public policy typically lack the sample size needed for such statistical testing. Short of that, they are not a scientifically reliable diagnostic tool.

The underlying premise of the Footprint accounts is based on the recognition that the ecosystem services demanded for human activities are competing for space, which allows biological processes to harvest rain and sunlight. All the mutually exclusive areas needed for all the demanded services then can be added up to the Footprint.

The area that is demanded is calculated by turning the formula for yield on its head. Since yield is defined as:

It follows that

Rather than expressing the area results in hectares, each hectare is adjusted for its respective biocapacity. These adjusted hectares are called *global hectares.* These global hectares are defined as biologically productive hectares with world average bioproductivity. They are the standard measurement units for both Ecological Footprint and biocapacity. One global hectare worth of any area is (in the idealized theory) able to produce a similar amount of ecosystem services. It is a ‘similar’ amount, because different hectares across the world do not provide identical services – even so, hectares across biomes and vastly different plant communities, from tropical to boreal, from wet to dry, can be compared for their productivity of meat, cereals, timber, or carbon sequestration capacity. The attempt behind the accounts (even though it is not fully realized yet in actual applications) is to base the comparison on the area’s potential Net Primary Productivity (see more on Net Primary Productivity below).

Ecological Footprint accounts attempt to track all competing demands for biologically productive surfaces. This includes the resource flows of all natural and renewable sources that are consumed by humanity and subsequent wastes that require sequestration capacity. It also includes bioproductive space converted to urban use. These flows are aggregated into six different area types for demand on nature (or Ecological Footprint): cropland, grazing land, forest products, carbon Footprint, built-up land and fishing grounds (see Figure 24.1). Two of the demand categories are provided by one biocapacity category: forest products and carbon Footprint both compete for forest land. Hence only five categories make up biocapacity.

<Figure 24.1 about here>



*Note:*<em>This graph shows the ratio between human demand and the Earth’s biocapacity, and the components of the human demand, from 1961 to 2008. In other words, the Footprint here is not expressed in global hectares, but in number of planets. It does not imply that biocapacity does not change over time – just that the number of planets available has been constant, even though the planet itself has changed over the time period.

*Source:*<em>Global Footprint Network (2011).

*Figure 24.1<em>World Ecological Footprint, 1961–2008*

Ecological Footprint accounts focus on the annual flows yielded by the biosphere’s assets. Fossil fuel deposits (or underground ores) are not considered to be biocapacity, but rather an economic asset in the lithosphere similar to gold in the bank’s safety deposit, with which the owners can buy products and services, such as biocapacity or services thereof. Lithosphere assets are thus included only to the extent that they place a demand on biosphere resources. As explained, the accounts do not include the stock of lithosphere resources, but rather include the biocapacity demand they induce, including the absorptive capacity of the planet to sequester carbon dioxide emissions from extracting and using lithosphere resources. Therefore the effects of oil exploration, refinery and final use are directly accounted for.

Climate change is not directly measured by the Ecological Footprint. Still, loss (or gain) of biocapacity is tracked by the Footprint from year to year (as long as the input data reflect these changes). But it is not possible to determine whether these changes are directly caused by climate change. However, predictions of climate models can be translated into estimates of biocapacity changes. Also annual fluctuation in the biocapacity of countries indicates higher vulnerability to changing weather patterns.

National Footprint Accounts use about 6,000 data points per country and year. The input data to the Ecological Footprint comes from a variety of international datasets, including the UN, FAO and IEA. Therefore the quality of the results of the National Footprint Accounts is dependent upon the level of accuracy and availability of these data. The primary inputs are detailed in the Appendix. The level of precision and accuracy of the Ecological Footprint is determined by the methodology and the input data to the National Footprint Accounts. Of course, both the accuracy and detail of the Footprint results need further development. Therefore, Global Footprint Network builds on 20 years of methodological development and continues to refine and develop the tool with inputs from its partner organizations and the advisory board. A number of national government organizations have independently tested and reviewed the accounts (See [www.footprintnetwork.org/reviews](http://www.footprintnetwork.org/reviews). Some reviews suggested improvements. Many of them are now incorporated in the accounting template for all countries). Underlying statistics unfortunately do not identify their confidence intervals either. Sensitivity analyses can indicate result ranges – but not describe these ranges with statistical probability.

In order to prevent exaggeration of the overuse of the planet’s regenerative capacity the method is constructed to be conservative. Therefore, the results are most likely an underestimate of overshoot. This only strengthens the argument for a significant and rapid reduction of resource throughput within the human economy in order to secure human well-being. Such reductions are in stark contradiction with most policies implemented today. Recognizing this contradiction, as well as the biophysical necessity to avoid staying in overshoot in order to maintain resource availability, it is highly unlikely that humanity, or any nation, would be better off with no Footprint results, despite the current limitations of the Footprint approach.

More on this calculation [methodology](http://www.footprintnetwork.org/en/index.php/GFN/page/methodology/) is available through Global Footprint Network publications, including the *Ecological Footprint* [*Atlas*](http://www.footprintnetwork.org/download.php?id=506) with the complete 2007 data and results (based on the 2010 edition), [a method paper](http://www.footprintnetwork.org/download.php?id=508) (Borucke et al., 2013) and a [guidebook](http://www.footprintnetwork.org/download.php?id=507) to the National Footprint Accounts (for 2008 accounts, for 2012 accounts forthcoming; all available at www.footprintnetwork.org/atlas). In addition to these scientific publications, a summary of the results for the general public is presented in *Living Planet Reports*, published by WWF (the Worldwide Fund for Nature), with support from Global Footprint Network, and the Zoological Society of London (see WWF et al., 2008, 2010, 2012). The 2011 Edition of the National Footprint Accounts was launched in December 2011 and, as with any edition, features a number of improvements (see Borucke et al., 2013). There are more substantive plans for methodological improvements for the 2015 edition, including a complete review of the equivalence factors as well as improvement of the trade portion, particularly in the light of advances in multi-regional input–output analyses.

<a>3.<em>Scales of Ecological Footprint assessments and their policy relevance

Ecological Footprint and biocapacity assessments can be applied at any scale.[[6]](#endnote-6) Biocapacity can be calculated for a particular plot of land, a region or the entire biosphere. Footprints can be assessed for any activity at any scale, be it for a single activity, the lifestyle of a person, a city, a nation or even humanity as a whole. Note though that organizations do not have a Footprint per se since it is not obvious what is included for an organisation, and what not. However, organisations’ activities have Footprints. Hence when analysing resource demands of organisations, the inquiry has to start by defining which organisational activities are being analysed.

Ecological Footprint accounts, like any accounting system, are documenting the past. Limited by global data availability, mainly UN data sets, they still have the ability to provide data for over 200 nations for 48 years (1961–2008). The historical time series help inform discussion about possible future trends. Also, any scenario outputs can be translated into Footprint and biocapacity outcomes (Moore et al., 2012).

The Ecological Footprint is a diagnostic tool that can be used to inform decision-makers of the position that they are currently residing in and how this compares to other nations of the world. It cannot be used to tell policy makers what exactly to implement, but can identify key areas where the problems lie and what the options might be. Similar to financial bookkeeping, Footprint accounts provide the context for decision-making, not prescriptions. This principle applies at all levels of analysis including the personal level. For instance, a variety of Footprint Calculators have been developed, including by Global Footprint Network, which offer diagnostics but do not prescribe actions. They are ‘yardsticks’ for resource use to help people make choices.

The power of the Ecological Footprint is often recognized for its ability to communicate (Costanza, 2000; Deutsch et al., 2000; Stiglitz et al., 2009). This also leads to the common criticism that it promises too much. If the user understands the research question behind the concept, the meaning of the results should be fairly clear. But the wider public may not know the exact research question. Still, the interpretation of ‘how many planet Earths would it take if all of humanity lived your lifestyle’ seems pretty self-explanatory.

<a>4.<em>The link between Ecological Footprints and Sustainable Development

Many users misunderstand the Ecological Footprint as a measure of sustainability. As pointed out by the Footprint standards ([www.footprintstandards.org](http://www.footprintstandards.org)), the Footprint is a measure of ‘unsustainability’, not a measure of sustainability. For instance, if humanity’s Footprint is larger than the world’s biocapacity, humanity is in an unsustainable state. So the Footprint and biocapacity numbers describe a necessary condition for sustainability, not a sufficient one. In this section, we further describe the link between ecological footprints and sustainable development.

Sustainable development implies a commitment giving all people the opportunity to lead fulfilling lives within the means of planet Earth. This kind of development continues to be identified as the primary overarching policy goal, as for instance in the emerging ‘Green Economy’ debate in the context of Rio+20 (2012), the OECD’s Green Growth strategy, or the search for Sustainable Development Goals by the UN. Yet when it comes to actual environmental strategies and policies, are decision-makers asking the right questions to lead us towards this goal? Over the last decades, the global sustainable development debate has been unfocused. Definitions abound, and long agendas are drawn up in international forums that lack specificity and consistency with the reality of planetary limits (the latest example includes ‘The future we want*’* produced for the UN’s Rio+20 conference in 2012). This lack of clarity is surprising, since the much earlier 1972 United Nations Conference on the Human Environment in Stockholm ran under the theme ‘Only one Earth’.

The current lack of specificity and consistency could be overcome with science-based benchmarks and quantitative tracking. Sustainable development, after all, builds on the UN’s original focus: economic and social development (as expressed in UNDP, 2011, the Millennium Development Goals, 2000, or the 1948 Universal Declaration of Human Rights, UN, 1948), and it is complemented by the adjective ‘sustainable’, recognizing that this development has to fit within this one planet. Sustainable development becomes the marriage of these two dimensions: ‘sustainable’ and ‘development’. This interplay between these two dimensions – the human development goal and the environmental boundary condition – is also at the heart, though implicitly, of the Brundtland Commission’s sustainable development definition. Their approach postulates to meet current needs, without compromising the ability of future generations to meet their own needs (UN, 1987).

By emphasizing the two sustainable development dimensions, it becomes possible to track the concept through a science-based measurement framework. By science-based we mean that the two objectives ‘sustainable – or does it fit within the confines of one planet?’ and ‘development – are human lives becoming measurable better?’ can be tracked through evidence-based outcome metrics. The first dimension, ‘development’, depends on how progress is interpreted, and what the key outcomes are that determine such progress. One of the most prominent outcome measures of development, particularly for comparing nations, is UNDP’s Human Development Index (HDI). They are described more below. The second dimension, ‘sustainable’, or to what extent such development can be supported within the means of planet Earth, is measured by the ratio between Footprint and biocapacity.

Sustainable development occurs at the intersection of these two dimensions:UNDP considers an HDI of more than 0.67 to be ‘high human development’. A first necessary condition for living within the means of nature occurs if the Footprint is within the available biocapacity. Currently, there are 1.8 global hectares of biocapacity available on the planet per person, but some of it is also needed to support wild species. The Ecological Footprint therefore compares a population’s demand on the Earth’s resource against the Earth’s or a region’s biocapacity (that is, its ability to regenerate resources and ecosystem services). This two-dimensional framework, now being used by organizations such as the WWF, the WBCSD and the UNEP’s Green Economy initiative, breaks down sustainable development into its core components: a commitment to human well-being and development within the means of planet Earth.

The resulting global graph provides a high-level snapshot view of countries’ or populations’ current development position.[[7]](#endnote-7) It can also be used to show progress over time, compare the situation of one community with another one, or illustrate patterns.[[8]](#endnote-8) Figure 24.2 depicts countries, and exemplifies the challenge of creating a globally-reproducible high level of human well-being without overtaxing the planet’s ecological resource base.

<Figure 24.2 about here>



*Note:<em>*Global sustainable developmentisassessed using UNDP’s Human Development Index (HDI) as an indicator of human development, and the Ecological Footprint as a measure of human demand on the biosphere. The presented results reflect the situation in 2008 (the HDI for 2008 being interpolated from 2009 and 2005 data points (UNDP, 2011)). An Ecological Footprint less than 1.8 global hectares per person makes those resource demands globally replicable. Despite growing adoption of sustainable development as an explicit policy goal, most countries do not meet both minimum requirements. Since every country has within its national boundaries different amounts of biocapacity, this analysis can also be adapted to each country. Also note that the world as a whole is outside the global Sustainable Development quadrant.

*Figure 24.2<em>Sustainable development indicator: HDI and Footprint of nations, 2008*

Making sustainable development measurable will not only accelerate the global debate, but it will also provide decision-makers with a robust metric to support them in exploring potential trade-offs and options. The simple, empirical framework proposed here could become an enabler for nations as it identifies risks to their own nation’s performance. Therefore, it represents neither conditionality nor an approach that requires international agreements. It merely recognizes that human development depends on access to ecological assets and the resources and services they provide.

<a>5.<em>Common questions and misconceptions

Ecological Footprints encounter a number of misconceptions, which we deal with in this section. Some people misunderstand the measure, or believe aspects are covered that are actually not in the account (for example, some might believe that the Footprint is a pollution measure). There is also confusion between the idea of the Footprint and its actual execution. The latter is more limited by available data. We also address a number of common issues raised in the academic and policy literature. These issues are taken from the Stiglitz Report (Stiglitz et al., 2009), Eurostat (Schaefer et al., 2006), Best et al. (2008), Kitzes et al. (2009), van den Bergh and Grazi (2010), and Grazi and van den Bergh (2012).

<b>Is the Term ‘Ecological Footprint’ Misleading?

Ecology is the study of nature’s household. One significant lens of the science of ecology is tracking the metabolism and energy flows of nature. That’s what ‘ecological’ refers to in ‘Ecological Footprint’. Also note that most of nature is heavily disturbed (or shaped) by human activity – yet continues to be in the realm of ecology.

But, of course, since the field of ecology is so vast, there is the potential that the name ‘Ecological Footprint’ could be misunderstood. This is true, of course, for any name. This is why Global Footprint Network emphasizes that ‘Ecological Footprint’ is a name for a particular research question: how much biocapacity is demanded by a given human activity? It is the research question that counts when analysing the concept, not the name. Yet it is now a widely used phrase that is intuitive and that many people can readily understand. The name ‘Footprint’ reflects ‘area demand’ as in ‘footprint of a satellite’ or ‘footprint of a building’.

The originator of the Footprint (Bill Rees and Mathis Wackernagel) as well as Global Footprint Network have deliberately not trademarked the term to make it available for public use. To protect its integrity, Global Footprint Network has developed standards and a partner network where partners commit to use the Ecological Footprint term in consistent ways, faithful to the research question and the standards. The more that large institutions such as WWF, WBCSD, UNDP, UNEP or EEA use the term in consistent ways, the less confusion is being generated.[[9]](#endnote-9)

Ultimately, the context for Footprint is larger: it is about biocapacity. Footprint is merely demand on biocapacity. If a country prefers to have ‘biocapacity accounts’ (rather than Footprint accounts), and call the Footprint ‘demand on biocapacity’, it may have a more scientific ring to it, but may reduce the concept’s ability to communicate the results.

<b>Why Focus on Biocapacity?

The quantity of human and non-human life on this planet is limited by the biosphere’s regenerative capacity and it is upon this premise that the Ecological Footprint tool is built. This limitation also includes access to non-renewable resources from the lithosphere. For instance, the use of today’s primary lithosphere resource, fossil fuel, is most restricted by the planet’s biocapacity – not by underground availability. This restriction is given by the biosphere’s limited capacity to absorb the waste from fossil fuel use (more specifically the CO2 emissions released when fossil fuels are burnt). For instance, if humanity burned all the fossil fuels already discovered, the carbon concentration in the atmosphere might grow beyond 1700 ppm (UK Institution of Mechanical Engineers,[[10]](#endnote-10) 2009). Or conversely, if CO2 emissions were to be limited in order not to exceed the 450 ppm CO2 concentration threshold in the atmosphere, which many climate scientists consider to be too high for securing ecosystems stability (Hansen et al., 2008 Lovejoy, 2008), then humanity has already found five times more fossil fuels in the ground than can be burned (Leaton, 2012). This divergence between the carbon that humanity has found in the lithosphere and the carbon that can be ‘safely’ released into the atmosphere makes clear that waste absorption is the most significant bottleneck for sustainable fossil fuel use, not supply. In other words, the biocapacity to absorb greenhouse gases is drastically more limiting for the human economy than fossil fuel supplies.

Ores are another resource from the lithosphere, largely to provide society with metals. Unlike fossil fuels, metals are used, not used up. Society may need more metals, or metal in use erodes and gets dispersed. Therefore, the use of metals depends on humanity’s ability to concentrate the elements. Given existing technology, this ability is largely limited by energy inputs. With much of the industrial energy use currently being sourced from fossil fuels, the limiting factor ultimately becomes, as explained above, biocapacity. In other words, use of metals is also ultimately limited by biocapacity.[[11]](#endnote-11)

In a time of increasing ecological constraints, the research question behind Ecological Footprint accounts described above could be the most critical one for the twenty-first century. More importantly, it is one that humanity cannot afford to ignore. Failing to live within nature’s budget will eventually lead to ecological bankruptcy and societal collapse. Thus there may be no single research endeavour more important than building an accurate understanding of humanity’s demand on the biosphere. Answering such a research question therefore requires an open, transparent and replicable process, based on empirical evidence. In other words, solid answers depend on rigorous scientific inquiry.

<b>Why Measure Biocapacity in Global Hectares, and not in TW or Tonnes of Carbon?

The sun powers planet Earth with about 175 000 terawatts (TW) of solar energy. This translates into as little as about 100 TW of biomass production in the biosphere, terrestrial and in the ocean (100 TW according to Nealson and Conrad, 1999; 75 TW according to Haberl et al., 2007). Possibly half of the biocapacity of the planet might be used for food production (Global Footprint Network 2010 National Footprint Accounts), meaning that this biomass production, plus significant fossil fuel input (approximately 2–3 TW of fossil fuel for the food portion of human consumption), turn into less than one TW of food (10 000 kilo joules/day per person times 7 billion people).

This example illustrates a long energy cascade, along which less and less energy is available, and the remainder is dissipated as energy waste. No energy is lost, but the quality is: and as a result, along the cascade, less and less energy becomes available. For this reason, expressing flows of biocapacity in terms of energy, or more precisely energy flows (such as TW), while scientifically valid, is difficult for both communication as well as scientific work, since one TW means something very different along the energy cascade – by orders of magnitude. Every TW would need to be described by ‘what kind of TW?’ Direct comparisons of results would become challenging and potentially confusing.

An alternative is to express biocapacity in terms of biomass production. In ecological sciences, this is called Net Primary Productivity. Much of the Ecological Footprint work is inspired by such assessments as, for instance, the one by Vitousek et al. (1986) and the many highly interesting and more detailed studies by the Social Ecology group in Vienna guided by Fischer-Kowalski and Haberl (Fischer-Kowalski and Haberl, 1993, 1997, 2007; Haberl and Schandl 1999, Haberl 1997; Haberl et al., 2002). A number of papers have described the link and differences between Ecological Footprint accounting and approaches such as HANPP (human appropriation of net primary productivity) – see for instance Haberl et al. (2004) and Moffatt (1999).

Focusing on one segment of the energy cascade (i.e., where sunlight is transformed into biomass) makes NPP or Footprint studies far clearer than more general studies of energy flows. Yet NPP studies faces two other challenges compared to Footprint accounting:

1.<em>How can we meaningfully compare one ecosystem with another one? For instance, crop areas are not managed for producing maximum NPP, but rather to produce maximum amount of the desired crop. The same area of cropland left as a forest might produce significantly higher NPP than the wheat field it currently hosts. Potential NPP helps to compare various biologically productive surfaces more meaningfully – even though it is difficult to measure since it depends on assumptions and extrapolations – but these can be tested against empirical evidence. Therefore potential NPP results are planned to be used also in Ecological Footprint accounts to estimate more robust equivalence factors (as discussed in more detail below).

2.em>But a more significant challenge is the difficulty of NPP assessments to compare supply with demand. For instance in a forest, which parts need to be included in the assessment of availability: tree trunks obviously, but branches? Leaves? Soil? Undergrowth such as ferns, bushes and mushrooms? Roots? How then is demand assessed? Does it include the branches of a tree, even though they are left back in the forest after harvest? What about the leaves, the disturbed undergrowth, the roots of the cut tree? How can the ‘harvestable limit’ be defined?</nl>

The Ecological Footprint’s agricultural perspective, while more crude than an assessment of an ecosystem’s entire NPP, makes the demand and supply comparison more direct. For instance, foresters can estimate the timber increment a forest generates, and inversely, the number of cubic meters of timber that are removed from a forest can also be measured.

For these reasons, expressing demand on the biosphere, and availability of regenerative production of the biosphere in agricultural terms, in terms of biologically productive surfaces, allows researchers to assess, with some degree of accuracy, human demand against nature’s supply. And luckily, the measurement units of such an analysis are also easy to understand by a wide public, thanks to the visual power of surface.

<b>Are the Equivalence Factors Adequate?

Equivalence factors attempt to compare hectares across various land uses. They are needed for consistent aggregation of biocapacity. Equivalence factors translate the area of a specific land use type available or demanded into units of world average biologically productive area (expressed in global hectares). Thus, they vary by land use type and year. Currently, the equivalence factors are calculated as the ratio of the maximum potential ecological productivity of world average land of a specific land use type (for example cropland) and the average productivity of all biologically productive lands on Earth. What does this mean?

To calculate equivalence factors Global Footprint Network currently uses the suitability indexes from FAO’s Global Agro-Ecological Zones (GAEZ) assessment combined with information about actual areas of cropland, forest and grazing area from FAOSTAT, a UN database provided by FAO. The GAEZ model divides all land globally into five categories, each of which is assigned a suitability score:

Very Suitable – 0.9

Suitable – 0.7

Moderately Suitable – 0.5

Marginally Suitable – 0.3

Not Suitable – 0.1

The current equivalence factor calculation assumes that the most productive land is put to its economically most productive use. The calculations assume that the most suitable land available will be planted to cropland, the next most suitable land will be under forest, and the least suitable land will be grazing area. The equivalence factor is calculated as the ratio of the average suitability index for a given land type divided by the average suitability index for all land types. This means that current (and future) equivalence factors are based on global-average agricultural suitability of various biomes.

But Global Footprint Network also agrees with Eurostat’s perspective (Schaefer et al., 2006) that the equivalence factors need to be strengthened, since they are at the core of Ecological Footprint accounting. Ideally, equivalence factors would be based on spatially explicit measures of potential net primary productivity. Globally consistent and reliable data sets on potential net primary productivity do not yet exist. However, approximations are needed to improve on the current even more basic estimates of equivalence factors.

One aspect Global Footprint Network is working on is to improve the calculation method by estimating equivalence factors according to actual land use (based on GIS maps), rather than merely assuming a hierarchy of land uses. The other aspect is to find adequate data sets on relative potential net primary productivity.

Also, better equivalence factors could help bridge the current gap between theory and practice of measuring global hectares. In ideal theory, a global hectare is independent of the chosen land use. However, in practical application this is not fully realized. Still, if a piece of forest is converted into cropland, it is incorrect to assume that biocapacity automatically goes up. While the equivalence factor goes up (cropland hectares represent typically higher biocapacity than forest hectares), the yield factor may drop. The latter factor drops because relatively high-yielding forest may be converted into relatively low-yielding cropland. But there is still a research and method development gap in that changes in land use in current accounts would most likely shift the resulting biocapacity estimate.

Research that has already been applied, but also needs to be deepened, is to isolate the portion of yield change that is human induced, and to present it as a separate factor (defined as ‘intertemporal yield factor’; see Borucke et al., 2013) capturing the change over time. This innovation enables us to more meaningfully depict time series. With this innovation, the measurement unit of global hectares becomes ‘constant global hectares’, to be more precise. This constant global hectares logic is similar to dollar measurements being expressed in constant (in this case ‘inflation adjusted’) dollars. These constant global hectares represent a set portfolio amount of products and services that an average hectare was able to provide in a given year. In this way, a given level of consumption (and production) can more meaningfully be compared across years. Even though National Footprint Accounts, starting with the 2011 edition, are using constant global hectares, they are still called global hectares to keep communication simple.

<b>Do Ecological Footprints Provide a Pollution Measure?

The Ecological Footprint attempts to measure demand on biocapacity. It does not include aspects outside of that scope. For instance, pollution affecting human health, but not biocapacity (such as noise, or urban air pollution, radioactivity), is not captured by the Footprint (Kitzes et al., 2009). However, pollution that affects biological productivity (or bioproductivity) should be included. There the limitation is that the demand on biocapacity of those kinds of pollution is not systematically tracked and therefore there are no globally comparable data sets to include those impacts in Ecological Footprint accounts. Examples of such pollution are acidification or eutrophication (some local Footprint studies have, however, included such pollution impacts) (Wackernagel et al., 1999).

Note, however, that as these pollution effects change biocapacity, this change will be recorded by future biocapacity accounts. But ideally, in more perfect accounts, this change in biocapacity should be debited against the present Footprint. This omission indicates the general bias of Footprint accounts: the high likelihood that they exaggerate biocapacity and underestimate Footprints.

<b>Is the Ecological Footprint Biased against International Trade?

Some critics have argued that Ecological Footprints are biased against international trade (van den Bergh and Verbruggen, 1999; Grazi et al., 2007; Stiglitz et al., 2009). The Ecological Footprint does not bias against trade, but instead simply reports the world as it currently stands. It documents that many countries are running biocapacity deficits and may therefore depend upon biocapacity from external sources or on local overuse. Some of this dependence may be covered in the form of net-imports. Just as money can be used to describe trade flows, so can Footprint accounting describe these flows in terms of embodied biocapacity. The Ecological Footprint approach is parallel to that of the many studies dealing with carbon (for example, Davis et al., 2011; Hertwich and Peters, 2009; Peters and Hertwich, 2006; Peters et al., 2011) or water (Hoekstra and Chapagain, 2007) embedded in international trade. The Ecological Footprint simply expands the analysis to assess a broader range of ecological resources and services embedded in internationally traded products. While it is true that some users of Ecological Footprint results have made anti-trade claims (Willey and Ferguson, 1999), the Footprint method as such offers no prescriptions about trade regimes.[[12]](#endnote-12) Rather it helps to show that resources within the world are limited and to recognize that if all nations run at a biocapacity deficit then this will inevitably lead to a global depletion of the planet’s ecological assets.

<b>Is the Carbon Portion of the Footprint Exaggerated?

Some critics have questioned the rationale behind the carbon portion of the Footprint (Ayres, 2000; IMV, 2002; Neumayer, 2013). The Ecological Footprint builds on the premise of capital maintenance. Its accounts answer the question of how much biocapacity is needed to provide all the services demanded by people. If people demand more services than are being regenerated (‘overshoot’) then the accounts calculate how much more biocapacity is needed to cover this demand. In the case of the carbon Footprint, the accounts calculate how much biocapacity is needed in order not to increase the carbon concentration in the atmosphere in that year (that is, not leaving a debt for future years). If carbon is absorbed through human means or technological intervention, then it is not counted. The accounts only include the carbon that humanity leaves for the biosphere to take care of. Given humanity’s significant dependence on fossil fuels, it should therefore not surprise that the carbon Footprint component currently makes up such a large proportion of the Ecological Footprint. Note that this was not the case in the past, and is not true either for most lower-income countries (see Galli et al., 2012a).

Hence, the dominance of carbon within the overall Ecological Footprint is by no means exaggerated, but simply represents the real amount of carbon dioxide that is emitted most prolifically through the burning of fossil fuels. Over the last few years there has been a tendency to focus upon the carbon issue, but this is not the only problem. The Ecological Footprint captures far more issues than the emission of carbon dioxide. Since the Footprint accounts track availability of and demand on natural resources from different land types, this information is useful for understanding the availability of space for biodiversity. Again, the accounts do not prescribe how much of the biocapacity should be left for wild species. Obviously the amount of biocapacity left for biodiversity shapes biodiversity outcomes, together with other factors such as invasive species, toxicity, fragmentation and management. Also, the Footprint accounts for the forestry land that is cut down and converted to cropland and therefore implies a loss of biodiversity and ecosystem services.

If indeed humanity should decide to move aggressively out of fossil fuels, Footprint accounting helps to identify to what extent this move leads to a burden shift to other land types, or truly reduces humanity’s demand on biocapacity. Lack of biocapacity also indicates risk, should it become necessary to move out of fossil fuels and require more biomass as energy source. Also, less availability of cheap fossil fuels may have a significant impact on agricultural productivity, potentially increasing the land demand for agriculture. All these effects are captured by Footprint accounting.

<b>What about Nuclear Energy?

While in earlier Footprint accounts, nuclear energy was included, assuming that the Footprint of nuclear electricity would be at par with that of coal-powered electricity (in order to avoid the debate whether coal or nuclear is better), accounts since the 2008 National Accounts Edition no longer include nuclear apart from the CO2 emitted through construction and use of the plants. But it is also emphasized that Ecological Footprint methodology may not be the most relevant framework for assessing the risks and benefits of nuclear energy. More significant are questions of costs, operational risks, long-term waste storage and the potential for nuclear proliferation.

Still, a more recent study, published by WWF Japan, showed the biocapacity impacts from the Fukushima nuclear accident in 2011. The exclusion zone, or ‘warning zone’ as it is officially called, with a 20 km radius, represents 2.7 per cent of Japan’s biocapacity. The report does not provide information on how long the exclusion zone may be unsafe for human use. But if this zone is not inhabitable or usable by people for 1000 years, it would imply that this one accident occupied 27-fold Japan’s biocapacity of that year. Also, the report documents that the area currently contaminated to a level that is higher than pre-accident legal limits is about 10 per cent of Japan’s biocapacity (WWF Japan, 2012).

<a>6.<em>How criticism is stimulating further development of the Footprint tool

As originators of the method and stewards of the most widely used Ecological Footprints accounts in use today, [Global Footprint Network](http://www.footprintnetwork.org/) ([www.footprintnetwork.org](http://www.footprintnetwork.org)) is the first to acknowledge that the Footprint accounts can and must be improved. Global Footprint Network considers the current National Footprint accounts as evidence that biocapacity accounting is possible, with far more potential for accuracy and detail. As a scientific organization aiming to implement policy-relevant tools and analyses, Global Footprint Network asks others to test and review the results, and depends on input and suggestions from others regarding calculation methods and potential improvements.

Global Footprint Network scientific testing goes a long distance beyond academic peer-reviews. It proactively seeks the review of the ultimate users of Footprint accounts – national governments. The main reason is that nations are the ultimate risk bearer of biocapacity deficits, and their governments need to have access to results they have confidence in.

To build this confidence, Global Footprint Network’s comprehensive review efforts start with transparency: the method is published on the Network’s website and in academic journals. Of course, it also engages in academic peer-reviews – but peer-review is just one element, because such reviews do not go deep enough, and the academic community does not depend on the reliability of results in the same way that national governments do. In addition, therefore, Global Footprint Network directly invites national governments (and their respective agencies) to verify the assessments – including suggesting improvements. About 12 such assessments have been completed (or are still under way) and some of them are listed on Global Footprint Network’s website at www.footprintnetwork.org/reviews. Completed assessments include that from the European Parliament (ECOTEC, 2001), Switzerland (von Stokar et al., 2006), Luxembourg (Hild et al., 2010), United Arab Emirates (Abdullatif and Alam, 2011), European Commission (Best et al., 2008), Japan (see for details WWF Japan, 2012, p. 49), or the UK (RPA, 2007). An interesting example of a government review is that of the French SOeS institute (SOeS, 2010), which independently reproduced the French Footprint time trends within 1 to 3 per cent of Global Footprint Network’s results, using their own data and the method described on Global Footprint Network’s website.

In the academic and the public policy literature, there are numerous valid critiques of the Ecological Footprint method, many of which form the basis for an active research agenda, a good summary of which is provided by Kitzes et al. (2009).

There are two types of criticisms: *fundamental* (is this a valid approach?) versus *incremental* (how can the approach be improved?). Fundamental criticism is essential. But to be valid, fundamental criticisms of any research need to follow a logical sequence, with each step building on the one before (see Box 24.1). The sequence starts with testing whether the research is based on a true research question (that is, one that is empirically testable). If it is, then critics should probe the relevance of the research question. Step 3 involves assessing whether a better method exists elsewhere to answer the research question (and if not, then reviewers can suggest possible ways to make the examined method stronger). Finally, if an examined study passes these three steps, critics can still reject it if they can show that society would be better off without the study’s results. This may be the case if the proposed answers are deemed to be more misleading than informing.

<Box 24.1 about here>

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| Box 24.1<em>Logical Sequence for Reviewing and Criticizing Research   1. Does it build on a clearly defined, valid research question? 2. If yes, is it a relevant research question? 3. If yes, are there more accurate methods available elsewhere for answering this particular research question? 4. If not, is society better off without the results this method generates? |

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Much Footprint criticism arises from the reviewers’ apparent confusion about what the research question behind Footprint accounting actually is. Because Footprint accounting takes a systems view, people often assume it covers issues that it is not designed to measure. Examples of such Footprint criticisms include van den Bergh and Verbruggen (1999), Grazi et al. (2007), van Kooten and Bulte (2000), Fiala (2008), or Grazi and van den Bergh (2012). None of those studies include step 1 and 2 of this logical sequence in their argument. As a result, many of these studies’ criticisms are irrelevant to the Footprint’s research question. Following steps 1 and 2 would avoid such fallacies. Others question the validity of the Footprint for conclusions they make themselves, rather than addressing the four steps outlined in Box 24.1. As a consequence they present immaterial conclusions. Examples are given in Box 24.2 and also include the Stiglitz Report (Stiglitz et al., 2009) or van den Bergh and Verbruggen (1999), which refute Footprint accounts for being anti trade (which they are not).

<Box 24.2 about here>

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| Box 24.2<em>‘The Footprint is not perfect, therefore we should not use it’  Some government agencies have used scientific reviews in order to legitimize their unwillingness to adopt Footprint accounting in their own practice. The argument boils down to the statement: ‘Footprint results are not perfect; therefore they should not be used’. An example of such an approach is RPA (2006) and RPA (2007), two consecutive studies commissioned by DEFRA, the UK’s ministry of environment. Mathematically speaking, such a statement is true for any research, because by definition, scientific inquiry is never perfect, but a continuous process of learning and improving. While rhetorically, such an argument generates the perception that diligent scientific analysis showed that the Footprint is unfit for use by the agency, the scientifically relevant and honest question to answer should have been: why would the agency be better off not having the analysis? (step 4). Therefore, we include the plea in this chapter to make sure criticism is driven by an honest scientific inquiry (as outlined in Box 24.1) rather than by rhetorical convenience. Obviously, this is true for any research, particularly research critical for public welfare.  In the same vein, few studies on fundamental Footprint criticisms explicitly discuss whether the Footprint question is relevant or not (a notable exception is Schaefer et al., 2006). Discussing the relevance of the research (step 2 of Box 24.1) should be a prerequisite for any fundamental criticism. Global Footprint Network’s position is that the Footprint research question is central to sustainability. It holds that sustainability cannot be meaningful unless the availability or regenerative capacities of the ecological constraints of nature, within whose boundaries sustainable development must act, are known. Just as it is important for farmers to know the size of their farm, whether their farmland extends over 5000, 500 or 5 hectares, as having this knowledge about the capacity of the land makes a significant difference to the opportunities that are available to the farmer, one could contend that the same logic applies to a region or even the whole world. By understanding the restrictions of the planet’s capacity and where the limitations lie, humanity can move towards sustainability in an informed manner. |

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*Incremental* criticism addresses the question: *How can the method be improved?* Most published criticism is of this incremental nature – and this is the area on which Global Footprint Network‘s current development of the methodology is also focused. For example, Global Footprint Network is working on making the trade assessments of the National Footprint Accounts compatible with the newest insights and analysis from Multi-Regional Input–Output (MRIO) models. But there is still significant work to be done to harmonize the approaches (Ewing et al., 2012, Galli et al., 2012b). Global Footprint Network is currently focusing on an MRIO-assessment based on the newest Global Trade Analysis Project (GTAP) database from Purdue University, GTAP8 (Narayanan et al., 2012). This provides a parallel methodology for analysing resource flows, in addition to the classical National Footprint Accounts trade analysis based on product flows documented by the United Nations’ COMTRADE database that tracks trade flows based on customs statistics of imports and exports. Other MRIO assessments are also emerging, such as the EXIOPOL model (Tukker et al., 2009) and the EORA model (Lenzen et al., 2012; Moran et al., forthcoming).

One challenge is that MRIO models do not offer the same level of detail of temporal, categorical or spatial coverage as the National Footprint Accounts. (GTAP8 covers the years 2004 and 2007, and divides the world into 129 nations, territories and regions, using only 57 categories; in contrast, current National Footprint Accounts include data for 1961–2008 for approximately 240 countries, of which around 150 are published, and assessments are based on about 6,000 data points per country and year).

Harmonizing National Footprint Accounts with the emerging MRIO models, together with the aforementioned search for understanding the ‘fragility of biocapacity’, represent the most significant research frontiers in the Footprint accounting science, opening significant analytical possibilities such as the possibility of tracking trade flows more consistently as well as to the country of origin. Further, it allows researchers to break overall demand into final demand categories.

<a>7.<em>Conclusions

Ecological Footprint accounting is an answer to just one basic question emerging from the need to make our societies and economies sustainable. It attempts to quantify the ‘scale question’ which is at the core of the Ecological Economics discipline (Daly, 1977; Daly and Farley, 2004). While there is still much room for improvement, a number of independent reviews by government agencies – as mentioned above – have confirmed the validity of the assessment.

Criticism is needed for improving the accounts so they can better answer the underlying research question. Much criticism is valid and is being addressed in the research agenda of the Footprint community. But there is also much criticism based on misconceptions about what Footprint accounting really is. Hopefully this contribution here helps to clarify the distinction between these two types of criticism.

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<a>APPENDIX: Fundamental sources and description for data used within the National Footprint Accounts

|  |  |  |
| --- | --- | --- |
| Dataset | Source | Description |
| Production of primary agricultural products | FAO ProdSTAT | Data on physical quantities (tonnes) of primary products produced in each of the considered countries. |
| Production of crop-based feeds used to feed animals | Feed from general marketed crops data is directly drawn from the SUA/FBS from FAOSTAT  Data on crops grown specifically for fodder is drawn directly from the FAO ProdSTAT | Data on physical quantities (tonnes) of feeds, by type of crops, available to feed livestock |
| Production of seeds | Data on crops used as seeds is calculated by Global Footprint Network based on data from the FAO ProdSTAT | Data on physical quantities (tonnes) of seed |
| Import and Export of primary agricultural and livestock products | FAO TradeSTAT | Data on physical quantities (tonnes) of products imported and exported by each of the considered countries. |
| Livestock crop consumption | Calculated by Global Footprint Network based upon the following datasets:   * FAO Production for primary Livestock * Haberl et al. (2007). Quantifying and mapping the human appropriation of net primary production in Earth’s terrestrial ecosystems. | Data on crop-based feed for livestock (tonnes of dry matter per year), split into different crop categories. |
| Production, import and export of primary forestry products | FAO ForeSTAT | Data on physical quantities (tonnes and m3) of products (timber and wood fuel)a produced, imported and exported by each country. |
| Production, import and export of primary fishery products | FAO FishSTAT | Data on physical quantities (tonnes) of marine and inland fish species landed as well as import and export of fish commodities. |
| Carbon dioxide emissions by sector | International Energy Agency | Data on total amounts of CO2 emitted by each sector of a country’s economy |
| Built-up/ infrastructure areas | A combination of data sources is used, in the following order of preference:   1. CORINE Land Cover 2. FAO ResourceSTAT 3. Global Agro-Ecological Zones (GAEZ) Model 4. Global Land Cover (GLC) 2000 5. Global Land Use Database from the Center for Sustainability and the Global Environment (SAGE) at University of Wisconsin | Built-up areas by infrastructure type and country. Except for data drawn from CORINE for European countries, all other data sources only provide total area values. |
| Cropland yields | FAO ProdSTAT | World average yield for 164 primary crop products |
| National yield factors for cropland | Calculated by Global Footprint Network based on cropland yields and country-specific un-harvested percentages. | Country-specific yield factors for cropland |
| Grazing land yields | Chad Monfreda (personal communication). (2008), SAGE, University of Wisconsin, Madison. | World average yield for grass production. It represents the average above-ground edible net primary production for grassland available for consumption by ruminants. |
| Fish yields | Calculated by Global Footprint Network based on several data including:   * Sustainable catch value ([Gulland, 1971](#_ENREF_33)) * Trophic levels of fish species (Christensen et al., 2008) * Data on discard factors, efficiency transfer, and carbon content of fish per tonne wet weight ([Pauly and Christensen, 1995](#_ENREF_72)). | World-average yields for fish species. They are based on the annual marine primary production equivalent. |
| Forest yields | World average forest yield calculated by Global Footprint Network based on national Net Annual Increment (NAI) of biomass. NAI data is drawn from two sources:  Temperate and Boreal Forest Resource Assessment – TBFRA ([UNECE and FAO, 2000](#_ENREF_93)).  Global Fiber Supply Model – GFSM (FAO, 1998). | World average forest yield. It is based on the forests’ Net Annual Increment of biomass. NAI is defined as the average annual volume over a given reference period of gross increment less that of neutral losses on all trees to a minimum diameter of 0 cm (d.b.h.). |
| Carbon Uptake land yield | Calculated by Global Footprint Network based on data on terrestrial carbon sequestration ([IPCC, 2006](#_ENREF_48)) and the ocean sequestration percentage ([IPCC, 2001](#_ENREF_47)). Further details can be found in [Kitzes et al.,(2009](#_ENREF_50), p. 69). | World average carbon uptake capacity. Though different ecosystems have the capacity to sequester CO2, carbon uptake land is currently assumed to be forest land only by the Ecological Footprint methodology. |
| Equivalence Factors (EQF) | Calculated by Global Footprint Network based on data on land cover and agricultural suitability.  Data on agricultural suitability is obtained from Global Agro-Ecological Zones (GAEZ). FAO and International Institute for Applied Systems Analysis 2000.  Land cover data drawn from ResourceSTAT | EQF for crop, grazing, forest and marine land. Based upon the suitability of land as measured by the Global Agro-Ecological Zones model ([FAO, 2000](#_ENREF_20)). |

*Note:*<em>a. In Global Footprint Network’s national accounts, ‘wood fuel’ is not considered to be a derived product because fuel wood productivity is higher than timber productivity since more of a tree can be used for fuel than for timber. It is treated in a same manner as the primary products in the Footprint calculation. Therefore, it is covered under primary products in the MRIO model.

1. <a>NOTES

   1.<em>The potential of the planet’s surface to provide net primary productivity. [↑](#endnote-ref-1)
2. 2.<em>Sometimes, results are presented in terms of ‘number of planets’. This is equivalent to showing the ratio between humanity’s Footprint and the planet’s biocapacity. [↑](#endnote-ref-2)
3. 3.<em>Ecological overshoot occurs when a population’s demand on an ecosystem exceeds the capacity of that ecosystem to regenerate the resources it consumes and to absorb its wastes (see also Catton, 1982). [↑](#endnote-ref-3)
4. 4.<em>For no accounts are the units totally pure, or universally interchangeable. They are just reasonably good approximations of more or less interchangeable units. For example, one dollar to a low-income person may be worth much more than to a billionaire; yet, the dollar is a good approximation of a comparable unit of purchasing power. Or the last cubic metre of freshwater removed from a dry area is far more damaging than the first, or the last kilogram of fish caught causes more impact on the fish stock than the first kilogram of fish. Also, depending on the species and the respective ecosystem health, the impact of consuming one kilogram of fish can vary by magnitudes. Yet it is a meaningful and scientifically robust research question to inquire: how many kilograms of fish were removed from this lake? This and all other questions based on a commensurable unit can be answered through accounting. [↑](#endnote-ref-4)
5. 5.<em>A global hectare is a common unit that encompasses the average productivity of all the biologically productive land and sea area in the world in a given year (Galli et al., 2007; Monfreda et al., 2004). Biologically productive areas include cropland, forest and fishing grounds, and do not include deserts, glaciers and the open ocean. [↑](#endnote-ref-5)
6. 6.<em>A comprehensive review of Ecological Footprint applications is provided by Bastianoni et al. (forthcoming). [↑](#endnote-ref-6)
7. 7.<em>This approach was originally developed as part of Aurélien Boutaud’s PhD dissertation (2002). His approach was developed further in a collaboration between Boutaud and Global Footprint Network (Moran et al., 2008; Global Footprint Network, 2009). [↑](#endnote-ref-7)
8. 8.<em>Note that the comparison with global average biocapacity mainly provides a global overview. This then can be taken a step further, comparing with local biocapacity. For many countries, local availability of biocapacity (and financial means to access biocapacity from elsewhere) are a more significant determinant of resource access than the global average. [↑](#endnote-ref-8)
9. 9.<em>The promotion, and slight distortion of the Carbon Footprint by BP was, in the eyes of Global Footprint Network, a lucky occurrence. Global Footprint Network had been concerned about the possibility that a large organization like BP could significantly distort and confuse the concept. But in this case, it has, in spite of the slight distortion from the original concept, helped to promote rather than thwart the understanding that there are global limits, and that consumption is an ultimate driver of resource demand (Fill and Hughes, 2008, p. 156; Safire, 2008). [↑](#endnote-ref-9)
10. 10.<em> In their 2009 Climate Change Adaptation Report, they state: ‘The report’s point of departure is that we are unlikely to be far more successful at curbing our CO2 emissions in the near future than we have been over the past decade or so. And even with vigorous mitigation effort, we will continue to use fossil fuel reserves until they are exhausted. However by then, atmospheric CO2 levels may have risen to about 1700ppmv compared to an average of 383ppmv today.’ (http://www.imeche.org/Libraries/Key\_Themes/ClimateChangeAdaptationReportIMechE.sflb.ashx). [↑](#endnote-ref-10)
11. 11.<em>In addition to energy for concentrating metals, mining itself can also affect biocapacity, not only through the loss of potentially productive areas but also through mining refuse and other waste products. [↑](#endnote-ref-11)
12. 12.<em>Humanity has maintained use of resources outside the realms of settlements since the beginning of civilization. Indeed most current communities are far from self-sustaining, and exist by drawing upon the resources beyond their borders. Even hunter-gatherer tribes depended on far larger areas than the settlements themselves. Thus the space required to sustain populations has historically been far larger than the main living space of communities. [↑](#endnote-ref-12)