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Ecological Footprint and Biocapacity

The world's ability to regenerate resources and absorb waste in a limited time period

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ABSTRACT

The Ecological Footprint (EF) is one part of a renewable resource accounting tool that is used to address the underlying issue of sustainable consumption. It measures the extent to which humanity is using nature's resources faster than they can regenerate. The components (variables) of sustainable consumption are aggregated using weighting factors based on the Earth's regenerative capacities for the considered resources. EF is usually presented together with biocapacity (BC), which measures the bioproductive supply. The mathematical difference between EF and BC is called either reserve or deficit (or overshoot for the globe).

The EF/BC concept is a good tool for awareness rising; EF/BC accounts link ecosystems and their (over-) use. For discussions among policy makers' current applications are too diverse and highly in-transparent. External reviewers should be part of the applied quality management using independent data sources for comparison. Not for all environmental problems the Earth has a significant ability for regeneration in a limited time period and the EF/BC transformation of these environmental pressures into an area of regeneration is questionable. A brief review of the strengths and shortcomings of the EF/BC accounting is provided. Additionally, some other tools measuring sustainable development are presented.

KEY WORDS AND CONCEPTS: Ecological footprint, biocapacity, EF/BC accounting.

1 INTRODUCTION

Nature can restore renewable resources only at a certain rate. However, humans consistently and increasingly consume renewable resources at a faster rate than ecosystems can restore them. The decisive factor is not just what we use and how much we use, but how fast we use a specific resource. The idea of using area units as a measure of life-supporting natural capital is based on the fact that many basic ecosystem services are driven by surfaces at which the process of photosynthesis takes place. Nowadays the broader regenerative process is included in the definitions of the ecological footprint and the available biocapacity.

The ecological footprint (EF) measures how much bioproductive area (whether land or water) a population would require to produce on a sustainable basis the renewable resources it consumes, and to absorb the waste it generates, using prevailing technology. Biocapacity (BC) measures the bioproductive supply that is available within a certain area (e.g. of arable land, pasture, forest, productive sea). EF and BC are tantamount to the concepts demand and supply in Economics. When used together, they form the EF/BC accounts. “EF/BC accounting” is frequently referred to only as “EF accounting”. However, we think the use of “EF/BC accounting” is more appropriate as it considers the fact that the accounting tool compares demand and supply - and not just demand (as suggested by the term “EF accounting”).

When the EF is larger than the BC the renewable resource accounting results in a deficit. A national ecological deficit can be compensated through trade with nations that process ecological reserves or through liquidation of national ecological assets. In contrast, the global ecological deficit cannot be compensated through trade, and is therefore equal to overshoot. A country with ecological reserves can still experience a local deficit (Global Footprint Network 2006). Vice versa, if the EF is smaller than the BC, one speaks of an ecological reserve. The EF decreases with smaller population size for a given area, less consumption per person, and higher resource efficiency (prevailing technology).

The EF concept was conceived in the early 1990’s and has been developed. The concept has generated considerable research efforts and has increasingly attracted the attention of policy makers. Being a recent and relatively “young” accounting tool and research topic, attention has to be paid to the scope of application and the question of interpretation Its intuitive appeal should not override its need for objective validation techniques and the consciousness of its limitations.

In this article, we present a critical appraisal of the EF concept and EF/BC accounting tool. In the next two sections, we outline the basic concepts of the EF/BC approach and explain how the approach relates and applies to specific human activities for illustrating consumption patterns; examples of applications are provided. In section 4, we analyze its strengths and weaknesses and at the same time make recommendations for improving the method. In section 5, we consider alternative established indicator tools that exist and that are used in the field of environmental accounting at Eurostat. The paper closes with a summary of the main findings and suggestions for further developments.

2 FUNDAMENTALS OF ECOLOGICAL FOOTPRINT

The EF/BC accounting addresses a necessary but not sufficient condition for sustainable consumption: “Is human demand within the regenerative capacity of the planet?” The accounts are divided into two parts: demand on nature (or Ecological Footprint, EF) and the ecological supply (or biocapacity, BC). It is a ‘snapshot’ estimate for a selected time period, which is normally one year. The resource use (built-up areas, the consumption of energy and renewable resources) is expressed in units of space. On the supply side, BC aggregates the production of various ecosystems in a certain area (e.g. of arable land, pasture, forest, or productive sea). Weighting factors harmonize heterogeneous contributions and transform different units (tonnes (t) or hectares (ha)) into a standardized unit (global hectares, gha). Each global hectare represents an equal amount of biological productivity. In this section, we first present the basic concepts of EF and BC and then the EF/BC accounting tool, which constitutes a more comprehensive approach to the EF analysis. The definitions are based on the nomenclature described in Wackernagel et al. (2005).

2.1 ECOLOGICAL FOOTPRINT

The Ecological Footprint (EF) is a method to answer the following research question: “How much of the regenerative capacity of the biosphere is occupied by human activities?” EF expresses the consumption of renewable resources (crops, animal products, timber, and fish), the result of the consumption of energy1 and the use of built-up areas in standardized units of biologically productive area (in gha). It is a measure of how much biologically productive land and sea an individual, population or activity requires to produce the renewable resources it consumes and to absorb the waste.

The *global yield factor by type of consumption* (e.g. crops, pasture, fisheries, timber) translates a product (or waste) into an area (local hectares) required to produce the product (or to absorb the waste). It describes the resource productivity for the selected time period (e.g. one year), the selected product (e.g. crops, animal product with pasture fed, fish) and the connected land type (e.g. cropland, pasture, fisheries area).

The *equivalence factor* (in gha/ha) translates a specific land type (such as crop-land or forestland) into a global hectare. This equivalence factor represents the world’s average potential productivity of a given bioproductive area relative to the world average potential productivity of all bioproductive areas. For example, because the average productivity of cropland is higher than the average productivity of all other land types, it needs to be converted using its corresponding equivalence factor in order to be expressed in global hectares. Equivalence factors are the same for all countries, but vary from year to year due to changes in the relative productivity of ecosystem or land-use types because of environmental factors (such as weather patterns). The equivalence factors are derived from the suitability index of Global Agro-Ecological Zones (GAEZ) 2000, which is a spatial model of potential agricultural yields.

EF measures the demand on nature that results from specific human activities. Normally, it is the action of an entity (person, city, country) that creates the demand on bioproductive space. The question arises whether the full impact of the resource use, e.g. for an airport, is included (the geographical principle) or only the part of the impact that is attributable to the population within the region (the responsibility principle). This has to be specified.

2.2 BIOCAPACITY

The biocapacity (BC) is a method to answer the question: “How many of the renewable resources have been made available by the biosphere’s regenerative capacity (are produced by the various ecosystems)?” BC represents the bulk of the biosphere’s regenerative capacity. It is an aggregate of the production of various ecosystems in a certain area (e.g. of arable land, pasture, forest, productive sea). Some of it may also consist of built up or degraded land. The earth’s BC increases with a larger biologically productive area and with a higher productivity per unit area (WWF 2005).

In 2004, the Earth had 11.4 billion hectares of biologically productive land and sea. This corresponds to approximately one quarter of the planet’s surface (2.3 billion hectares of ocean and inland water,

[1] The EF of fossil fuel is calculated by estimating the biological productive area needed to sequester carbon dioxide; the recovery of coal, oil or gas is not included. See also section 4, point 3.

1.5 billion hectares of cropland, 3.5 billion hectares of grazing land, 3.8 billion hectares of forest land and 0.2 billion hectares of built-up land; UN Food and Agriculture Organization). A global hectare (gha) is a unit of land containing the earth's average productivity. It is a universal unit of biologically productive area including the absorptive capacity for waste[2].

Biocapacity is dependent not only on natural conditions but also on prevailing land use practices (e.g. farming, forestry). The *country-specific yield factor* describes the discrepancies between countries in productivity of a land type and technological advancements. Each country and each year has its own set of yield factors. For example, in 2002, German cropland was 2.5 times more productive than world average cropland. The German cropland yield factor of 2.5 is used to convert German cropland into world cropland.

Again, the *equivalence factor* (in *gha/ha*) translates a hectare of a specific land type (such as cropland, pasture, forestland, marine water, or built-up areas) into a global hectare. It is the same for all countries but vary from year to year (see 2.1).

2.3 THE EF/BC ACCOUNTING

The EF/BC accounts are formed by combining the EF and the BC, thereby turning the approach into a more complete accounting tool for natural resources. The algebraic difference between BC and EF is called "Ecological Deficit" if it is negative or "Ecological Reserve" if it is positive.

EF/BC accounts make use of extensive data sets largely from national and international statistical and scientific bodies like UN agencies or countries' annual statistics in areas like agriculture, forestry and energy. Domestic production and trade are taken into consideration for consumption (or final demand) calculation. Data gaps are filled in with the help of a variety of governmental, academic or private sources. The margin of error of EF/BC accounts based on shortcomings of the data sources is hard to quantify.

The EF project community has grown, forming the Global Footprint Network (GFN). The intention of the GFN is to establish the EF accounts as a default indicator for sustainability and to present it as an organizing framework for discussion among policy makers (Charter for GFN Committees from 28 March 2005). Therefore, the scientific credibility and accuracy of the EF/BC accounts is of great importance. We will come to this point in section 4. In general, the definition of "sustainable development" contained in the EU Sustainable Development Strategy makes reference to a four-pillar definition or approach: the economical, social, environmental and institutional pillar. It is clear that the EF/BC approach does not, and cannot, cover all of these four key aspects of sustainable development. Moreover, even the environmental dimension cannot be completely covered by the approach, as we will see below.

3 APPLICATIONS

The applications of the EF range from the study of resource demand at global, national and much smaller level (i.e. regional, city, household, or type of product). Recent examples of EF studies that have been carried out at international level are the WWF "Living Planet Report 2004" (WWF, 2004) and the "Europe 2005 The Ecological Footprint" report (WWF 2005). The methodological notes to calculate the EF/BC accounts are reported in Wackernagel et al (2005). In a recent study (EEA 2005b) the Earth's biologically productive area was approximately 11.2 billion hectares or 1.8 global hectares per person in 2002 (assuming that no capacity is set aside for wild species). In 2002, humanity's demand on the biosphere, its global Ecological Footprint, was 13.7 billion

[2] Only waste where nature has a significant absorptive capacity in the selected time period (e.g. one year) can be covered by the concept. See section 4, point 3.

global hectares, or 2.2 global hectares per person. Thus in 2002, humanity's Ecological Footprint exceeded global biocapacity by 0.4 global hectares per person, or 23 percent. This finding indicates that the human economy is in an ecological overshoot: the planet's ecological stocks are being depleted faster than nature can regenerate them. This means that we are eroding the future supply of ecological resources and operating at the risk of environmental collapse.

Examples of national and regional EF studies are: "An Ecological Footprint of the UK. Providing a Tool to Measure the Sustainability of Local Authorities" (Barrett and Simmons 2003), "The Ecological Footprint of Greater Nottingham and Nottinghamshire" (Birch et al. 2005), and "An ecological footprint analysis of Essex - East England" (Vergoulas and Simmons 2004).

For the moment, the two main uses of the EF/BC concept are for communication and education purposes. The EF/BC accounting is a pedagogical presentation of a complex model that aims to answer the question of the sustainable consumption of the earth's renewable resources. It shows whether the current consumption is respecting the limits of what the earth can sustain. This is because EFs can be presented in a very "visual" and "accessible" manner. To be used for policy-makers an appropriate quality management needs to be applied for EF/BC accounts as it is done for Economic Accounting or for the UN Framework Convention on Climate Change (UNFCCC) greenhouse gas inventories.

4 MERITS AND SHORTCOMINGS

In this section, we will focus first on the strengths of the EF/BC accounts and afterwards we will analyze some of its weaknesses. Our objective is to clarify merits and shortcomings of the EF/BC accounts.

As already referred to in section 3, EF concept is quite attractive and intuitive. This is probably its main strength. In the last decades, humanity has been wakening to the ecological problem of sustainable development. EF is probably a result of this self-consciousness and at the same time it became an engine to operate it. Its attempt to quantify the ecological consumption and supply, the simplicity of a single calculated figure gives it the status of an objective tool for measurement of phenomena that are difficult to quantify. EF's potential for pedagogical purposes and dissemination is without any competitor.

However, we also think the tool suffers from important shortcomings that we enumerate in what follows. The weaknesses are perceived as points where the methodology needs improvements.

1. Non-robust policy message: The use of other data sources, modifications in the choice of input variables, and/or in the weighting system can change the message significantly.

2. Heterogeneous ingredients: The EF/BC accounts aggregate a variety of sub-components (consumption of food, fiber, timber, energy and prevailing land use) according to their estimated demand on biocapacity. The fact that a single figure is obtained does not guarantee that its interpretation is straightforward.

3. Limitation of scope: The EF/BC concept cannot represent the full range of environmental problems: resources without a significant regenerative capacity do not fit in the concept of biologically productive area. For example, the biocapacity needed to sequester CO_2 emissions is covered but not the regeneration of the "burnt" fuel stocks. Moreover, nature has no significant absorptive capacity for several important environmental problems: pollution by heavy metals, radioactive materials or persistent synthetic compounds. That means that substances without a significant absorption or regenerative capacity cannot be covered by the EF/BC accounts.

4. Sensitivity to problems of data quality: High quality is needed for all input variables. The analysis relies on having access to a reliable environmental database. Available statistics contain missing values, which call for some kind of imputation technique to estimate them. Often data gaps are filled under the use of a variety of different sources with different quality standards. The margin of error of EF/BC accounts based on shortcomings of the data sources is hard to quantify.

5. In-transparency of the assumptions and selections: The construction of the composite indicator involves a number of stages at which the analyst has to make judgments. For example, the selection of input variable (consumption of resources and generation of waste), the choice of weighting factors and the treatment of missing values (imputation technique) requires a number of decisions which are not transparent due to lacking detailed documentation although there is the possibility to get a academic edition by signing a license.

6. Scientific basis of the weighting factors: EF/BC accounting includes a huge set of variables (or resource categories) for which weighting factors have to be applied. The estimation procedures for these factors are not adequately documented to allow independent reviews to be carried out. It is unclear what kind of environmental pressure is included in the transfer coefficients and how this is scientifically justified. In the WWF (2005) study, a unit of nuclear energy is considered as equal to one unit of fossil energy. This politically-wanted transfer coefficient does not reflect the environmental pressure from nuclear power activities.

A guidebook with clear standards could help to solve some of the problems, e.g. the "lack of international standards and lack of transparency". At the moment the selection of variables, the origin of the data and the weighting factors that are used can be perceived as being of an arbitrary nature and based on in-transparent assumptions. Moreover, a guidebook should give clear guidelines to the issues of "validation techniques" and "quality assessment". The Global Footprint Network is preparing a first draft of a Standardization Guide. However, not all weaknesses are addresses for the time being and it is still not clear if the standards therein are widely accepted.

EF/BC accounts could take as a role model the independent reviews performed for the UNFCCC greenhouse gas inventories, which have proven to be very important for the high quality of these inventories. It should be possible to carry out a quality assessment including the comparison with alternative techniques.

For further reading: Barett et al. (2004), Nijkamp et al. (2004), DG Research (2001), and two studies from the Department of Environment, Food and Rural Affairs (DEFRA) in the UK (2005).

5 AVAILABLE TOOLS AT EUROSTAT

In this section, we make reference to other statistical tools for monitoring sustainable development at Eurostat: Structural Indicators (SI), Sustainable Development Indicators (SDI), and NAMEA (National Accounting Matrix including Environmental Accounts). These frameworks are more transparent and they make it possible to identify areas where efforts have to be done. Moreover, the results of EU policy on both, renewable and non-renewable resources, and moreover on sustainable production and consumption patterns, can be monitored in detail using these techniques.

SI and SDI are used to monitor the Lisbon Strategy and Sustainable development Strategy, respectively. These two sets of indicators include a breakdown by policy issues (environmental, social and economic aspects). Some of these aspects are also touched by the EF/BC accounting (e.g. distribution and availability of renewable resources) but some others not (non-renewable resources, biodiversity, pesticides).

Environmental Accounts is a satellite system to the National Accounts and therefore fully comparable with the well established economic system. NAMEA, National Accounting Matrix including Environmental Accounts, is a conceptual tool that organizes and holds information on the economy and the environmental pressure expressed in monetary and physical units. In the environmental accounting the view of land as providing economic benefits is only part of the picture. In the System of Environmental and Economic Accounts (SEEA) the Land and Ecosystem Accounts (LEAC) consists of statistics on land cover, land use and changes in stock. Especially in the land cover-oriented accounts the basic accounts are extended by describing in more detail the potentials of land and the aspects of biodiversity. The potential of land relates to the richness of natural habitats in terms of extent of biodiversity, their vulnerability, to the characteristics of the soil, and to the social and economic activities, which it supports (SEEA 2003). At the moment the EEA has a LEAC database, based on Corine land cover data (EEA 2005a).

Eurostat has previously not been involved with EF/BC accounting. Despite this fact, Eurostat is open to supply any available data that are necessary for the production of EF/BC accounts. The role of Eurostat is to provide good and sound statistics that can be used to follow-up policies. With the establishment of the three data centers on Integrated Product Policy (IPP), Waste and Natural Resources at Eurostat a further way of co-operating could be envisaged. The IPP policy seeks to minimize the impact of products on the environment, from their manufacturing, use and disposal, and to take action where it is most effective. The Natural Resources Strategy goes the same way, and asks for the environment impact of the use of Natural Resources. This is where the EF/BC accounts may be helpful for crosschecks, data exchange and estimation aid in the detailed information available within the EF/BC account.

SUMMARY

The Ecological Footprint (EF) measures the extent to which humanity is using nature's resources faster than they can regenerate. EFs are usually presented together with biocapacities (BCs), which measure the bioproductive supply. If an EF is larger than the available BC for a selected time period the EF/BC resource accounting results in a deficit or overshoot. A deficit occurs in case of human resource extraction and waste generation exceed an ecosystem's ability to regenerate the extracted resources and to absorb the generated waste. A global overshoot (at the planet level) leads to a depletion of the earth's life supporting natural capital and a build-up of waste.

In this paper, we reviewed the EF/BC accounting tool. The strength of the EF/BC accounts is also its weakness: it is a complex, multi-dimensional composite indicator. It summarises some of the problems of the sustainable consumption using several technical decisions (e.g. selections of input variable, weighting factors, and data sources), which are not transparent or comparable with other information due to the lack of agreed standards. Additionally, its scope is limited to renewable resources, i.e. resources that can regenerate in a limited time period can be covered by knowledge-based weighting factors. A number of important environmental issues cannot be included appropriately because nature has no significant regenerative or absorptive capacity.

The problem of standardization and transparency can be solved by a guidebook. As yet, there is only a first draft of a guidebook available to set standards for the variables included in the accounting or the weighting factors based on the concept of regenerative capacities. Additionally, to improve the transparency of the methodology all used data sources and the date of extraction have to be specified. Moreover, the handling of missing values and estimation procedures has to be specified. A high transparency of all procedures and clear standards for the quality assessment, together with independent reviews, are essential to give the EF/BC accounting the status of a science-based tool.

Eurostat is open for future co-operation and will be available for any further questions concerning statistical expertise or data deliveries.

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