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True cost economics: ecological footprint

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Abstract

The paper proposes a measure of renewable bio-capacity. We argue that some dimensions of ecological sustainability should not be included in the Ecological Footprint. These include human activities that should be phased out to obtain sustainability, such as emissions of persistent compounds foreign to nature and qualitative aspects that represent secondary uses of ecological areas and do not, therefore, occupy a clearly identifiable additional ecological space. We also conclude that the Ecological Footprint, by aggregating in a consistent way a variety of human impacts, it can effectively identify the scale of the human economy by comparison with the size of the biosphere.

Keywords: susieinabilitys, method for estimatimg, bio-capacity;

1. Introduction

The Ecological Footprint (EF) concept, introduced by Rees and Wackernagel (e.g.1994), measures the biologically productive area necessary to support current consumption patterns, given prevailing technical and economic processes.

The latest estimates show that, on average, a Canadian requires close to 7 ha of ecologically productive land and 1 ha of ecologically productive marine area to provide for his or her current level of consumption (Wackernagel et

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al, 1997). These 8 ha (in total) are the equivalent to more than ten soccer fields. In comparison, the average American occupies a footprint approximately 30% larger; the average Italian, one third smaller. The average Swede occupies over 6 ha.

There is solid evidence that these figures may be underestimates of the biologically productive areas necessary to produce the resources these people consume and to assimilate the corresponding waste they generate, all using the existing technology.

Dividing all the biologically productive land and sea on this planet by the number of people inhabiting it results in an average of 2,3 ha per person, less than one third of what is necessary to accommodate a typical Canadian footprint.

If we put aside 12% of the biologically productive space for preserving the other 30 million species with whom we share this planet which is politically ambitious but ecologically insufficient, the available space per capita shrinks to 2 ha. With an anticipated global population of 10 billion for the year 2050, the available space will be reduced to 1, 2 ha per person.

Already, the average Italian uses 210% more than is available per capita worldwide, or 320% more than is available per Italian within their national territory. Sweden is still one of the fortunate few counties whose ecological footprints are smaller than their national biologically productive space.

Worldwide, however, humanity's footprint may exceed global carrying capacity by 30% - in other words, humanity consumes more than what nature can regenerate and is decreasing the globe's natural capital stock. It is not only the non-renewable and renewable resources that are declining but also the ability of nature to assimilate the waste (for example, emissions of carbon dioxide or acidifying substances).

The ecological footprint builds on a variety of earlier analytical attempts to measure human load in order to estimate the dependence of human life on nature (see for example, Martinez-Alier, 1987).

The theoretical foundations of cost-benefit analysis are well established, although we no pretend that all the problems are solved. Essentially, cost-benefit analysis compares the gains and losses associated with an investment project or with a policy, the setting of an environmental standard.

The distributional issue was perhaps never fully resolved. Those who wanted to integrate it into cost-benefit analysis found answers in "distributional weights", weighting factors applied to a benefit or a cost to reflect the income of an individual affected.

2. Ecological Footprint from this Sustainability Perspective-

The main question that the footprint answers is how much biologically land would be required on a continuous basis to provide the necessary energy and resources consumed by a population and to absorb the wastes discharged by the population. An EF analysis, therefore, is close to an assessment of human appropriation of net primary production (or NPP). The principal difference from other NPP studies is that the footprint expresses the results in spatial measurement units rather than energy or mass equivalents.

EF esimates are calculated to account for as many ecological impacts as possible without exaggerating humanity's current impact. For example, optimistic yield figures are used and some impacts are not yet included in the calculations. In addition, the estimates do not double count areas that can give several services simultaneously, since this would exaggerate people's true use of nature. Underestimating human use of nature's productivity ensures that the EF results do not depict the ecological situation as more severe than it. This chosen strategy secures the widest possible acceptance of the results.

Both people's EF and the biosphere's areas of biologically productive land are expressed in common units: world average land with world average productivity. In most assessments, official data are used – not because they are the most accurate, but to delegate responsibility and show that even with the official data, once interpreted from an ecological perspective, significant new conclusions can be generated.

The EF calculations have so far included land for energy supply, food, forest products, and the built environment, degraded areas, and sea space for fishing. For the waste side, the land needed for sequestering CO_2 is included in the EF.

2.1. Fossil fuels and carbon dioxide

There are three different approaches to calculate the footprint of fossil fuel consumption – and all three results in approximately the same area. All three are motivated by the idea that, in order to be sustainable, humanity must not undermine functions and biodiversity of the ecosphere (Table 1). This is the essence of the first three principles for sustainability.

Table 1.Ecological Footprint from this Sustainability Perspective – Fossil fuel CO_2

Aspects of sustainability	Present EF calculations	Can the aspect be related to sustainability through EF	Can progress towards sustainability be measured for this aspect in the EF method ?
Fossil fuel induced CO_2	Area in calculated as the bioproductive area needed for sequestering CO_2	Possibly, but there is no strict rationale by which consumption of fossil fuels can be related to an area	Not in all cases. A transition from fossil fuels to bio-fuels can lead to a larger area using the current method

One way to calculate the EF for fossil fuels would be to account for the corresponding area needed for the sustainable production of bio-fuels. The rationale for this way of calculating would be the close relationship between fossil fuels and bio-fuels, such as methane or ethanol. They have the same origin (photosynthesis), they are of similar quality and they can be applied in almost the same technological systems (in combustion engines for instance). The required productive area for that type of energy supply, built on closed carbon cycle (i.e. no net increase of CO_2 in the atmosphere), would then be the rational basis for the EF calculation. This method would lead to the biggest footprint estimates for fossil fuel. However, there is some considerable controversy about the degree to which bio-fuels can substitute for the global use of fossil fuels considering the competition for land areas for other purposes like food, materials and biodiversity.

Another way of calculating the fossil fuel footprint would be to calculate the area needed to compensate only the biochemical energy of the burned fossil, without taking into account that the biochemical energy in the woods has not the same technical quality as fossil fuel or bio-fuels. This would lead to slightly lower ecological footprints for fossil energy.

The method is based on CO_2 sequestration, arguing that the amount of fossil fuel may not be the limiting factor but rather the absorption of the waste gases. In this method, the area is calculated by assessing the extension of newly planted forest required for sequestering the CO_2 released by the combustion of fossil fuel. Such land serves as a CO_2 sink during a period of between 40 to 100 years, depending on climate and species of forest. In order not to release the sequestered CO_2 the mature forest would have to be left for the future with no harvest, so spontaneously renewing itself. As the absorbing forests mature, additional forest areas for CO_2 sequestration would be needed in order to avoid increasing levels of CO_2 in the atmosphere in the case of continued use of fossil fuels. Obviously, this third method leads to the smallest footprints for fossil fuel. It is chosen because it avoids results which could exaggerate human impact of fossil fuel use. Nevertheless, the accumulation of CO_2 in the atmosphere from the use of fossil fuels is only one of many impacts this energy system has in the ecosphere. Therefore, the current conversion rate of 71 gigajoules per hectare and year for liquid fossil fuel-based on sequestration estimates published by the Intergovernmental Panel of Climate Change – are still significant underestimates of this energy's true ecological load on the biosphere (Wackernagel et al, 1997). In addition, no significant land area is set aside exclusively to sequester CO_2 from fossil fuel burning (or for the replacement of fossil fuels by wood biomass).

In conclusion, all methods described above have their limitations. For example, a real transition from fossil fuels to bio-fuels should lead to a smaller footprint area – current footprint accounting practice, however, should show the opposite. These methods are, though, helpful for the monitoring of increased overall efficiencies of the energy system, as well as the transition towards much more area-efficient sources of energy, like photovoltaic.(Besides being area-efficient, photovoltaic have the additional benefit of not needing to occupy biologically productive surfaces). The method has the advantage of giving the smallest area of the three methods and does not, therefore, exaggerate the area needed. This method is also more relevant when considering emissions of CO_2 from other sources than fossil fuels (for example, cement production since it is not based on a substitute for the energy supply).

2.2. Waste assimilation (apart from carbon dioxide)

The waste assimilation, apart from CO_2, has hitherto not generally been considered in EF assessments. Only some newer assessments of the EF include the use of space for breaking down biodegradable waste, particularly in water (Wackernagel et al, 1998). For example, the area of ponds and protective wetland areas which should be needed for effective reduction of the load from leaching plant nutrients from productive agricultural land have been included in a detailed calculation of the Swedish national footprint.

A systematic inclusion of such waste in EF calculations is difficult because the assimilation capacities in the ecosphere are known only for a few of the naturally occurring substances. In these cases, the anthropogenic flows of such a substance can be converted to an area needed for assimilating the substance. Relevant anthropogenic flows to consider are actual emissions of substances to the ecosphere or, alternatively, the potential emissions estimated from the extraction rate of virgin substances from the lithosphere or, in the case of human made products, the amounts of these substances manufactured. For a region, the net import of substances should be added to the extraction and production of substances within the region.

When assimilation capacities are not known, it can be possible to indirectly estimate them, for example, by considering some natural flows (Table 2).

Table 2. Ecological Footprint from this Sustainability Perspective – Waste assimilationof non-syntetic substances other than CO2

Aspects of sustainability	Present EF calculations	Can the aspect be related to sustainability through EF	Can progress towards sustainability be measured for this aspect in the EF method ?
Waste assimilation of non-synthetic substances other than CO2	Area needed for detention of nutrients. (Metals and minerals are calculated indirectly through their energy needed).	Some, when the assimilation capacity can be estimated and it can be transformed into an area	Yes, this is possible for the compounds that are included

The assimilation capacities of metals are usually not known, but can be assumed to be proportional to their natural flows, such as in their weathering and sedimentation rates. If the anthropogenic flows of a metal are much larger than the natural flows, the risk increases that such flows will cause accumulation in the ecosphere. The anthropogenic flows of a metal could be converted to an area proportional to an area from which the same amount of metal will be weathering. A difficulty is that the natural concentrations and weathering rates vary for different regions.

To avoid double counting of productive areas and erroneously large footprints, it is necessary to consider that the area needed for assimilation of substances can still be made applicable for other purposes, for instance, productive forests and crop land, provided that these areas are not destroyed because of high concentrations of the emitted compounds. Further, the same area can be applied for the assimilation of more one compound. We define additive aspects as those that can be added to each other when calculating the total footprint without risk of double counting of area, e.g. food and fiber production. In contrast to exclusive (primary or additive) aspects, the secondary (or non-additive) aspects should not be added to each other since the same area can be used for several of these aspects, e.g. assimilation of substances can be done on the same area as is used for fiber production. Note that built-up land is also an additive aspect but this area cannot be used for assimilation of substances. If none of the emissions of compounds exceed their assimilation capacities corresponding to the productive area needed for additive aspects, there is no need to add any productive area occupied by this function to the footprint area, i.e. $A_{footprint} = A_{additive\ aspects}$. On the other hand, if some of the emissions of compounds exceed their assimilation capacities of the productive area needed for additive aspects, the footprint should increase the more the assimilation is exceeded. The most appropriate strategy would then be to calculate how much the productive area for assimilation of the most dominant compound would need to be extended in order not to have accumulation of that compound, i.e. $A_{footprint} = A_{assimilation} + A_{built\text{-}up\ land}$.

The assumption that then needs to be made is that the various compounds would not influence each other's assimilation thresholds in the ecosystems, or each other's impact on the ecosystem. That assumption is often true, but not always.

It is definitely not true for various compounds that lead to acidification (like emissions of SO_2 and NO_x), and that add to each other's negative effects on area productivity. On the other hand, this could be adjusted for by simply adding the corresponding areas for such compounds that have additive impacts on the ecosystems productivity into a sum. Here, H^+ equivalents from different compounds could be used. If that sum exceeds the needed extension of the assimilation area for any of the other compounds that can be estimated to be independent of each other, this sum should then be applied to the footprint.

Substances for which it is not possible to estimate their assimilation capacities cannot be considered in the EF method and have to be accounted for in same other way. Also, substances that have such low assimilation rates that the EF would become absurdly large may not be compatible with a sustainable society. Since the EF only includes potentially renewable aspects of the human economy, these not-sustainable substances cannot be included in the accounting.

Another assessment problem for potentially renewable substances, however, can be to find data for anthropogenic flows of substances such as emissions and the net intake of substances.

A shift to a substance with lower equivalent impacts (for example a more naturally abundant metal) would give a smaller area for the same amount of anthropogenic flows. This way of calculating substances could thus be used as an indicator measuring the progress towards sustainability.

Conclusions

An essential part of sustainable development is to reduce the throughput of resources in relation to the added human value. All processes degrade the quality of energy, and more or less waste is generated. From a thermodynamic point of view, those „bills" must be paid for through processes run by energy from outside the ecosphere.

The sun-driven biogeochemical cycles of nature are essential to maintain life on Earth. Therefore, most of those bills must, in the end, be paid for by productive areas receiving sunlight. Consequently, the method of foot printing, relating various throughputs of resources to the respective fertile areas required, offers an attractive possibility of auditing sustainable development.

A culture's lifestyle, with its demands of services on the one hand, in combination with its technical and organizational skills to provide services per throughput of resources on the other, gives us the footprint, and then calculating the footprints for various options, more resource efficient way of meeting human needs can be evaluated and launched. So, the EF is not only relevant for estimating the situation with regard to the areas needed to sustain us today, but also for testing different strategies for the future.

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