Using Ecological Footprint accounts: from analysis to applications

Mathis Wackernagel*, Sahm White and Dan Moran

Global Footprint Network [1], 1050 Warfield Ave,
Oakland, CA, 94610-1612 USA
E-mail: mathis@footprintnetwork.org
http: www.FootprintNetwork.org
*Corresponding author

Abstract: It is argued in this paper that sustainability has specific, definable requirements, including the need to avoid ecological overshoot – that is, a level of resource demand that exceeds ecological carrying capacity. This paper demonstrates how ecological overshoot can be measured. Our evidence suggests that humanity is already in overshoot. Indeed, most industrialised countries run significant ecological deficits. To move out of ecological deficit, governments can develop ecological accounts to track overshoot. Social marketing campaigns can also be run to gather popular support for reducing human pressure on the biosphere.

Keywords: Ecological Footprint; overshoot; sustainability; measurement; ecological accounting; policy; ecological deficit; social marketing campaigns.

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Biographical notes: Mathis Wackernagel is the Executive Director of the Global Footprint Network. Mathis is also an adjunct faculty at SAGE of the University of Wisconsin-Madison, and the Scientific Advisor of the Centre for Sustainability Studies in Veracruz, Mexico.

Following his graduate work in the social studies of science and technology at the Massachusetts Institute of Technology in the early 1990s, Sahm White has pursued his research on and advocacy work with the Center for Eco-Literacy in Berkeley, California, and the Global Footprint Network. He currently lives in Santa Cruz California and is Associate Director of Progressive Secretary, a leading web based source of legislative constituent commentary.

Dan Moran is Director of National Accounts at the Global Footprint Network. Earlier, Dan worked for Stanford economist, Paul Romer, as a Research Associate and Editor for the upcoming Krugman and Romer economics textbook. He also served as President of MyTwoFrontTeeth.org, a web-based service provider for charities. Dan now oversees development of the national Ecological Footprint accounts and is currently working on the analysis for WWF's *Living Planet Report 2004*. Dan holds a BA in Philosophy from Whitman College.

1 The problem: human demand is eroding the planet's natural assets [2,3]

While much discussion of global resources over the last few decades has focused on the depletion of non-renewable resources such as minerals, ores, and petroleum, it is increasingly evident that renewable resources, and the ecological services they provide, are also at great or even greater risk [4,5]. Examples include collapsing fisheries, carbon-induced climate change, stratospheric ozone depletion, species extinction, deforestation, desertification, and the loss of groundwater in much of the world. The depletion of these assets is serious since people are a part of nature, and depend on its steady supply of the basic requirements for life [6]: food, water, energy, fibre, waste sinks, and other life-support services. The depletion is particularly serious since the human demand for these resources is still growing, thereby accelerating the liquidation of natural assets.

Out of this concern, the sustainability proposition emerges. Sustainability is a simple idea. It is based on the recognition that when resources are consumed faster than they are produced or renewed, the resource is depleted and eventually used up. The elimination of essential resources is fundamentally problematic; substitution can be expensive or impossible, especially when considering global ecological resources. Worsening ecological conditions threaten people's well being. When humanity's ecological demands in terms of resource consumption and waste absorption exceed what nature can supply, we move into what is termed 'ecological overshoot'. Just as constant erosion of business capital weakens an enterprise, such overshoot erodes the planet's 'natural capital', and reduces humanity's ecological resources, our ultimate means of livelihood [7]. Thus, sustainability is a commitment to creating satisfying lives for all within the means of nature.

Defining core requirements for sustainability is fairly straightforward. By defining them in specific, observable terms, these requirements become measurable and hence potentially manageable. While these necessary conditions can be met, they are obviously not sufficient. There are additional barriers. For instance, in the context of current economic incentives that reward 'unsustainability', trying to make the world sustainable is at times frustrating and confusing, and the task can appear overwhelming. Moreover, it can be seen as ominous, since recognising ecological limits challenges how, according to conventional economic development, we organise our lives – even though the purpose of sustainability is to secure our well being.

At the core of this quest for sustainability is the need to live within ecological limits. These limits are not like a rigid wall that brings a speeding car to a halt. Rather, ecological limits can be transgressed easily. More timber can be harvested than it re-grows, more fish can be caught than are spawned, more CO_2 can be emitted than nature can reabsorb, and topsoil can be eroded while crops grow. Initially, most of these transgressions go unnoticed.

The importance of avoiding overshoot is still routinely ignored, not only in general conversations but also in many public policy discussions of sustainability. In fact, our ability to transgress ecological limits without perceptible consequences may create influential misconceptions in the sustainability debate. There is a perception, often voiced in the business press, that because there are no apparent shortages of raw materials, the concept of limits has been overstated. This confusion is caused by the seeming elasticity of ecological limits, and new technologies that enable rapid resource extraction and easier access to remote locations and resource reserves. A simple analogy would be a car.

If a car is low on fuel, accelerating to ninety miles per hour does not disprove the fuel gauge. Similarly, pumping water out of an aquifer more quickly does not change its ultimate capacity or recharge rate.

Once humanity exceeds the biological limits or the carrying capacity of the planet, further expansion in this direction impoverishes us, since growth of this nature is not achieved by using the 'interest' of regenerative nature, but by liquidating natural productive capital. This is why systematic resource accounting – documenting the cumulative effect of humanity's consumption of natural capital and generation of waste – is at the core of achieving sustainability. As long as our governments and business leaders do not know how much of nature's capacity we use or how resource use compares to the existing stocks, overshoot may go undetected – thereby increasing the ecological deficit and reducing the capacity available for society both now and, more importantly, in the future. The depletion of ecological assets systematically undermines the well being of people. Livelihoods disappear; irreconcilable conflicts emerge; families are hurt; land becomes barren; and resources become more costly before they are eventually exhausted. However, continued overshoot is not inevitable; it is possible to have satisfying lives for all within the means of nature.

2 The goal: satisfying human needs

The kind of development required is that which enhances humankind's potential to enjoy and experience both healthy and secure lives; a development that is fair to people alive today and in the future; and development that maintains the integrity of our ecological assets. That is what we mean by "rewarding lives for all within the means of nature".

Rewarding lives for all is not only possible, but also a probable enabling ingredient for achieving sustainability. Here are three reasons why this is likely to be the case:

- First, social and economic inequities threaten political stability and international security. How can one expect constructive cooperation in an increasingly interdependent and fragile world if large social or geographical sectors of humanity do not have access to basic amenities for healthy and secure lives? Recent contentions such as resistance to privatisation of public services, the collapse of the Cancun WTO meetings, and challenges over Kyoto Protocols have each been predicated on issues regarding internationally equitable use of natural resources. Increasing ecological scarcity and competition for ecological capacity will likely fuel destructive social conflict and degrade our social fabric.
- Second, once humanity is in ecological overshoot, development based on expansion of resource consumption becomes a negative-sum game. If the planet is 'full' of people who are depleting its natural capital, making more stuff cannot make people better off. Such development not only appropriates nature's future income, but also erodes nature's capacity to provide present and future services. As a consequence, addressing standards of living and equity through increasing resource use becomes a physically impossible strategy that only accentuates the conflict over resources. A true sustainability package must devise more realistic strategies that recognise the implications of ecological limits and their consequences for social equity, rather than just promising more production.

- Third, development needs to take advantage of people's desires, rather than ignoring or combating them. Essentially, people want fulfilling lives – an aspiration that can become a positive engine for sustainable development. After all, successful programmes for a sustainable society cannot be built on martyrdom and suffering. To make sustainability a reality, we must find ways for people to thrive in all senses without needlessly overtaxing the ecosystems that support us.

Most science-based definitions resonate with this shorthand for sustainability. They centre on the interplay of the ecological and the human sustainability imperatives. For example, in *Caring for the Earth*, the World Conservation Union (IUCN), together with the United Nations Environment Programme (UNEP) and the World Wide Fund for Nature (WWF), defined sustainable development as "improving the quality of human life while living within the carrying capacity of supporting ecosystems" [8]. In their brochure, 'action for global sustainability', the Union of concerned scientists argues that "humanity must learn to live within the limits of natural systems while ensuring an adequate living standard for all people". The 'four system conditions' of sustainability developed by the Natural Step, under the leadership of Karl-Henrik Robèrt, provide a comprehensive framework for sustainability. They also build on the dual sustainability imperatives: one system condition explains the human imperative while the remaining three detail what living within the means of nature involves [9]. In essence, sustainability requires that we not turn our resources into waste any faster than nature can reconstitute waste into resources.

All of these approaches agree that the current conflict between these two imperatives – staying within the capacity of our ultimate means (our 'natural capital') and reaching our ultimate ends (satisfying lives for everybody) – is at the centre of the sustainability challenge. It is this tension that defines the dynamic of unsustainable behaviour.

Framing sustainability with these two core requirements makes the concept more tangible and effective. Some may object that this approach leaves out an often-mentioned 'third element', the economy. But it does not. The economy is the domain where all the action happens. While economic performance is not a goal in itself, it is a means by which to achieve the goal: meeting the human imperative without violating the ecological imperative.

3 Present obstacles to sustainable resource management

While simple to spell out, sustainability is hard to implement. Some initiatives have successfully reduced human pressure on distinct ecosystems, but on the whole, humanity has not lived up to the challenge to reduce, or even stabilise human pressure. Reasons abound. The most prominent one may be that the challenge seems too daunting. It is daunting for the population of the developed nations, the 'golden billion' that is blessed with unprecedented personal wealth and material abundance, since the current situation provides them with comfortable lives, while their privileges might be called into question if the world adopts a sustainable path. It is also daunting for the other over five billion members of humanity, since they lack resources for mobilising the kind of development that will not liquidate natural and social assets. Many are caught in daily survival

struggles that make it nearly impossible to allocate resources for redirecting our common course.

Very few of the institutions and organisations that exist to serve the developed nations have taken an active stand to give sustainability the teeth it requires and to make progress towards measuring sustainability. On the contrary, they have a propensity to keep the debate fuzzy which, by conveniently diffusing the pressure to address the challenge, helps to maintain the status quo. This allows such institutions to minimise accountability for their own actions and to avoid abandoning the system that maintains their privileges.

Vagueness is also advanced by a few misconceptions of core concepts. For example, ecological limits are considered to be visible and obvious. But they are not visible. The most influential decision makers in this world, including most professionals, live urban industrial lives where scarcity is not overtly present in their daily routines. On the contrary, urban shoppers enjoy an explosion of diverse and refined products and thus take for granted the basic supply of energy and clean water needed to sustain the production of such goods.

Nor are ecological limits obvious. As explained above, resource use can increase even after ecological limits have been transgressed (i.e., once overshoot has taken place). Since nature has some reserves, humanity can, for a while, take more than nature can regenerate. This overshoot eats up nature's reserves and weakens its capacity to regenerate. Without balancing our ecological books, we do not know whether human draw on nature's 'accounts' exceeds nature's 'interest payments'. An excessive flow of resources can continue for some time by eating into the resource stocks that generate the flows.

Also, society cannot perceive ecological limits through a monetary lens. For wealthy people, resource prices have decreased over the years, as pointed out by a long tradition of economic studies [6,10,11]. However, prices only signal availability of a resource on the market, not its availability in the biosphere [12]. In other words, price is much more a reflection of extractive capability than unextracted supply (i.e., of resource flows rather than resource stocks).

Finally, many have claimed that it is impossible to assess with certainty the remaining stocks of resources. Depending on the degree of 'certainty' one is talking about, this may be true for most non-renewable resources that are hidden in the Earth's crust. However, the argument does not apply to the more critical renewable resources, since they are above ground and therefore visible and measurable.

For all these reasons, sustainable resource management is only possible if sustainability is defined in a way that is accountable and consistent with ecological realities. This paper argues in the following sections that the sustainability approach outlined above can serve as a consistent and specific accounting framework for meeting the challenge of sustainable resource management.

4 Keeping track of humanity's use of nature with the Ecological Footprint

As simple and generic as it sounds, 'living within the means of nature', the ecological bottom-line condition for sustainability, turns out to be a specific, measurable criterion. It is measured by determining:

- How much nature, or more specifically regenerative Biological Capacity, is available for human use.
- Comparing this supply with human demand. Only if annual human demand does not exceed nature's annual supply can we claim to meet the criterion.

The 'Ecological Footprint' methodology provides a natural capital account that can determine at each scale, from the global down to the household, how much of nature's services are appropriated for supporting these entities.

The supply side of the equation is the most straightforward part of the resource assessment. The amount of nature or bioproductive capacity (or 'Biological Capacity') that humanity has available worldwide is given by the size of the planet's areas that are biologically productive [13]. To determine the per capita supply of Biological Capacity, the biologically productive land and sea that exist in a given year is divided by that year's population. For the year 1999, this resulted in an average of 1.9 hectares per person, while in 1996 this was still at 2.0 hectares (see Table 1) [14].

Table 1 The alphabetic list of 22 nations shows the Ecological Footprint and the Biological Capacity per person and for each country as a whole. (For a list of 150 countries, see [22] at www.panda.org)

	Population [millions]	*Ecological Footprint* [*global* ha/cap]	*Biological capacity* [*global* ha/cap]	*Ecological deficit* (–) *or reserve* (+) [*global* ha/cap]
World	*5,978.7*	*2.3*	*1.9*	*–0.4*
Argentina	36.6	3.0	6.7	3.6
Australia	18.9	7.6	14.6	7.0
Brazil	168.2	2.4	6.0	3.6
Canada	30.5	8.8	14.2	5.4
China	1,272.0	1.5	1.0	–0.5
Egypt	66.7	1.5	0.8	–0.7
France	59.0	5.3	2.9	–2.4
Germany	82.0	4.7	1.7	–3.0
India	992.7	0.8	0.7	–0.1
Indonesia	209.3	1.1	1.8	0.7
Italy	57.5	3.8	1.2	–2.7
Japan	126.8	4.8	0.7	–4.1
Korea, Rep.	46.4	3.3	0.7	–2.6
Mexico	97.4	2.5	1.7	–0.8
Netherlands	15.8	4.8	0.8	–4.0
Pakistan	137.6	0.6	0.4	- 0.2

Table 1 The alphabetic list of 22 nations shows the Ecological Footprint and the Biological Capacity per person and for each country as a whole. (For a list of 150 countries, see [22] at www.panda.org) (continued)

	Population [millions]	*Ecological Footprint* [*global* ha/cap]	*Biological capacity* [*global* ha/cap]	*Ecological deficit* (–) *or reserve* (+) [*global* ha/cap]
Philippines	74.2	1.2	0.6	–0.6
Russian Federation	146.2	4.5	4.8	0.4
Sweden	8.9	6.7	7.3	0.6
Thailand	62.0	1.5	1.4	–0.2
UK	59.5	5.3	1.6	–3.7
USA	280.4	9.7	5.3	–4.4
Combined	*4,048.6*	*2.5*	*1.9*	*–0.6*

In the last column, negative numbers indicate an ecological *deficit,* positive numbers an ecological *reserve.*

Note that numbers may not always add up due to rounding. Ecological Footprint results are based on 1999 data.

Data Source: *Living Planet Report 2002* [22].

We shall call these hectares 'global hectares', since they are hectares of biologically productive space with world-average productivity. Global hectares allow us to adjust areas according to their biological potential. One hectare of marginal land would be counted as less than an average global hectare, while a hectare of productive rainforest would appear as more than one global hectare.

Expressed in global hectares, of these 1.9 hectares per person, 0.86 are forests, 0.8 agricultural land, and 0.14 biologically productive ocean areas, most of which are located on continental shelves. The remainder corresponds to the Biological Capacity occupied or compromised by built-up areas.

Humanity may choose not to use all the 1.9 global hectares per capita since the human species is not alone on this planet. People share this planet with over ten million other species – most of which are excluded from the spaces occupied intensively for human purposes; for example, through industrial agriculture and urbanisation.

There is a wide range of opinion about how much bioproductive area should be kept relatively untouched for other species, even merely for the utilitarian reason of maintaining species that are necessary for basic life-support services. Some conservation biologists suggest setting aside at least one quarter for bio-preservation, and in some areas up to 75%. The highest conservation targets in policy documents are far smaller. The authors of the Brundtland report *Our Common Future* [15] invited the world community to protect 12% of all biologically productive space. While politically courageous, this still may be ecologically insufficient [16,17]. In contrast, leading Harvard biologist, Prof. Wilson, proposes setting aside 50% of the Earth's Biological Capacity [18]. Using the smaller conservation goal put forward in the Brundtland report, the bioproductive space available per person today shrinks from 1.9 to 1.7 global hectares.

The supply of bioproductive space can be compared to humankind's demand for Biological Capacity, which is calculated by adding up the various areas from all over the

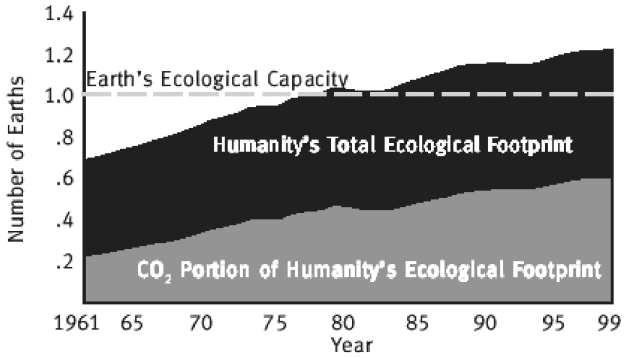
world that are occupied to produce the resources they consume and to absorb the waste they generate. This total represents a population's Ecological Footprint, which is proportional to the level of consumption, and population size, and inversely proportional to the efficiency of the prevailing technology. Non-renewable resources, such as metals, are reflected in the accounts only to the extent that their use damages the biosphere – for instance, through mining, resource processing, and consumption. We currently account for the embodied energy (the total energy used to produce the product and all the resources it is composed of) associated with the use of non-renewable resources.

Box 1 Human overshoot of the biosphere

Figure 1 shows how the Ecological Footprint compares human demand with the regenerative capacity of the biosphere (or the planet's 'Biological Capacity'). Over the last 40 years, humanity's draw on nature has grown from using 70% of the biosphere's capacity to 120% – or the equivalent of 1.2 Earths [19]. With a population of over six billion people and an average Ecological Footprint of 2.3 global hectares per person, the world is currently operating with an ecological debt of 0.4 global hectares per person. This overuse is possible because resources can be harvested more rapidly than ecosystem can regenerate them – by liquidating natural capital rather than living off is interest – as in overfishing, overharvesting of timber, or depletion of groundwater.

This overshoot is the globe's ecological deficit. It represents the amount by which the Ecological Footprint of humanity exceeds the Biological Capacity of the space available to humanity. Nations can also run ecological deficits if their Ecological Footprint exceeds the Biological Capacity of the country. To compensate the deficit, nations can either import resources or deplete their natural capital stock. But for the planet as a whole, the only option is depletion since there is no inter-planetary resource trade.

Figure 1 Human demand compared to the planet's regenerative capacity



Source: Wackernagel et al. [19]

The Footprint approach we have developed over the last few years builds on publicly available statistics from United Nations agencies and aims at providing robust underestimates of human demand on nature in order to avoid exaggerating the severity of the present ecological condition. We do this by leaving out aspects that are not conclusively documented. Examples include the use of freshwater with very locally specific impacts, or the emission of a variety of pollutants.

Also, if an area performs various functions, it is only counted once in a Footprint assessment. This means that none of the services or resource flows included in the Ecological Footprint accounts is provided on the same piece of land or sea space, ensuring that all areas are added only once to the Ecological Footprint. Otherwise double counting would inflate the estimation of overall demand. Contrary to some misinterpretations of the Ecological Footprint, this does not imply that areas are unable to provide a number of services simultaneously, or that the accounts are built on such an assumption. Ecological Footprint accounts merely document to what extent a particular human use of nature excludes other human uses of nature. For example, if an area provides timber and also, as a secondary function, collects water for agricultural irrigation, the Ecological Footprint only includes timber use, the primary function. Or in cases of double cropping, both crops are included, but only at their percentage share of the crop area.

Finally, if there is uncertainty about the yields of a given bioproductive space, we use an optimistic figure to provide a conservative estimate of human demand. To make Footprints internationally comparable, we express them in standard hectares: global hectares as defined above. Hence, each nation's or region's actual productive area is multiplied by the relative productivity ratio of each type of terrain such that global hectares credited to regions with large areas of low productivity are adjusted for comparison with other more productive regions.

Similar to static GDP accounts that document economic performance, Ecological Footprint accounts describe ecological outcomes by documenting human dependence on ecological flows. It does this by using static accounts that add up resource flows as captured by national statistics, and therefore does not depend on extrapolation or an understanding of causal relations. As with GDP accounts, Footprints also provide a myriad of other indicators or subcomponents that can be extracted from the overall accounts. In other words, Footprints offer not just a single result, but also a comprehensive accounting system that allows for a variety of analyses [20,21].

Our latest and most complete estimates, based on 1999 data [22–25], show that the average American required approximately ten hectares to provide for his or her consumption. This Ecological Footprint is over five times more than is available per person worldwide. In comparison, the average German's Footprint was half that size (4.7 hectares). Table 1 lists the results for a number of sample countries. A table with the world's largest 150 countries is provided in WWF's *Living Planet Report 2002*, available through www.panda.org.

In addition to using optimistic yield figures and leaving out impacts due to insufficient data, Ecological Footprint figures are conservative estimates of human demand on nature because they do not include substances and activities that are systematically at odds with sustainability and should be phased out. Examples are the use of bio-accumulative and eco-toxic substances such as plutonium, mercury, CFCs, DDT, and PCBs. In other words, Footprint results point out how much biological capacity is necessary to maintain only the potentially sustainable activities of humanity.

In spite of these underestimates, the accounts show that global overshoot is occurring. Even though the average Footprint of all 6.3 billion people on Earth is 2.3 hectares per person, significantly smaller than the average of most industrialised nations, put together humanity's Footprint still exceeds the biologically productive capacity that exists worldwide by over 20%. If we set aside 12% of the globe's Biological Capacity for other species and ban all consumptive human uses in these areas, then overshoot amounts

to over 30%. In other words, it would take nearly 1.3 years to regenerate what humanity consumed during 1999.

The global North-South divide becomes powerfully evident from looking at Footprint results. While the one billion people living in high-income countries (primarily OECD countries) have an average Footprint of 6.5 hectares per person, the two billion people living in lowest-income countries use 0.8 global hectares per person [26]. OECD countries' Footprints exceed their biocapacities by an average of 2.9 hectares per person [22]. This is what we term an 'ecological deficit'. All the non-OECD countries put together run barely an ecological deficit, since their collective Footprint is about equal to their Biological Capacity.

5 Limitations of Ecological Footprint analysis

Footprint accounts as established for our analysis of nations do not provide the full picture for managing resources sustainably. Particularly, as their aim is not to exaggerate human demand on nature, many significant impacts or resource uses are understated or neglected. Most prominently, the accounts undercount the waste side of the human economy, as well as its dependence on freshwater. Footprint analyses also say nothing about the quality of life. They merely reflect the draw on nature from a given lifestyle.

There are many aspects of Footprint accounts that could be enhanced to make them more robust, versatile, and sensitive [27]. But we would utterly contest van Kooten and Bulte's claim that these imperfections make Footprint accounts 'useless for policy analysis' [28]. In fact, these authors and others [29–31] seem caught in a few misconceptions about carrying capacity and Footprint analyses. For example, they claim that [32,33]:

- Carrying capacity accounts are questionable since "the evidence from exercises involving crops and food, and from fuel wood availability, suggests that quite a few African countries have gone well beyond carrying capacity. But this means that they must be steadily dying or starving (independently of any crisis droughts etc), or that the numbers are wrong, or that they have found other strategies for coping with physical scarcity" [29]. However, our point is that a country with an ecological deficit can deal with their overshoot problem in two main ways. It can:
  - import Biological Capacity (as in the case of Egypt) or
  - continue to overshoot its own Biological Capacity, which is only possible for some time.

  Nonetheless, the unavoidable impact of overshoot is natural capital stock depletion – exactly what we are witnessing throughout many parts of the world, and for the atmosphere as a whole. Prime examples are loss of forests, arable land, fish stocks and water sources due to overfishing, overharvesting, overgrazing and aquifer depletion, each of which temporarily supports unsustainable levels of consumption.
- "Carrying capacity indicators imply zero substitutability between assets" [28, p.265]. On the contrary, Footprint accounts document how much capacity can be used without depleting the natural capital stock. Since Footprint accounts aggregate a number of ecological services, they imply considerable substitutability among various natural capital services. In fact, Footprint accounts possibly exaggerate the

degree of substitutability among various land types. The bottom-line conclusion of Footprint assessment is that the overall or aggregate use of natural services must not exceed nature's regeneration rate if overshoot is to be avoided. Focusing on avoiding overshoot may be interpreted as adhering to 'strong' sustainability – i.e., the credo that securing people's well being depends upon maintaining natural capital intact. Some observers argue that strong sustainability is unnecessarily stringent because other assets, such as technology and knowledge, can compensate for lost ecological assets. Even if this criticism is accepted, managing resource assets on the basis of a 'weak sustainability' stance also requires a reliable record of asset accounts. For instance, if Ecological Footprints become larger than the available Biological Capacity, policy analysts still need measures to track natural capital in order to determine whether the loss is being adequately compensated by other forms of capital.

- "Carrying capacity is irrelevant since resource yields can be increased in the case of renewable resources, and depletion profiles can be extended by technology in the case of non-renewable resources" [29]. Indeed, carrying capacity or Biological Capacity, as we call it, can be altered. It can be eroded as in the case of desertification, and enhanced as in the case of careful management schemes. That is why Ecological Footprints are always compared to the Biological Capacity of a given year. Footprints merely document what happened, not what could happen. In fact, as Footprint accounts point out, technological efficiency is one possible strategy to reduce humanity's draw on nature (as long as the efficiency gains are not outpaced by an increase in consumption).
- "Carrying capacity calculations have limited relevance when trade is possible since the scarce resource can be imported in exchange for another asset in which the exporting nation has a comparative advantage". Footprint accounts do not argue against trade or for 'self-sufficiency'. They point out that not all countries can be net importers of Biological Capacity if global overshoot is to be avoided. Footprint accounts make ecological trade imbalance visible and show to what extent nations depend on net imports of ecological services. Further, Pearce's interpretation that shifting to imports from high-yield areas will reduce a country's overall Footprint is incorrect. From a global perspective, the change of ecological burden from such a shift would be a zero-sum game at best. In fact, in our accounts, a shift to imports from higher-yield areas does not reduce the importer's Footprint. Also, it is not our point to claim that "certain economies that are highly urbanised (Netherlands, Singapore, Hong Kong) can never be sustainable on the basis that they can never meet their ecological demands from their own land" [29]. Rather, we point out the ecological impossibility of all countries following the Dutch example – or, as pointed out above, that of the OECD as a whole.
- "Carrying capacity is a *survivability* concept not a *sustainability* concept. Survivability is about maximising the time available on Earth for human species, independently of the quality of that existence" [29]. We agree. Living within carrying capacity is a minimum requirement for sustainability. In other words, living within global carrying capacity is necessary but not sufficient for sustainability. Currently, humanity does not even meet Pearce's survivability criterion. This points to the need to reduce overall human demand and the need for robust carrying capacity accounts to track progress.

- Calculating the fossil fuel Footprints in terms of area needed to absorb the corresponding CO_2 is inadequate according to some critics [29,30]. We argue that this approach is the prevailing way of dealing (or rather not dealing) with atmospheric CO_2 accumulation. This space represents the degree by which the planet would need to be larger in order to cope with anthropogenic CO_2 output. Finding other ways to combat atmospheric CO_2 accumulation would open dramatic possibilities for reducing humanity's Footprint. Another method of calculating the fossil fuel Footprint is to assess the biological area necessary to produce a substitute. This would lead to even larger Footprints.

In summary, and in spite of the possibilities for improvement, current Footprint accounts are reasonably robust underestimates of the extent to which nations' (or the world's) ecological demands are exceeding nature's regeneration rate.

6 Interpreting Ecological Footprint results

Ecological Footprints and ecological deficits provide us with a number of critical insights. The case for the globe as a whole is simple: most fundamentally, the minimum requirement for global sustainability is that humanity's Footprint must be smaller than the biosphere's Biological Capacity. In contrast, the implications for nations are less straightforward. For example, is Sweden, with a large Footprint per person and an even larger Biological Capacity per person, ecologically sustainable? What about Egypt, which has a per capita Footprint smaller than the global average Biological Capacity, yet larger than its domestic Biological Capacity? Clearly, if everyone in the world led the same lifestyle as the average Swede, the Earth would not be able to sustain its human population for very long. Nor would humanity be sustainable if all countries ran an ecological deficit like Egypt – or like all OECD countries combined.

While Footprint analyses do not answer the question of whether a given country should live within the world's average Biological Capacity, or within its national Biological Capacity, they offer a quantitative measure of the ecological challenges and conflicts humanity needs to resolve if it wants to achieve global sustainability.

Apart from scrutinising the ecological performance of countries from a number of angles [34], Ecological Footprints also provide a context for analysing, exposing, and counteracting overshoot. They make a case against running ecological deficits, an issue even more serious than accumulating economic deficits. For instance, the existence of an ecological deficit implies there is no ecological collateral to secure the mounting debt. Moreover, it signals a lack of intention on the part of the present generation to pay back future generations. Finally, without solid Ecological Footprint accounts, there is no explicit mechanism to document how much ecological debt we owe. The present generation is writing checks without balancing the (ecological) books. More specifically, these analyses help to:

- manage common assets more effectively rather than valuing them at zero because their contributions to society are not systematically assessed
- serve as a warning device for economic and military long-term security; to recognise emerging scarcities and overall global trends

- recognise (decreasing) options by analysing the compound effect of a number of ecological pressures such as climate change, fisheries collapse, agriculture, forestry conflicts, and urban sprawl
- identify local and global possibilities for climate change mitigation and the competition between domestic sinks, joint implementation, and domestic CO_2 reduction
- test policy options for future viability and possible unintended consequences.

But there is another benefit to establishing Footprint accounts. As it turns out, a nation can profit from analysing its ecological deficit. How? Reducing ecological deficits has the potential to increase a country's competitiveness – a conclusion drawn in *Winners and Losers in Global Competition*, a study sponsored by a Swiss bank and released in 2000. For this study, we analysed to what extent national competitiveness, as defined by the World Economic Forum, correlates with the ecological sustainability and ecological performance of nations. In a more recent piece, we compared ecological performance to countries' credit rating [35].

Obviously, there are countries that are competitive while still living with an ecological deficit. Examples are Switzerland, Holland, Singapore, and Japan. These are all countries that were lucky to enjoy an early headstart which allowed them to accumulate financial assets at a time when economic expansion was relatively easy. With this financial advantage, these countries are able to access resources via importation.

In the future, however, these countries are likely to find it increasingly difficult to maintain or gain international competitiveness as the global ecological deficit increases and resources become scarcer. These countries are well advised to reduce their ecological deficit in order to decrease their risk exposure and secure future well being. Also, countries without ecological deficits will be enticed to become more protective about, and give more care to, their strategic ecological reserves as they become ever more valuable assets. At the same time, both these strategies strengthen global sustainability.

Those non-competitive countries living beyond their Biological Capacity will have great difficulty keeping afloat. Their ecological deficits may manifest themselves in terms of an ever larger ecological liability. In these countries, sustainability requires a structural change in the economy that will be difficult to achieve given their poor competitive position and their lack of financial assets to pay for such a transition. These countries are faced with the daunting challenge of eliminating their lagging competitiveness, resulting from weak infrastructure and a scarcity of financial resources and training, while at the same time dealing with the liability of an ecological deficit.

This is particularly significant in global terms, since the world economy's ecological deficit is increasing. As this ecological debt builds, ecological productivity is reduced. Because this depletion of natural capital will make it more difficult for countries to cover their ecological debt, it is in the self-interest of nations with an ecological deficit to reduce it. In an ecologically indebted world, it will also become more difficult for every country to cover its ecological deficit by foreign purchasing. In the short term, this predicament can be circumnavigated with strong currencies, improved access to less exploited resources, and cheaper extraction methods. In the long term, however, ecological scarcity will be a major brake on the economy. And not only in terms of resource availability: waste sinks, currently used almost free of charge, will become a

cost factor in the light of international agreements such as Kyoto (on carbon dioxide), Montreal (on stratospheric ozone-depleting gases), and Basel (on the export of industrial waste). It will therefore be critical for all countries to reduce ecological deficits with an eye towards creating economic stability and ensuring nations' quality of life.

For those countries with abundant ecological endowments, such as Finland or Sweden, it is easier to remain competitive. They have greater room to manoeuvre. For them, too, it makes strategic sense to restrict their resource consumption and waste production since, as ecological creditors, they are in a position to enhance their current and future competitive advantage. Using up their ecological reserves or even reducing them would jeopardise their future economic advantage, thus making them more vulnerable to economic downturns. It is therefore in the interest of every nation – whether they be an ecological creditor or debtor – to reduce their own Ecological Footprints.

This insight could serve as an incentive for all countries to reduce their national Footprints and more effectively manage and protect their ecological resources, particularly as these resources increasingly become a strategically significant part of national wealth. If countries act in their long-term self-interest, the result will be global sustainability.

7 Policies necessary to reduce human pressure

While recognising the need to reduce human pressure seems obvious and straightforward, addressing this challenge so that people feel better off is nothing short of a thorny affair. National governments have a large array of options for affecting the way resources are managed. These possible actions can be classified into three groups:

- *Keeping an eye on national assets*. Governments account for their national assets in two ways. First, they compile statistics on a number of national assets and activities such as economic performance, social health, international trade, and resource consumption. The choice of which statistics are collected greatly influences what is considered important and what gets attention. Second, governments engage in compliance: making sure that individuals and organisations follow laws and regulations.
- *Managing national assets*. Governments directly manage a number of national assets. These include research facilities, educational institutions, public health and social security organisations, national defence, public land and parks, clean air, forests, and fisheries. Each of these assets needs to be managed for, and can help shape, society's sustainability.
- *Guiding markets*. Governments are most visible in the way they manage markets. This is done not only through monetary policies, but even more so by setting standards and regulations, some of them in the context of international negotiations, and by developing incentive systems (subsidies, taxes, and natural capital use fees) to appropriately direct markets and to generate revenues. In addition, through procurement, governments can develop or strengthen emerging markets that are considered beneficial to the national economy.

No single policy initiative will redirect a nation's use of resources towards sustainable possibilities. Rather, society must pursue the whole spectrum of opportunities in order to be successful. A myriad of policy options could reduce a nation's ecological deficit. Here are a few examples:

- *Keeping an eye on national assets*
    - Establish transparent and publicly available sustainability indicators and accounts that track core requirements of sustainability. This includes developing natural capital (or 'Biological Capacity') accounts in each country, and setting specific targets for natural capital use.
    - Strengthen enforcement of regulations that affect sustainability, such as pollution control, land-use zoning, or restricted forestry practices.
- *Managing national assets*
    - Adapt infrastructure for sustainability. For example, avoid expansion of built-up areas, particularly for car use; and transform energy infrastructure to favour energy savings over production, and efficient, small scale energy sources over large power plants.
    - Support research for sustainability. For example, support research towards steady-state economics, efficient urban systems, and low-impact and resource-saving production systems.
    - Strengthen education's contribution to sustainability. For example, encourage educational initiatives that teach how to reduce human pressures on ecosystems.
    - Reorient public health and social security to enhance sustainability. For example, develop humane, equitable, and widely acceptable policies to reduce human population; encourage a change of eating habits away from resource-intensive foods such as meat and dairy products, and processed foods that are transported long distances.
    - Protect natural assets. For example, establish a network of ecologically representative protected areas covering significant areas of each ecosystem type; designate marine protected areas to safeguard marine ecosystems and give depleted fish populations a chance to recover; eliminate destructive fishing practices, such as cyanide and blast fishing on coral reefs.
- *Guiding markets*
    - Develop regulations and standards that encourage sustainability. For example, ensure that forests outside protected areas are well managed according to standards set by the Forest Stewardship Council; raise farming standards to encourage sustainable farming systems that do not systematically degrade Biological Capacity; protect soil from erosion and degradation caused by intensive agriculture, overgrazing, or salinisation; discourage the use of agricultural chemicals by taking into account the local assimilative capacity of agro-ecosystems; stop the use of hazardous pesticides and increase the use of biological control and pest-resistant varieties.

- Put in place incentive and tax systems that encourage equitable reductions in resource consumption that phase out perverse subsidies that promote excessive resource use, pollution, and population growth. An example would be the cutting of subsidies that contribute to over-fishing while simultaneously promoting market incentives for sustainable fishing, such as the Marine Stewardship Council; eliminate export subsidies; encourage policies to incorporate environmental costs in the price of goods and services; shift energy subsidies from fossil fuels to energy sources, which reduce or eliminate pollution, especially renewable sources such as solar and wind; increase energy prices to cover the full environmental costs of energy use, and eventually, remove government subsidies on energy.
- Support international negotiations that promote sustainability. For example, ratify and strengthen international agreements that discourage countries from externalising their ecological costs – for example, the Kyoto Protocol or the Basel Convention; assist lower-income countries to invest in sustainable energy technologies.
- Redirect government procurement towards sustainable alternatives to set good examples and stimulate new markets. For example, promote the recycling and reuse of wood and paper products by only consuming those types of forest products.

Box 2 Footprint application in public policy

Municipal

There may well be over one hundred Ecological Footprint studies for cities, ranging from student projects to comprehensive analyses of a metropolitan area's demand on nature. London, for instance, has already gone through three rounds. ln 1995, urban sustainability expert Herbert Girardet estimated that the UK capital's Footprint was 125 times the size of the city itself. In other words, in order to function London required an area the size of the entire productive land surface of the UK to provide all the resources the city uses and to dispose of its pollutants and waste.

In 2000, under the leadership of Mayor Ken Livingstone, London commissioned a more detailed Ecological Footprint study called *City Limits*. The report, sponsored by organizations including the Chartered Institution of Wastes Management, the Institution of Civil Engineers (ICE), and the Biffaward programme on Sustainable Resource Use, was produced by Best Foot Forward and launched in September 2002. Results for this city and its seven million inhabitants are available at: http://www.citylimitslondon.com.

To respond to the challenges identified by the *City Limits* report, London Remade, a business membership organization supported by over 300 of the capital's major businesses and higher education institutions, wanted to analyze possible steps for reducing London's Footprint. In collaboration with London first, a waste management partnership, it commissioned consulting companies WSP environmental and natural strategies to identify the reduction potential in a project called *Toward Sustainable London: Reducing the Capital's Ecological Footprint*. The first of four reports, *Determining London's Ecological Footprint and Priority Impact Areas for Action,* is available at: http://www.londonremade.com/london_remade/download_files/Phase%201%20Final.pdf

Others have studied aspects of city living using the Ecological Footprint. For instance, the sustainable consumption unit of the Stockholm Environment Institute – York has led a number of studies of cites or regions (http://www.york.ac.uk/inst/sei/IS/sustain.html). They also contributed, with BioRegional, to a WWF-UK report called *One Planet Living in the Thames Gateway* which identifies Footprint saving potentials for greener urban developments. The report is available at: http://www.wwf.org.uk/filelibrary/pdf/thamesgateway.pdf.

Bill Dunster, UK's leading ecological architect, uses the Footprint as the context for his designs. More on his work can be found at http://www.zedfactory.com.

National and Regional

A number of national and regional Footprint studies have contributed to policy discussions, some in close cooperation with government agencies. For example: Wales (pop.2,900,000). The National Assembly for Wales adopted the Ecological Footprint as their headline indicator for sustainability in March of 2001, making Wales the first nation to do so. The first report was commissioned through WWF-Cymru and executed by best foot forward. This report details Welsh energy, transportation and materials management. It can be found at: http://www.wwf-uk.org/filelibrary/pdf/walesfootprint.pdf.

The State of Victoria, Australia (pop.4,650,000). EPA Victoria, the lead state agency responsible for protecting the environment, established a series of pilot projects in 2002 in partnership with a wide range of organizations and businesses to further investigate the practical applications of the Ecological Footprint to promote sustainability. See http://www.epa.vic.gov.au/eco-footprint The campaign is expanding its reach for 2004.

The County of Sonoma (30 miles north of San Francisco, California; pop.495,000). Under a grant from the US EPA, Sustainable Sonoma County, a local NGO, used the Ecological Footprint as the foundation of a 2002 campaign. By inviting wide public participation and comment on the study before it was released, it was able to generate strong local buy-in. As a result, the launch of the study got county-wide media coverage and built the groundwork for an subsequent campaign. The latter resulted in all municipalities of Sonoma County committing simultaneously to reduce their CO_2 emission by 20%, making it the first US county to do so. To meet this commitment, they established programs that track progress towards meeting this reduction goal. The Sonoma Footprint study is available at: http://www.sustainablesonoma.org/projects/scefootprint.html.

International

The European Parliament commissioned a comparative study on the application of Ecological Footprinting to sustainability. This study included case studies exploring potential uses of the Footprint in international legislation. The study, completed in 2001, was supervised by the Directorate General for Research, Division Industry, Research, Energy, Environment, and Scientific and Technological Options Assessment (STOA). It is available at http://www.europarl.eu.int/stoa/publi/pdf/00-09-03_en.pdf or as ten-page summaries in 11 European languages at http://www.europarl.eu.int/stoa/publi/default_en.htm.

The United Nations Population Fund (UNFPA) report *State of World Population 2001 – Footprints and Milestones: Population and Environmental Chang*e builds on Ecological Footprint concepts. See http://www.unfpa.org/swp/2001/english/ch03.html#5.

8 Building public support for action

There are a great number of policy options for reducing ecological deficits. But there is less indication that the public is calling for their implementation – at least not yet. Support will build only once it is viscerally clear that ecological deficits threaten their well being and, furthermore, that the protection of ecological assets can provide overriding incentives and preferable alternatives to the status quo. This is not a call for public information campaigns. There is sufficient information available to people explaining the ecologically delicate situation humanity finds itself in today.

Rather, the question is how to help the public recognise that these ecological trends are relevant to their lives and that current patterns of economic expansion are undermining their own possibilities by liquidating the ecological (and social) assets that fuel the human economy. Once this recognition translates into broad concerns, the perceived heat will focus society's attention on the cost of ecological decline, thereby forcing every industrial sector to bring forward appropriate solutions. Libraries are stacked with possible solutions and promising policy options. But only people's active desire for them will give them traction.

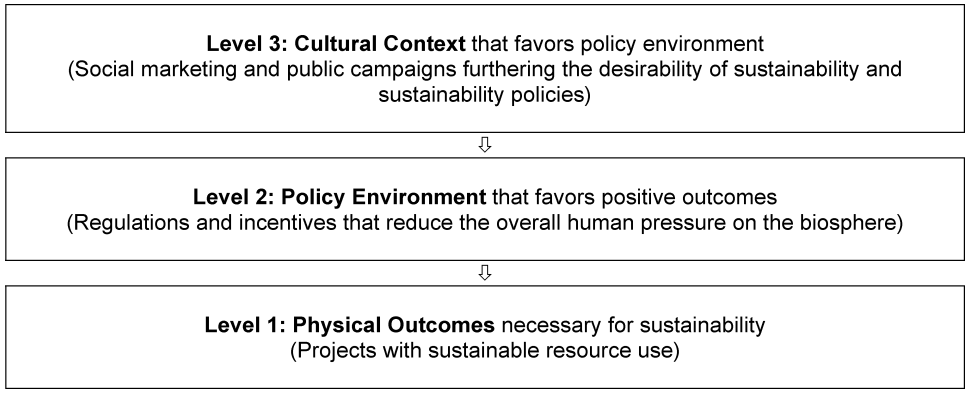
Another barrier to generating social support for such propositions is the perception that sustainability is a daunting task. Some even see it as an impossible venture. All this does is generate and perpetuate a pervasive and paralysing sense of futility. However, the question is not so much whether sustainability is possible, but rather the cost of humanity 'getting' there. Procrastination renders solutions more costly, the transition possibly painful, and resources more scarce since, in the meantime, continuing overshoot will erode valuable Biological Capacity.

Governments can help society address sustainability. This does not mean imposing particular values. It means catalysing a discussion of how to deal with the difficult decisions that nations, regions, and businesses face in a world with a declining resource base and increasing human demands. Activities for catalysing this discussion include:

- *Clarifying in specific and accountable terms what sustainability means.* Being explicit and clear about the goal, offering well-defined measures to track progress towards the goal, and identifying responsibilities for action sharpens the debate. It is the specificity that generates the actions and reactions necessary for a public debate.
- *Showing that addressing sustainability is desirable.* Without examples of what a sustainable society could look like and what benefits it brings to our lives, people will remain reluctant to abandon the current patterns of living that are both familiar and comfortable. Still, while some claim that "we can not afford sustainability", it is increasingly clear that society can even less afford unsustainability. In fact, in a world with growing overshoot, the costs of inaction may be rising steeply.

This means that effective policies for sustainable resource management may depend more heavily on social marketing than has been recognised before. This may require policy analysts to broaden their conception of policy development. But social marketing is not new to government policies. The public health field, for example, with AIDS prevention and anti-smoking campaigns, has a long tradition of using a broad array of intervention options. Essentially, this broader policy approach involves working on three levels simultaneously (see Figure 2).

Figure 2 Three levels for policy intervention. While the conventional policy interventions focus on Level 2, combining them with Level 1 and 3 interventions will produce more promising results



Level 1 of Figure 2 refers to policies that can change the physical outcomes of human activities. This could mean being as creative as possible in making resource decisions within the existing economic constraints. Examples include resource-saving initiatives of companies, some of which involve decision frameworks such as the one developed by The Natural Step [36,37]. Other examples include experimenting with possibilities that while not yet economically feasible, may be so in the future once the technology is established and proper incentives are put in place. Examples include the development of new technologies such as fuel cells, hyper-efficient cars, or new advancements in renewable energy [38–42].

Exploring and implementing such policies are essential, not only to push the envelope of technology to reshape markets and catalyse breakthroughs, but to capture people's imaginations. It is with such specific examples that remote dreams crystallise into attainable possibilities.

Level 2 focuses on redirecting market forces to realign individual interests with social ones. Various policy initiatives outline a variety of 'carrots and sticks' that can be used. Of great interest is the discussion on an ecological tax reform [43–45].

Level 3 may be the most neglected, though most promising, intervention point. Its focus is to redirect the culture in a way that makes it crave for sustainability and to support the restructuring of incentive systems in favour of the sustainability objective. To capture people's imagination, examples at Level 1 need to exist to make the new options realistic. At the same time, campaigns can help reshape the public's perception of the costs and benefits of competing development scenarios [46–48]. One of the most powerful ways to focus society's attention is to stimulate conversations around sustainability. It is the conversations that determine in each decision-making process which aspects will be considered significant. In the case of controversial topics, such as ecological sustainability, the conversation demands extra support to overcome the social temptation of avoidance. Public campaigns that are attractive, factually correct, and non-judgemental, can become invaluable, since they help 'legitimise' carriers of sustainability discussions.

9 Conclusion

To achieve sustainable resource management, it is essential to abandon fuzzy sustainability concepts and become specific about the core requirements of sustainability. These requirements can be spelled out in explicit terms, the most paramount being to avoid ecological overshoot.

From the perspective of resource management, overshoot may be the most central sustainability concern. The good news is that it can be measured – the bad news is that it is no longer merely a possibility: in many regions and even for the planet as a whole, we are already in ecological overshoot. As pointed out, OECD countries generate not only a disproportionate share of human pressure on the biosphere, but also represent the segment of humanity that exceeds its own Biological Capacity by the greatest proportions.

While these trends can still be ignored today while diminishing reserves of natural capital remain, as the biosphere accumulates an ecological debt, impending costs point clearly to the ultimately overriding undesirability of continuing ecological overshoot on both social, economic, and security grounds.

Nations can protect themselves from the fallout of overshoot first and foremost by developing ecological accounts that are able to track it. They also need to run effective social marketing campaigns that gather popular support for reducing human pressure on the ecosphere. Without this groundwork, it is unlikely that policy reforms for building a sustainable society will be successful.

References and Notes

1 The Global Footprint Network is advancing the science of sustainability. It increases the effectiveness and reach of the Ecological Footprint by strengthening the Footprint community, standardising the tool, and building wide government support for bringing human demands in line with Earth's limited resources.

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7 This approach is consistent with the notion of 'strong sustainability', Strong sustainability refers to the criterion of not depleting natural capital. Weak sustainability, in contrast, implies no depletion of total capital, i.e., natural as well as human-made capital. This means that natural capital could be diminished as long as it is compensated by a commensurate increase of human-made capital. Apart from the lack of adequate methods to compare the value of

human-made and natural capital, such weak sustainability would assume that there is substitutability between human-made and natural capital. While there is some substitutability among different aspects of natural capital (e.g., fuelwood vs. bio-fuel from corn), and even some marginal substitutability between natural capital and human-made capital (e.g., fuel-wood vs. wind-mills), there is no absolute substitutability, since human and non-human life depend on the functioning of the biosphere. In the past, weak sustainability may have been a sufficient criterion for beneficial development. But this is no longer the case in a time of global overshoot. Since humanity is using the biosphere's capacity more rapidly than it can regenerate, further trade-offs of building human-made capital at the expense of natural capital undermine the well being of future generations. Nevertheless, strong sustainability does not condemn humanity into stagnation. On the contrary: stagnation is more likely with weak sustainability policies since they could continue to liquidate natural capital. In contrast, societies adopting strong sustainability could continue to flourish. For example, human-made technology can become more effective in providing services to people without increasing its draw on natural capital, or costs of expanding human infrastructure can be saved by stabilizing or even reducing human population.

8 Page 10 in World Conservation Union (IUCN), the United Nations Environment Programme (UNEP), and the World Wide Fund for Nature (WWF) (1991) *Caring for the Earth*, World Conservation Union (IUCN), Gland Switzerland.

9 For more information on *The Natural Step*, see www.naturalstep.org.

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13 We define the biologically productive space on the planet as the area that contains the productive ecosystems. Deserts and highly marginal lands (both of which contain life and significant biodiversity) are excluded. Our rough estimates suggest that this 'biologically productive space' may harbour over 90% of the biosphere's biomass production.

14 One hectare corresponds to 10,000 m^2 or 2.47 acres. One hectare is roughly the size of a soccer field.

15 World Commission on Environment and Development (WCED) (1987) *Our Common Future aka: The Brundtland Report*, Oxford University Press, Oxford.

16 Today, about 3% of biologically productive space is set aside as protected reserves worldwide. However, conservation biologists believe that, independent of interspecies fairness, it may require far more merely for the utilitarian goal of biodiversity preservation. Wildlife ecologist and Scientific Director of the Wildlands Project, Reed Noss, along with Allen Cooperrider, conclude that most regions will need protection of some 25–75% of their total land area in core reserves and inner buffer zones. These projections all assume that this acreage is distributed optimally with regard to representation of biodiversity and viability of species, and is well-connected within the region and to other reserve networks in neighbouring regions [17].

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