ECOLOGICAL FOOTPRINTS OF NATIONS

HOW MUCH NATURE DO THEY USE? -- HOW MUCH NATURE DO THEY HAVE?

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SUMMARY

This "Footprints of Nations" report compares the ecological impact of 52 large nations, inhabited by 80 percent of the world population. It also shows to what extent their consumption can be supported by their local ecological capacity. One key finding is that today, humanity as a whole uses over one third more resources and eco-services than what nature can regenerate. In 1992, this ecological deficit was only one quarter.

After introducing the rationale and assessment method for this study, the report explains how such biophysical analyses can help build a sustainable future. A *computer diskette* is included in this report. It contains the data and the calculations for the ecological footprints for each country.

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Why measure our use of nature?

When the Earth Summit concluded at Rio in 1992, the world was challenged to lessen its impact on the Earth. Five years later, we live in a riskier world with more people, more consumption, more waste and more poverty, but with less biodiversity, less forest area, less available fresh water, less soil, and less stratospheric ozone layer.[2] We all know that we are further away from sustainability. *But how far?*

If we cannot measure, we cannot manage. To make sustainability a reality, we must know where we are now, and how far we need to go. We need measuring rods to track progress. The good news is that since Rio, these essential tools for governance, business management and grassroots organising have made substantial headway (see Box 2). This report uses one of them. Here we use the ecological footprint concept to assess the sustainability of nations.

Calculating the ecological footprint of nations

Everybody (from a single individual to a whole city or country) has an impact on the Earth, because they consume the products and services of nature. Their ecological impact corresponds to the amount of nature they occupy to keep them going. In this report, we quantify, nation by nation, the biologically productive areas necessary to continuously provide their resource supplies and absorb their wastes, using prevailing technology. In other words, we calculate the "ecological footprints" of these countries.[3]

Ecological footprint calculations are based on two simple facts: first, we can keep track of most of the resources we consume and many of the wastes we generate; second, most of these resource and waste flows can be converted to a biologically productive area necessary to provide these functions. Thus, ecological footprints show us how much nature nations use. However, in reality this footprint is not a continuous piece of land. Due to international trade, the land and water areas used by most global citizens are scattered all over the planet. It would take a great deal of research to determine where their exact locations are. To simplify, the occupied space is calculated by adding up the areas with world average productivity that are necessary to provide us with all the ecological services we consume.

Now, these ecological footprints can be compared to the biological capacity available within each country. Which countries are analysed? The report examines 47 nations discussed by the World Economic Forum's *Global Competitiveness Report* plus 5 others[4] Together, these 52 nations house 80 percent of the world population and generate 95 percent of the World Domestic Product.

BOX 1:
Sustainability and people's use of nature

Sustainability requires decent and equitable living within the means of nature. Not living within our ecological means will lead to the destruction of humanity's only home. Having insufficient natural resources, not living decently and equitably will cause conflict and degrade our social fabric.

Therefore we need to know whether people's quality of life improves over time. Even more urgently, we need to start monitoring whether we are living within our ecological means or at what rate humanity is depleting the biosphere. We must ask: "How much nature does humanity, our country or our household use to sustain itself?"

After all, people are part of nature, and depend on its steady supply of the basic requirements for life: energy for heat and mobility, wood for housing, furniture and paper products, fibres for clothes, quality food and water for healthy living, ecological sinks for waste absorption and many life-support services for securing living conditions on our planet. This use of nature is measured in this report, nation by nation

FIGURE 1: The ecological footprint measures our dependence on nature. *Every nation depends on ecological capacity to sustain itself. A nation's ecological footprint corresponds to the aggregate land and water area in various ecosystem categories that is appropriated (or claimed) by that nation to produce all the resources it consumes, and to absorb all the waste it generates on a continuous basis, using prevailing technology. (Illustration after Phil Testemale).*

BOX 2: Measures of carrying capacity and human impact on the Earth[5]

Studies about nature's capacity to support human life go back many centuries. Some focus more on energy requirements, others on non-renewable resources, and others again on photosynthetic potentials. But all are based on the same principle: tracing resource and energy flows through the human economy. Much intellectual ground-work was laid in the 1960s and 1970s. Examples are Eugene and Howard Odum's eMergy analysis examining systems through energy flows, Jay Forrester's advancements on modelling world resource dynamics, John Holdren's and Paul Ehrlich's IPAT formula, or, in the spirit of the International Biological Programme, Robert Whittaker 's calculation of net primary productivity of the world's ecosystems. The last ten years have witnessed exciting new developments: life cycle analyses (e.g., Müller-Wenk), environmental space calculations (Johann Opshoor and the Friends of the Earth), human appropriation of net primary productivity (Peter Vitousek et al.*), mass intensity measures such as MIPS (Friedrich Schmidt-Bleek and the Wuppertal Institute), the Sustainable Process Index SPI (Christian Krotscheck, Michael Narodoslawsky), the "Polstar" scenario model (Stockholm Environment Institute), or the ecological footprint concept (Mathis Wackernagel and William Rees, and similar studies by Carl Folke), to name just a few. Their applications may vary, but their message is the same: quantifying human use of nature in order to reduce it. As most of them are compatible, results from one approach strengthen the others.*

Biological productivity available on this planet

Various uses of nature are competing for space. Land used for wheat production cannot be used for roads, forests or grazing, and vice versa. These mutually exclusive uses of nature are all added up to assess the total ecological footprint. In this analysis, six main categories of ecologically productive areas are distinguished: arable land, pasture, forest, sea space, built-up land and fossil energy land:

Fossil energy land is the land that we should reserve for CO_2 absorption. But today we don't - insignificantly little area is set aside to absorb CO_2. In other words, neither the biochemical energy of the used fossil fuel is replaced nor its waste products absorbed. In this respect, humanity is living off nature's capital rather than its interests. Also using fossil fuel based products or burning fossil fuels can release toxic pollutants, an additional ecological hazard not yet included in these footprint calculations (for example, plastics can contain heavy metals such as cadmium etc.).[6]

Arable land is ecologically speaking the most productive land: it can grow the largest amount of plant biomass. According to the Food and Agriculture Organization of the United Nations (FAO), nearly all of the best arable land, or about 1.35 billion hectares, is already under cultivation. 10 million hectares of it are abandoned annually because of serious degradation.[7] This means that today, there exist less than 0.25 hectares per capita world-wide of such highly productive land.

Pasture is grazing land for dairy and cattle farming. Most of the 3.35 billion hectares of pasture, or 0.6 hectares per person, are significantly less productive than arable land. For example, its potential for accumulating biomass is much lower than that of arable land. In addition, conversion efficiencies from plant to animal reduce the available biochemical energy to humans by typically a factor of ten. Expansion of pastures has been a main cause of shrinking forest areas.

Forest refers to farmed or natural forests that can yield timber products. Of course, they secure many other functions too, such as erosion prevention, climate stability, maintenance of hydrological cycles, and if they are managed properly, biodiversity protection. With 3.44 billion hectares covering our planet, there are 0.6 hectares per capita world-wide. Today, most of the forests left occupy ecologically less productive land with exception of some few remaining inaccessible jungle areas.

BOX 3: Agricultural productivity and ecological subsidies

Many people hope that augmented agricultural productivity will be able to save humanity from the ecological squeeze. What they often forget is that high agricultural productivity is mainly possible thanks to massive ecological subsidies such as loss of ground water, loss of top soil and input of fossil fuel consuming fertilisers and other agro-chemicals.[8] *The case of hydroponic greenhouses may be particularly telling. There, the yield per square meter greenhouse exceeds by a magnitude that of open-field production. However, once the ecological subsidies are included, the balance turns upside down. Yoshihiko Wada, for example, calculated that the requirement of ecological space for hydroponic greenhouses in British Columbia for the same amount of tomatoes was 10 to 20 times higher than that with more traditional open-field methods.*[9] *This reflects a sustainability tragedy: humanity becomes increasingly dependent on an energy and resource intensive agriculture, while the resources and energy stocks necessary to sustain this agriculture are getting depleted.*

Built-up areas host human settlements and roads and extend approximately 0.03 hectares per capita world-wide. As most human settlements are located in the most fertile areas of the world, *built-up land* often leads to the irrevocable loss of prime arable land.

The sea covers 36.6 billion hectares of the planet, or a little over 6 hectares per person. Roughly 0.5 hectares out of these 6 hectares harbour over 95 percent of the seas' ecological production.[10] This marine production is already harvested to the maximum. Because the fish that people fancy are high up in the

FIGURE 2: The biologically productive areas on our planet. *The Earth has a surface area of 51 billion hectares, of which 36.3 billion are sea and 14.7 billion are land. Only 8.3 billion hectares of the land area are biologically productive. The remaining 6.4 billion hectares are marginally productive or unproductive for human use, as they are covered by ice, find themselves with unsuitable soil condition or lack water.*

food chain, the food gains from sea space remain limited. These 0.5 hectares provide approximately 18 kilogram of fish per year of which only 12 kilogram end up on people's dinner tables, securing thereby only one and a half percent of humanity's caloric intake. Measuring the ecological activity of the sea by its area (and not its volume as many intuitively think) makes sense. It is surface which determines its productivity, as both the capturing of solar energy and the gas exchanges with the atmosphere are proportional to the surface.

The ecological benchmark: how much nature is there per global citizen?

Adding up the biologically productive land per capita world-wide of 0.25 hectares of arable land, 0.6 hectares of pasture, 0.6 hectares of forest and 0.03 hectares of built-up land shows that there exist 1.5 hectares per global citizen; and 2 hectares once we also include the sea space. Not all that space is available to human use as this area should also give room to the 30 million fellow species with whom humanity shares this planet. According to the World Commission on Environment and Development, at least 12 percent of the ecological capacity, representing all ecosystem types, should be preserved for biodiversity protection.[11] This 12 percent may not be enough for securing biodiversity, but conserving more may not be politically feasible.[12]

Accepting 12 percent as the magic number for biodiversity preservation, one can calculate that from the approximately 2 hectares per capita of biologically productive area that exists on our planet, **only 1.7 hectares per capita** are available for human use.[13] These 1.7 hectares become the ecological benchmark figure for comparing people's ecological footprints. It is the mathematical average of the current ecological reality. Therefore, with current population numbers, the average footprint needs to be reduced to this size. Clearly, some people may need more due to their particular circumstances -- but to compensate others must therefore use less than the average amount available. Assuming no further ecological degradation, the amount of available biologically productive space will drop to 1 hectare per capita once the world population reaches its predicted 10 billion. If current growth trends persist, this will happen in only little more than 30 years.

The calculation procedure used in this report

The assessments are based on 1993 data, the latest year with a complete data set available.[14] The national footprints and the available ecological capacity, are calculated using published statistics from the United Nations.[15] Each country is analysed on a spreadsheet of over 100 lines and 12 columns.[16] The lines represent resources or product types.[17] The columns specify the productivity[18], the production, import, export and consumption of these resources or product types. Consumption is calculated by adding imports to production and subtracting exports. With biological productivity data, consumption is translated into land and water areas -- the footprint components.

The spreadsheet is composed of three main areas (see Figure 3). The upper part consists of a consumption analysis of over 20 main resources. Using FAO estimates of world average yield, consumption and waste absorption is translated into the occupied ecologically productive area. The middle part provides an energy balance of the traded goods. This is necessary to adjust the directly consumed energy within the country by the embodied energy that enters and leaves the country through the import and export of finished products. For example, in Costa Rica, only a bit more than half of their consumed commercial energy is used within the country, the rest is needed to produce their import goods.

In the bottom part, the results are summarised in two boxes. The left box itemises the ecological footprint in the six ecological categories and gives the total. To make big and small countries comparable, we present all results in *per capita* figures. Multiplying the per capita data by the country's population gives the total footprint of a nation.[19]

The right box shows how much biologically productive capacity exists within the country. However, the mean productivity of a country may differ from the world average. Therefore, the biologically productive areas of the country cannot be contrasted directly to the footprint areas. To make them comparable, the number of physical hectares of biologically productive area that exist in each ecological category within the country (second column in the right box) is multiplied by the factor by which the country's ecosystems are more productive than world average (first column in the right box). We call this factor the "yield factor" [20]. A yield factor of 1.5 would mean that the local productivity is 50 percent higher than world average -- absorbing 50 percent more CO_2 or producing 50 percent more potatoes per hectare. Multiplying the yield factors by the number of physically existing hectares gives an equivalent area with world average productivity, which we identify as the "adjusted area" (third column in the right box).

The applied calculation method is still not complete. It leaves out some uses of nature for resource production and waste absorption. Particularly in dry countries, fresh water becomes a critical resource that should be covered by footprint assessments. There, human settlements, agriculture and other ecosystems compete for this use of nature. Furthermore, water is diverted for human uses, at high energy costs and often with significant ecological impacts. Also the ecological impacts of contamination are only marginally included in current assessments. Contamination, manifested in industrial areas of the former Soviet Union, or in the many areas affected by acid rain all over the world, can significantly reduce ecological productivity or make products of nature unfit for human use. These aspects should be included in later even more detailed studies. By not including them yet, current results are underestimates of human use of nature.

FIGURE 3: Calculation spreadsheet *for each country contains over 100 lines and 12 columns, as presented in this schematic representation. The upper third analyses the consumption of over 20 main biotic resources. The middle part provides an energy balance of the traded goods. The bottom part summarises the results. Every country corresponds to a file on the attached disk. All files can be printed out, viewed on the computer screen or manipulated with new data.*

Accuracy could be improved by analysing fossil energy in finer categories as the CO_2 release per energy unit can vary by a factor of two. Also, traded goods should not only be accounted for in terms of embodied energy but also according to their embodied resources and waste discharges. *Note*: the calculations presented here result in larger ecological footprints than the ones documented in our earlier publications. The reason is threefold. First, present calculations include the use of the sea. Second, we found in more recent literature reviews that average productivities of pasture and forests were lower than what we assumed before. Third, the documentation of consumption in these calculations is more complete than in our earlier efforts.

The merit of the current method is its easy replicability. It is sufficiently detailed to give a general indication of the magnitude of human impact globally. Also, by using the same assumptions for all assessments, the results of the countries are comparable in relative terms. The absolute precision of the calculations may be within the range of 5 percent too big and 30 percent too small. A major weakness consists of the date sources themselves. Not all national statistics are equally reliable. Even within the UN publications, we could find discrepancies between the same data reported in different publications.

Ranking the ecological impact of nations

Table 1 summarises the results of our calculations. The first two number columns show the countries' 1997 population and their per capita ecological footprint. The footprint data of the 52 analysed nations indicate their respective ecological impact world-wide. A five hectare footprint would mean that five hectares of biologically productive space (with world average productivity) are in constant production to support the average individual of that country. Compared to the available 1.7 hectares per world citizen, this five hectare footprint occupies three times more ecological space. Countries with footprints lower than 1.7 hectares per person have a global impact that could be replicated by everybody without putting the planet's ecological long-term capacity at risk.
However, some countries are particularly well endowed with ecological capacity. As a consequence, they may be able to sustain their citizens at a higher level of resource throughput. We measure the extent to which this is possible by comparing their ecological footprints (second number column of Table 1) with the biologically productive space available within each country, including the share of sea space (third number column of Table 1). For example, the Netherlands are listed with 2.8 hectares available capacity per capita, including sea space. As their local productivity is about four times larger than world average, these 2.8 hectares are more than the existing physical space within the country.[21]

If the footprint exceeds the available biologically productive area of the country, it runs an ecological deficit (fourth column of Table 1). In this case, the country's area alone cannot provide sufficient ecological services to satisfy its population's current patterns of consumption.

Now let's rank them! Figure 5 organises them according to their ecological footprint and Figure 6 with respect to their ecological deficit.

The ranking of ecological footprints points out which people are on the ecologically most sustainable trajectories and which ones exacerbate the current ecological squeeze. In fact, only in ten out of the 52 countries, the average citizen uses less than what is available on a per capita basis world-wide. In other words, if all people of the world adapted the lifestyle of the first 42 countries, there would simply not be enough ecological capacity to support them sustainably. We could say that the ecological footprint shows people's contribution to global ecological decline.

FIGURE 4: Ecological deficits*. The ecological footprint measures how much ecological capacity we occupy. Some countries claim more ecological capacity than there is within their boundaries. This means that they run an ecological deficit. Consequently, they need to import their missing ecological capacity -- or deplete their local natural capital stocks (above). Countries with footprints smaller than their capacity are living within their nation's ecological means (below). Often, however, the remaining capacity is used for producing export goods rather than keeping it as a reserve.*

TABLE 1: The ecological footprint of nations*: For each country, this table lists its 1997 population, ecological footprint, available ecological capacity and ecological deficit. The last three are provided on a* per capita *basis. The ecological deficit is calculated by subtracting the footprint from the available ecological capacity. Negative numbers indicate a deficit, positive numbers show the still existing remaining ecological capacity. If you want to know a nation's total ecological footprint, multiply the per capita data by the country's population.*

	population in 1997[22]	**ecological footprint (in ha/cap)**	**available ecological capacity (in ha/cap)**	**ecological deficit** *(if negative)* **(in ha/cap)**
		(all expressed in world average productivity, 1993 data)		
WORLD	5,892,480,000	2.3	1.8	-0.5
Argentina	35,405,000	4.6	3.8	-0.8
Australia	18,550,000	8.1	9.7	1.6
Austria	8,053,000	5.4	4.3	-1.1
Bangladesh	125,898,000	0.7	0.6	-0.1
Belgium	10,174,000	5.0	1.6	-3.4
Brazil	167,046,000	2.6	2.4	-0.1
Canada	30,101,000	7.0	8.5	1.5
Chile	14,691,000	3.5	4.9	1.4
China	1,247,315,000	1.2	1.3	0.1
Colombia	36,200,000	1.7	1.3	-0.4
Costa Rica	3,575,000	2.5	2.0	-0.5
Czech Rep	10,311,000	4.2	2.5	-1.7
Denmark	5,194,000	5.8	2.1	-3.7
Egypt	65,445,000	1.2	0.6	-0.5
Ethiopia	58,414,000	1.0	0.9	-0.1
Finland	5,149,000	6.3	9.6	3.3
France	58,433,000	5.7	3.8	-1.9
Germany	81,845,000	4.6	2.1	-2.5
Greece	10,512,000	3.9	1.3	-2.6
Hong Kong	5,913,000	2.7	0.5	-2.2
Hungary	10,037,000	2.5	2.0	-0.5
Iceland	274,000	9.9	2.5	-7.4
India	970,230,000	0.8	0.8	0.0
Indonesia	203,631,000	1.6	0.9	-0.7
Ireland	3,577,000	6.6	8.3	1.7
Israel	5,854,000	3.1	1.1	-2.0
Italy	57,247,000	4.5	1.4	-3.1
Japan	125,672,000	6.3	1.7	-4.6
Jordan	5,849,000	1.5	0.6	-1.0
Korea, Rep	45,864,000	2.0	0.7	-1.3
Malaysia	21,018,000	2.7	1.7	-1.0
Mexico	97,245,000	2.3	1.4	-0.9
Netherlands	15,697,000	4.7	2.8	-1.9
New Zealand	3,654,000	9.8	14.3	4.5
Nigeria	118,369,000	1.7	0.8	-0.9
Norway	4,375,000	5.7	4.6	-1.1
Pakistan	148,686,000	0.8	0.9	0.1
Peru	24,691,000	1.7	1.5	-0.2
Philippines	70,375,000	2.2	0.7	-1.5
Poland, Rep	38,521,000	3.4	2.3	-1.1
Portugal	9,814,000	5.1	2.2	-2.9
Russian Federation	146,381,000	6.0	3.9	-2.0
Singapore	2,899,000	5.3	0.5	-4.8
South Africa	43,325,000	2.6	1.6	-1.0
Spain	39,729,000	4.2	2.6	-1.6
Sweden	8,862,000	5.8	7.8	2.0
Switzerland	7,332,000	5.0	2.6	-2.4
Thailand	60,046,000	2.8	1.3	-1.5
Turkey	64,293,000	1.9	1.6	-0.3
United Kingdom	58,587,000	4.6	1.8	-2.8
United States	268,189,000	8.4	6.2	-2.1
Venezuela	22,777,000	2.6	1.4	-1.2

FIGURE 5: Ecological footprint ranking of nations. *The ecological footprint shows the global impact of consumption by average citizens of those nations. The arrow points to 1.7 hectares per capita, the amount of biologically productive space available world-wide. Only people from nine countries use less.*

FIGURE 6: Ecological deficit ranking of nations. *The ecological deficit shows the ecological overshoot of each nation. It represents the amount a nation is consuming beyond its local ecological capacity to regenerate. Bars to the left show deficits, bars to the right indicate remaining ecological capacity.*

The more locally oriented measure is the ecological deficit of each country. It indicates which country consumes beyond local ecological capacity. A positive number means that consumption exceeds local supply, while a negative number reveals that there is some remaining capacity. In many cases, this remaining capacity, however, is used for the production of export goods, rather than leaving it as a principle in reserve. The deficit represents a country's ecological load compared to the resource capacity within its borders and the level of appropriation from other regions that is required to offset the deficit. The ecological deficit induced by local consumption above locally available ecological production represents the country's overshoot and the beginning of self-destructive growth. Hence, it is an indicator of potential vulnerability.

The data reveals that humanity lives too heavily on the Earth. Humanity's average ecological footprint measures 2.3 hectares of ecologically productive space. In contrast, as explained above, only 1.7 hectares are available. This means that the average footprint is more than 35 percent larger than the available space. This overshoot indicates that humanity's consumption exceeds what nature can regenerate on a continuous basis. In 1992, this ecological deficit was still closer to 25 percent. The 10 percent growth since then demonstrates humanity's fast expansion.

In fact, most countries analysed here occupy more ecological capacity than their country provides, adding thereby to the global ecological deficit. In fact, if the 12 percent of space put aside for preserving biodiversity should prove to be insufficient (as many conservation ecologists suggest), the ecological deficit would be even more dramatic. India, Pakistan and China are three notable exceptions. According to the calculations of this study, they are among the few countries that consume at a level which could be reproducible for everybody in the world without endangering the planet's life-support capacity. Also each of them shows a small ecological remainders. However, for both Pakistan and India[23] their land based footprint is larger than their terrestrial ecological capacity - the ecological remainder comes from their comparatively low use of sea space as their fish consumption is much below world average. China, in contrast, can even count on some remaining land based ecological capacity. China's ecological remainders does not mean that the country is out of the danger zone. First, the ecological deficits calculated here may be an underestimate of the true deficits. Second, if their population and per capita consumption continue to grow, this possible remainder will soon be used up.

Implications for governance, business administration and the grassroots

The ecological footprint is not about how bad things are. It is about *how* they are -- and what we can do about it. The figures should not merely lead to a more informed discussion of our challenges ahead. More importantly, such assessments can help governments, businesses and NGOs shape sustainable development. At last, these organisations have at hand a clear and comprehensive measure of human impact on the Earth. The measure shows us where we are, in which direction we need to go, and which projects and programs move us there. This type of simple and accessible tool can finally put the abstract sustainability concept into concrete terms and cut through the paralysing and widespread confusion.

To conclude, we discuss how these biophysical assessments can move the sustainability agenda to action. We concentrate on five areas: what the numbers of this report tell us, how such assessments can be used for monitoring progress, how they can encourage change, in which way they sharpen our understanding of the world, how they complement economic thinking and how they can help businesses become promoters of sustainability.

Shrinking footprints with a factor four revolution

Tell a German or US citizen that his country is over-populated while China and India are not. He or she will be outraged. Associating over-population with the developing countries is one of the deepest routed prejudices in the North. Mathis Wackernagel and his team have the great merit of educating their readers chiefly from the North that this prejudice may be profoundly wrong if consumption standards are taken into account. What is perhaps more alarming and important to know is that all in all the Earth is already over-populated and that, evidently, current trends make things worse. I see the urgent need both in the North and the South to rapidly introduce technologies and life-styles, drastically reducing the ecological footprints per capita. Using existing technologies, a factor of four can be reached in the reduction of ecological loads per service delivered. That *factor of four*[24] could be attained on a world-wide scale by 2040. Buying so much time could just be sufficient to simultaneously arrive at a stabilisation of the world population.

Regardless of this good news, efforts should be made to also redefine satisfaction, economic growth and services. Further accelerating the "hamster wheels" of economic turnover may help arithmetically to reduce unemployment but may at the same time make it even more difficult to answer the sustainability challenges. As Wouter van Dieren clearly says in his Report to the Club of Rome *Taking Nature into Account*, an increasing part of the present GDP is no longer contributing to welfare but just to meaningless turnover.[25]

It is my wish that the calculations of ecological footprints will impress the world community and help politicians, business, engineers and the public at large to find new and exciting paths towards sustainable development.

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President of the Wuppertal Institute for Climate, Environment and Energy
Germany

If we leave enough places in the world:

where silence is not broken with
our noises,

where space is not altered with
our objects,

where evolution is not interrupted with
our progresses,

where misery is not consolidated because of
our greeds,

we will be worthy of being part
of the shared miracle of life

Manfred Max-Neef
Rector of the Universidad Austral de Chile
Chile

Treading too heavily on the surface of the planet

There have been a number of innovative research initiatives to help us get a grip on what is meant by Sustainable Development.

Among the most substantive and illuminating, if not the single most helpful of all, is the work by Mathis Wackernagel and his colleagues on "ecological footprints".

Their fine statistical analyses show us which nations are treading too heavily on the surface of the planet -- and, equally, which few nations are keeping within the bounds of Sustainable Development.

Norman Myers
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FIGURE 7: Humanity's overshoot. *Our calculations show that the ecological footprint of humanity is larger than the biologically productive space that exists on the planet. This overshoot indicates that humanity's consumption is bigger than what nature can regenerate on a continuous basis. If we take into account that at least 12 percent of the existing land should be left aside for biodiversity protection and would therefore not be available for direct human use, humanity's overshoot measures over 35 percent.*

a) Reading this report's numbers

Footprints are too large. Most countries presented in this report live on footprints larger than what their own ecosystems can support. On a global basis and even by conservative measures, humanity's footprint has overshot global capacities by over 35 percent. This frames the sustainability challenge: it shows the extent to which humanity's economic activities have to become less resource consumptive and less contaminating. Also, it helps us to comprehend the ecological impact of humanity's growth with its doubling in the next half century.

Knowing where we are. Not knowing what is sustainable, not knowing where we are, or where we are going makes our future even more risky. In contrast, understanding our ecological constraints and identifying future risks supports informed decision making, This reduces threatening uncertainties and points to new opportunities.

Extracting other insights from the compiled data sets. The statistical information compiled in the appended spreadsheets can be used for various other biophysical assessments. For example, they can reveal the extent of food and fibre footprints of other countries accommodated within a nation's territory. Or, they can show the amount of renewable resources consumed, and whether there is enough biological capacity within the country to renew them. We include the electronic files of the calculations so readers and researchers can examine them in detail, test them with different assumptions and newer data and adapt them for their own needs.

The equity challenge. The footprint numbers point to unequivocal equity implications. They reveal the extent to which wealthy people and countries have already "appropriated" the productive capacity of the biosphere. In fact, based on the conservative assumption that the wealthy quarter of humanity consumes three quarters of all the world's resources, this wealthy quarter alone already occupy a footprint as large as the entire biological capacity of the Earth. However, there is only one cake and everybody wants a piece. If some take big pieces there are only small ones left for the others. Furthermore, such overconsumption is hard to compensate for. Simple mathematics show that consuming 3 times the amount available per capita in the world (as is typical in industrialized countries) implies that for each overconsumer there have to be 3 other people using one third of the global average. Otherwise humanity is not within sustainable limits. More specific and socially stratified footprint assessments can also shed light on equity within countries. This may show that the highest income quintile of countries like Argentina, Botswana, Brazil, Chile, Guatemala, Mexico or Malaysia may live on footprints at least as large as those typical for industrial nations.[26]

Population versus consumption. The numbers show the impact of both consumption and population. Clearly, the high levels of consumption in industrialized countries take the biggest share of the planet's bounty. But with ever larger populations it becomes progressively less likely that a reasonable quality of life can be secured for everybody. Particularly the rapidly growing populations will lose their prospects even faster. This underlines that population growth is first and foremost a local problem. The good news is that the benefits of reducing demographic growth will also stay local.

The ecological benchmark. It is a physical fact: there is on average only 1.7 biologically productive hectares available per person, assuming the fragmented 12 percent of nature suffice to secure biodiversity. Population growth and ecological deterioration are reducing this area even more. The key question is therefore: how can we squeeze high and attractive quality of life out of these 1.7 hectares. We require experiments and case studies to highlight this question and show how we can best live within these limits. *How about an international competition on examples of best living on less than 1.7 hectares?*

b) Assessing progress

Time series. Such biophysical assessments can summarise progress toward sustainability by tracking and comparing the ecological situation year after year, as done with economic indicators. For every scale, from the globe down to the nation, the region, the municipality, the business or the household, measures of natural capital such as the ecological footprints can point out to what extent this particular population is closer or further away from sustainability. The presented assessments become the starting point for more detailed local comparisons and time series. Historical analysis can show the path of the past and illuminate to what extent economic and demographic growth have enlarged a nation's or region's footprint. Also, they offer themselves as indicators of countries' potential vulnerability and their contribution to global ecological decline.

National accounts. The ecological footprint method provides a systems approach for global, national, regional, local and personal natural capital accounting that can trace demand and supply. Such natural capital accounts could complement Gross Domestic Product (GDP) measurements as they allow to document ecological risks and social equity. The concrete benefits?

Ecological Footprints Lead to the "Smoking Gun"

In the late 1970s, when I introduced the regional capsule model, a predecessor of the ecological footprint concept, I was looking for a tool to teach young urban-planners-in-training a rudimentary fact of human ecology: although more and more people are living in cities, the land that actually supports them lies far beyond the urban boundary. In an era of incipient global change, it was time to extend the domain of urban planning to account for all the land upon which urban populations actually depend. With global change now upon us the message of ecological footprinting acquires a keener urgency.

Indeed, the present report on the "ecological footprints of nations" is a startling wake-up call to a world addicted to growth but in deep denial of the consequences. This document provides solid evidence that the human enterprise already far exceeds the long-term biophysical carrying capacity of the planet. People today are living on the biophysical heritage of their children. Most significantly for the sustainable development debate, eco-footprint analysis shows that it is the high-income countries that have appropriated most of the world's ecological output.

Following the lead of *Our Common Future*, it has been convenient to target poverty as the greatest threat to sustainability. Who can deny that the rural poor are often forced by sheer necessity to abuse the land or that the urban poor in squatter settlements throughout the developing world suffer appalling public health and environmental conditions? It is also true that greater wealth can provide safe drinking water, functional sewers, and improved local air quality. All this has fostered the popular (and politically acceptable) view that, as one prominent economist puts it, " ...the surest way to improve your environment is to become rich." However, while the acute environmental problems afflicting world's poor are essentially local in both cause and effect, eco-footprint analysis shows that the chronic global problems that threaten us all (e.g., ozone depletion and climate change) stem from material wealth. The "smoking gun" of *global* change is the consumer excess that accompanies high GDP/capita, not debilitating poverty. By all means then, let us improve our own local environments but this is no license for private consumption to savage the global commons. Agenda 21 notwithstanding, we simply cannot grow our way to sustainability in a world that sees people first as potential consumers and only second as responsible citizens.

Ecological footprinting explodes another myth of our industrial culture. We generally see technology as having made us less dependent on nature. In fact, it merely extends the efficiency and range of our exploitative activities. Together with trade, technology thus cushions us from the negative consequences of local resource depletion while invisibly expanding our ecological footprints. The aggregate effect brings us closer to global collapse.

Governments everywhere are obsessed with reducing their fiscal deficits but ignore their cumulative debt to nature. Material consumption in high-income countries today increasingly exceeds their sustainable natural income. Unless the wealthy nations act to reduce their growing ecological deficits global sustainability will remain a receding dream.

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Planners and administrators of each country will have a tool to analyse the ecological state of their country on issues such as: the extent to which a country can support the consumption of its people; the trends in a nation's dependence on nature; the potential "interests" that the national natural capital can yield; and the extent to which these interests are used. In short, they point not only at potential risks but also identify missed opportunities. In this way they help avoiding dangerous overexploitation and finding sustainable options.

c) Encouraging change

Deflecting confusion. Confusion about what sustainability means has slowed down progress. This confusion, infused with unnecessary conceptual complexity has been convenient for those who are interested in preserving the status quo. Such delaying also undermines the exercise of precaution. Now we must move beyond the Brundtland definition and assess sustainablity in concrete terms. Only clear and measurable objectives help us manage for sustainability. Simple benchmark yardsticks that compare human consumption with nature's limited supply help refocus public attention on the sustainability challenge. They clarify ecological boundary conditions and make way for meaningful debates on development. By providing common ground, such assessments build bridges between different world views, they amplify the resonance between all disciplines working on sustainability. From there we can build shared visions for a sustainable future.

A tool to check. With this simple and reproducible evaluation tool at hand, governments, businesses and NGOs can adapt the ecological footprint for better national assessments (for example with sectorial analysis). Also, they can redesign it for other tasks such as budget reviews, technology and policy assessments or eco-labelling. In this way they can detect whether their own initiatives are moving in the right direction. NGOs can audit more effectively whether "sustainable" initiatives of government and business really hold what they promise. In this way, these checks can reveal whether initiatives are effective or if they are merely "sustainable posing", as we call it. In an ecologically overloaded and inequitable world, after all, only those projects that improve people's quality of life while reducing humanity's resource consumption and waste production promote sustainability.

Positive and accessible information. NGOs and governments can use footprinting not only to assess progress, but also to make local sustainability efforts work. Many people, in government, businesses and the grassroots, know that humanity lives beyond ecological capacities, but are not willing to act. Therefore, the bottleneck for action is seldom "information". On the contrary, too much information on problems that seem overwhelming demoralises people. Rather, information needs to be accessible. To encourage people's participation, it has to show the positive impact of a proposed action. By summarising ecological impacts in perceivable units, the message becomes simpler. Also, it provides easily understandable feedback by revealing how much ecological capacity has been or can be saved, and what benefits can be expected by proposed programs or projects.

Inside and outside the classroom. Such simple sustainability tools become powerful educational resources, for primary school up to university courses. They can integrate sustainability thinking in all kind of subjects: science, mathematics (statistics, geometry, algebra, computer skills), geography, arts, social studies, etc. as demonstrated by already existing curricula[27]. Such courses not only provide tools but also stimulate interest and seed enthusiasm for a better future. They become the building block for positive changes in a spirit of co-operation.

d) Sharpening our understanding

Loss of biodiversity. Biophysical examinations of humanity's resource throughput reveal why we witness such rapid loss of biodiversity. Human activities just occupy

FIGURE 8: From overloading to caring. *Sustainable development means to move from overloading planet Earth to living decently and equitably within the means of nature.*

too much space. Footprint numbers illustrate the basic premise of sustainability and conserving biodiversity: the need to live with nature, within its regenerative and waste assimilation capacity and with other species with whom we share the planet.

Participating in the web of life. Analysing our dependence on nature underlines the often forgotten fact that we are part of nature. As obvious as this fact may sound, it has profound implications for the way we should construct our cities, machines and economies. Understanding our relationship with nature requires first hand experiences. However, most of the influential decision-makers are city people, who live in a world psychologically shielded from this basic reality. Biophysical assessments may help those who lack these experiences to grasp the implication of the "forgotten fact" that humanity is an integral component of the global ecosystem just as one cell is part of a living body.

Seeing the "big picture". Traditional scientific thinking fragments issues and can get people lost in details. In contrast, the ecological footprint helps us see the "big picture" of our current reality. It shows the connections between the environmental issues and puts them in a quantitative perspective. It clarifies the links between resource constraints and social conflicts. This is what we need today to comprehend the sustainability challenges: systems thinking and numeracy that goes beyond percentages. People must understand magnitudes - the magnitude of the human load as compared to the magnitude of the planet's finite carrying capacity.

Psychological barriers. Clear and accessible measurements of our overuse of nature can help us explore human and social psychology. One large obstacle to sustainability is the cleft between "realising" the ecological and social crisis, and "doing" something about it. As long as

More than ever, we need biophysical accounting systems

The work by the authors of the Ecological Footprint method is both stimulating and useful for obtaining an estimate of our impact on the environment. Five years after the Earth Summit I see in this respect two great priorities for the global political agenda. One is the development of a *biophysical accounting system*. The internationally accepted system of national economic accounting used to calculate Gross Domestic Products (GDP) neglects the depreciation of natural capital, such as the loss of topsoil from erosion, the destruction of forests, or the depletion of the protective stratospheric ozone layer. As a result, the universally used GDP greatly overstates progress. Failing to reflect reality, it generates environmentally destructive economic policies. An expanding economy based on such an incomplete accounting system can be expected to slowly undermine itself until collapse through the destruction of its support systems. This is exactly what we are witnessing. Therefore, we desperately require biophysical accounting systems. The lack of information on sustainable use or yields allows governments to permit excessive demands on natural systems, leading to their gradual destruction. Luckily, with reports like WWF's *A Real Value for Nature* and the Club of Rome's *Taking Nature into Account*, a new movement to develop such biophysical accounting systems is emerging. Now these concerns need to get transformed into political commitment.

The second priority is the development of a global indicator for calculating our pressure on the environment and monitoring progress toward a sustainable society. The work done by Wackernagel and his colleagues in this field is precious. As they write in this report: "If we cannot measure, we cannot manage. To make sustainability a reality, we must know where we are now, and how far we need to go. We require measuring rods to track progress". The Ecological Footprint method is particularly useful for this task because it starts to quantify the biologically productive area necessary to provide the supplies of a given human population and to absorb its wastes. It nicely complements the "environmental space" method first elaborated by the Dutch economist Jan Opschoor and now enriched by the researchers at the German Wuppertal Institute on Climate, Energy and Environment in several studies such as *Sustainable Europe*.[28]

The results of this *Ecological Footprints of Nations* Report developed for the "Rio+5 Forum" are insightful. Great quantitative differences among countries in their consumption patterns become evident. It is clear that the rapid growth in consumption of some countries particularly in South East Asia could be unsustainable in the close future if we in rich countries don't reduce ours. For example, with 1,2 billion Chines moving up the food chain -- consuming more pork, poultry, eggs, beef, beer and other grain intensive products, the world's food balance will alter and food prices will raise everywhere, as Lester Brown pointed out in his book *Who Will Feed China?.* And China's case is not unique.

In his last *State of the World*, Brown shows the same industrialisation effects for Western Europe and North America when entering their period of rapid modernisation after World War II creating a modern consumer economy.[29] However, they contained "only" 440 million people (280 in Europe and 160 in North America). Today Asia -- the region from Pakistan eastwards till Japan -- has 3.1 billion people, more than half of the world's population. Excluding Japan, the economy of this region has grown by some 8% a year from 1991 to 1995, much faster than the growth achieved by either Western Europe or North America. There is no historical precedent for so many people moving up the food chain so fast. For the moment, the ecological footprint of China or India, for example, are not high but in the future they will grow if their consumption patterns will increase.

It is clear that if we want to reverse the trends of environmental destruction of the last few decades the solution lies in finding an effective mix of eco-efficiency and eco-sufficiency. It is important to adopt, therefore, a "factor ten" increase in energy and resource productivity as a strategic goal for the new Millennium, as suggested by the "Factor 10 Club", and simultaneously to reduce our ecological footprint, particularly in rich countries, adopting a sufficiency strategy as suggested by the Wuppertal Institute.

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we deny our addiction to a materialistic, but in the end highly destructive lifestyle, we may not be able to close the gap between realisation and action. Simple sustainability concepts with easily understandable measurements may allow us to explore people's perception, fears and willingness to act. This may help to explain the apparent lack of urgency to get sustainability going, and to find strategic intervention points for effective programs.

e) Rethinking economics

Current blindspots. Biophysical measurements are indispensable complements to monetary studies. Monetary assessments detect changes in the *circular flow of money* and commodities between households and firms. While such financial analysis are crucial to understand budget constraints and determine optimal allocation of resources, they are blind to questions of *resource throughput* and scale. By focusing only on financial flows, we behave like the medical doctor whose preoccupation is limited to the patient's blood circulation while giving no attention what so ever to his digestive tract or body weight, to use Herman Daly's metaphor.[30] This is unacceptably dangerous for any organism, be it patient or a nation.

Developing an ecological basis for economics. Economics is concerned with the distribution and allocation of resources. Much of its work, however, focuses on financing and financial flows only. Biophysical assessments can offer economics thermodynamically and ecologically informed tools to enhance their important analyses. This will help them identify at which point economic growth becomes impossible on a finite planet. Also, it gives us meaningful yardsticks to measure to what extent the much celebrated technological substitution, efficiency gains and "deindustrialisation" have decreased society's resource throughput. Such studies may show that technologies that seem to substitute ecological functions such as filters or sewage treatment are requiring more natural capital input than their ecological counterparts.

World competitiveness. Ecologically informed studies reveal the effect of competitiveness on sustainability. Jeffrey Sachs and Andrew Warner define competitiveness in the World Economic Forum's *Global Competitiveness Report* as "the fitness of a country's economic institutions and structures to produce growth, in view of the overall structure of the global economy". They believe it to be a positive-sum game in terms of GDP growth.[31] However, in an ecologically overloaded world, it may be short-sighted to measure gains purely with GDP. To begin with, natural capital decline is not captured by GDP. Also many defensive expenditures such as pollution induced health costs, pollution prevention or ecological damage costs, should never be added to the GDP measure. Furthermore, GDP growth has been linked in the past with higher resource throughput and expanding footprints, as scholars have shown.[32] This means that continued economic growth will turn out to become a negative-sum game, impoverishing humanity, and removing us further from sustainability. Therefore, we may require rules and institutional frameworks to direct competitiveness towards producing the best services, at minimal social risk and lowest resource throughput.

Trading off our future. By encouraging all regions to exceed their local ecological limits, by minimising the perceived risk for local people to deplete their local natural capital and by exposing all the world's natural capital indiscriminately to global demand, trade as we witness it today diminishes global carrying capacity and intensifies the long-term threat to everyone.[33] Therefore, trade may represent the single most powerful mechanism in the world, governing global economics and environment. In spite of the recommendations on trade made in *Agenda 21*, the General Agreement on Tariffs and Trade (GATT) had shown little or no interest in including environment or sustainable development issues into multilateral trade negotiations. Neither has the "Trade and Environment Committee" of the World Trade Organization (WTO) so far addressed these fundamental sustainability issues. Biophysical assessments can reveal the ecological capacities embodied in trade and measure to what extent they correspond to true ecological surpluses. After all, if each nation were to export only true ecological surpluses, then the net effect would keep the world economy cushioned by ecological stability.

Measuring scarcity. Market prices indicate little about biophysical scarcity of resources. They only reflect the scarcity of the commodity on the market. For example, the gasoline price tag tells us more about how expensive it is to get the liquid out of the ground and shipped around the world, than how much is left. In spite of declining forests, drying-up oil wells, loss of topsoil and lowering water tables, resource prices are dropping -- at least for people living in countries with strong currencies. The reason is simple: harvest, extraction and shipping technologies are getting cheaper and more powerful. Accessing the resource stocks becomes easier while they are actually shrinking. Furthermore, by relying on the monetary assessments, the analysis gets one step farther removed from reality and may become less sensitive for time lags and non-linear effects, both characteristic for human and ecological systems. Therefore, relying solely on monetary information keeps us in the illusion of ecological cornucopia. However, the opulent lifestyle can only be temporary, accumulating ecological debts. It is like money in the bank: easier access to our saved capital does not make our capital produce more -- rather, we'll exhaust it faster. Biophysical accounts can give us a more realistic picture of our state of wealth. Ecological footprint measures, for example, show nation's natural capital stock, and the flow (or "interests") it can produce.

Counting our wealth. Wealth of nations is a core issue of economics. However, by focusing solely on monetary wealth and disregarding the value of natural capital, these conventional measures become misplaced. If we count our personal and national monetary wealth with such obsession, precision and sophistication, it is hard to understand the feeble efforts for taking nature's assets into account. We should be even more obsessed with measuring our natural wealth, as it is this wealth which truly supports life. If we do not know how much our greatest assets are worth, or whether we are actually gaining assets, we will never know if we are sustainable.

Money footprints. The ecological impact of spending can be made visible. For example, the calculated numbers show the ecological capacity necessary to support the expenditure of one dollar, one pesos or one franc. For example, the average dollar (or six francs) spent in France corresponds to 3 square meters of biologically productive space occupied for one year. Of course not every dollar has the same impact. For example, one dollar of US gasoline bought in the United States occupies 13.5 square meters for one year[34]. In poorer countries, one dollar may have a larger footprint than in affluent countries as it can purchase more in comparison, but in return far fewer dollars are turned over.

Strategies to reduce our ecological footprint. Ecological footprints can be reduced by improving ecological productivity (e.g., terraces for agriculture on slopes, recycling of compost, careful management regimes), increasing the efficiency of resource use (e.g., energy saving light-bulbs, high-efficiency wood stoves, solar heated warm water) and reducing consumption (e.g., work less and spend less). Economists can use footprint and related assessments to evaluate which strategies and programs produce the highest benefits.

Redefining welfare and quality of life. Much economic research and many economics inspired policy recommendations build on the implicit assumptions that "economic growth = progress" and "consumption = quality of life". As we cannot build a sustainable future on these assumptions, and as there is little evidence that conventional economic growth leads to higher standards of living in lower income brackets, these concepts need to be rethought. The challenge of economics becomes finding ways to maximise quality of life while maintaining sustainable footprints.

f) Making business promoters of sustainability

Competitive advantage. Biophysical assessments are critical to making businesses become more competitive. In a time when products and their prices are becoming increasingly similar, product sustainability may determine the competitive advantage on the market. Among comparable products, the modern consumer will pick the more sustainable choice. Also for companies, sustainable production will reduce long-term costs and exposure to risks like pollution damage or resource exhaustion. Footprint based eco-labels could be an effective strategy to differentiate products. The companies introducing them first will achieve their product differentiation cheaper and more effectively than the followers.

Investing in sustainability. Ethical investments are fast growing in the world of finances. These investments are not only socially and ecologically more responsible, but remain often competitive compared to traditional investments. Production costs of the companies eligible for these investments may be higher, but their markets are also more favourable, and their social and ecological risks lower. Also, the future is on their side as the demand for their services is secured by future ecological scarcity. Green investors however require tools to detect investment opportunities and to screen their ecological performance. Biophysical assessments in a systems context become a viable means to distinguish between rhetoric and fact. They may come handy to empower investors to detect the companies that are part of the solution.

Business as leaders for sustainable development. With hardly any exception, conventional corporate greening and "environmental responsibility" have side-stepped measurable and meaningful improvements toward sustainability. To date no business has established a basis for assessing sustainability and declared its performance. Their indices, measures, conventions or codes of conduct have served only to increase the noise and obscure the signal. The result is crushed public confidence and little action. However, sustainable behaviour can be business driven if appropriate measures and ethics are applied. In fact, it can create a potential renaissance for business. Activities of benefit to the environment generally have lower social costs, which eventually will pay back for the company, its shareholders and society. These advantages of environmental leadership have been well elaborated by organisations like *The Natural Step*.[35]

Wasting waste. Tools like the ecological footprint to assess resource inputs and waste discharges can become valuable tools for managers to analyse business operations and technologies. Knowing in physical terms what enters and what leaves a business and its production processes helps detect unnecessary costs and untapped opportunities. It points to waste that could become a resource and to resources that are squandered. It also assists the planning of ecologically sounder production and business operations.

No planet, no profit. The ecological footprint is an indicator of sustainability and risk, globally and locally. It shows where humanity needs to improve and where innovation will be required. This can be of strategic value for businesses thinking about the next generation of their technology and service innovations. In this way they can use systems knowledge to evaluate risks and economic success much like the principles of backcasting advocated by *The Natural Step* pedagogy which opens new opportunities for business development by adding value through sustainability. In this way businesses can secure their economic success and become leaders for sustainable development.

We have shown: sustainability can be measured. The ecological footprint indicates clearly where we are and where we need to be. Now we can evaluate which projects and programs can get us there. Assessments as presented here can give direction for local, national and global efforts to close the sustainability gap. They become an effective strategic planning tool and a guidepost for a more secure, equitable and sustainable future.

Measuring Progress toward Sustainability

© ***Hazel Henderson***
independent global futurist
author of Building a Win-Win World *(1996)*
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This report takes the methodology of Ecological Footprint Analysis (EFA) to a new level of sophistication. The data on which the report is based are the most credible official sources, from the U.N. and its many special agencies to the business-oriented World Economic Forum and major academic institutes. This will allow for continuous updating and cross-country comparisons so necessary for future reports. The quantitative basis of this report will sharpen the debate between economists and natural scientists over appropriate criteria for measuring "productivity".

This vital debate has been difficult and halting since it has involved sharply differing paradigms and underlying assumptions as I discussed in the *Harvard Business Review* (1968, 1971, 1973). Economics, while not a science, became arguably the most powerful of professional disciplines together with law, since, they explained and ratified the evolution of industrialism and its enormous flowering of inventions and entrepreneurship over the past 250 years. This industrial and technological revolution was underpinned by developing the doctrine of the Scientific Enlightenment: individual and property rights and the philosophy of human material progress. For example, "merchant venturers" were chartered (today's limited liability chartering of corporations) and the institution of markets as a social space for free exchange of goods and services.[36] This regime, governed by the legal structures of private property and free markets allowed the rise of corporations which today are global in scope. Economists and lawyers became the professional custodians and adjudicators of these free markets that are spreading rapidly world-wide and protected in such trade agreements as NAFTA, GATT, and now institutionalized in the World Trade Organization (WTO).

While law and economics became relatively more powerful with the spread of free markets, the natural and life sciences had somewhat different constituencies. Physics, math, and much of engineering and material sciences became tools of Cold War military policies; microbiology spawned and now serves powerful new industrial biotechnology sectors, while botany and ecology for many years remained descriptive more than instrumental -- often short-changed in Cold War funding contests. All this began to change in the 1970s with the birth of popular environmental movements world-wide. Citizens, consumers, and traditional sectors outside the official money economy were often on the receiving end of policies maximizing production measured by economists as GNP-growth: those "externalities" that economists' models had previously excluded, i.e. pollution, resource depletion, desertification, and the loss of biodiversity.

The first truly ecological economist was British chemist Frederick Soddy, who shared the Nobel Prize with Edward Rutherford for discovering isotopes. I described in *Politics of the Solar Age* (1981, 1988) how Soddy tried to engage the economics profession of this day with his *Cartesian Economics*, published in London in 1913. Soddy pointed out that all economic value came from solar energy: those free incoming photons which plants and other biota inhabiting land and sea captured via photosynthesis. Soddy was ridiculed by the more powerfully organized economics profession, whose banking and corporate clients were based on fossil fuels and resource extraction.[37] Few other natural scientists attempted the task of challenging the power of the economics profession until Nicholas Georgescu-Roegen (Herman Daly's teacher) published his monumental *The Entropy Law and the Economic Process* [38] Georgescu-Roegen, natural scientist and economist, demolished economics' deductive assumptions and erroneous models in a mere three chapters of this paradigm-shifting work.[39] Georgescu -Roegen was isolated and vilified just as Soddy had been and suffered a similar fate to that of Rachel Carson, whose *Silent Spring*, in 1962 had ignited the environmental movement. Like Soddy before them, both died discredited and in obscurity.

These early foundations of Ecological Footprint Analysis (EFA) were further augmented by Eugene F. Odum in the 1960s (my fellow member of the Advisory Council of the U.S. Office of Technology Assessment from 1974 to 1980) and his brother, Howard T. Odum, who published *Environment, Power and Society* in 1971. I studied at the University of Florida in 1972 (along with Robert Costanza, Chair of the International Society of Ecological Economics) the Odums' concepts of energy accounting and "eMergy" (the energy embodied in products and services throughout their life cycle from extraction to waste). I compared these natural science methodologies for more accurately assessing productivity with the global modelling of Jay Forrester's Systems Dynamics Group at the Massachusetts Institute of Technology. It was clear that such methods could lead to multi-disciplinary approaches to understanding what was then called "the global problematique" -- essentially all the issues of human population and planetary carrying capacity we face today.

The EFA methodology is soundly constructed on all this pioneering work, as well as that of the social and ecological indicators movement.[40] Such multi-disciplinary efforts to expand policy tools and correct Systems of National Accounts (SNAs), include the Human Development Index (HDI), published by UNDP annually since 1991, and Herman Daly and John Cobb's ISEW and its versions in Europe and North America. My own approach, Country Futures Indicators[sm] (CFI), is unbundled and multi-disciplinary and does not rely on a macro-economic framework as do HDI and ISEW. The first version of CFI for the U.S.A. will be released in 1997 as the Calvert-Henderson Quality-of-Life Indicators with the Calvert Group, Inc. of Washington, DC, managers of socially responsible mutual funds.

Clearly, economics is too narrow and flawed a framework to deal with carrying capacity, since technology is too often assumed as given, and that technological substitution will somehow continue to be called forth "at the right price." Absolute scarcity is therefore deemed remote and unlikely, Macro-economics is also too reliant on such concepts and assumes general equilibrium. SNAs will remain an unsuitable framework for weighting broader ecological data and social "value" issues that lie beyond markets. Thus, many supplemental analyses, including EFA are vital. For example, economics still holds that there is an iron trade off between efficiency and equity (fairness). Both ecologists and the new studies in economics come to the opposite conclusion.[41] Environmentalists for Full Employment, a movement of U.S. environmentalists which I co-founded in 1975, also showed that a full employment society would tend toward less resource intensity and waste. The group's Employment Impact Statements were an early forerunner of today's debate about shifting tax codes from incomes and payrolls to resource depletion and pollution. All this clearing out of old intellectual underbrush is now proceeding rapidly. Evidence of the world-wide effects of pursuing economists' dreams of GNP-growth become incontestable in today's visible losses of forests, top soil, biodiversity, and ozone, as well as in the build up of atmospheric CO_2.

Yet bastions of old economic orthodoxy do not yield easily, particularly at the central banks, the International Monetary Fund, and the World Bank. Even when knowledgeable international financier, George Soros, commented on the dangers of unrestrained free markets and today's unstable financial system ($1.3 trillion of currencies sloshing around the planet daily, 90 percent of which is speculation), in the *Atlantic Monthly* (February, 1997), the London-based *The Economist* magazine ridiculed him as "confused", "hallucinating", "ignorant" and "full of errors".[42] Today's capital asset pricing models (CAPMs) still ignore social and environmental costs, yielding sub-optimal and often irrational investment decisions, particular in the energy and transportation sectors of the world's economy.

The WTO's economists can not see that including social and environmental costs into their analyses and systems of national accounts would not only reveal true costs of investments, but also reduce the irrationality of much of today's world trade. Simply shipping similar goods back and forth around the world at subsidized energy and transportation costs is highly entropic -- rather than efficient of productive. Likewise, WTO rules that ban eco-labelled products on the basis of their manufacturing process (the real key to improved efficiency) must be informed by data from the natural sciences, such as that in EFA. When economic and thermodynamic calculations are finally aligned, we will see that many local, provincial, and regional efficiencies of scale in production and distribution were correct after all. EFA now joins with other multidisciplinary policy tools such as technology assessment, and social and environmental indicators. All are helping to chart the paths of human development toward sustainability.

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GLOSSARY

appropriated carrying capacity is another name for the ecological footprint. "Appropriated" signifies captured, claimed or occupied. Ecological footprints remind us that we appropriate ecological capacity for food, fibres, energy, waste absorption etc. In industrial regions, a large part of these flows is imported.

biological capacity refers to the total of the biologically productive areas. See also "biologically productive areas".

biologically productive areas are those areas of a country with quantitatively significant plant and animal productivity. We summarise the biologically productive areas of a country as its biological capacity. Arable land is the potentially most productive area.

ecological deficit of a country measures the amount by which their footprint exceeds the locally available ecological capacity.

ecological footprint is the land and water area that is required to support indefinitely the material standard of living of a given human population, using prevailing technology.

ecological remainder or remaining ecological capacity. Countries with footprints smaller than their locally available ecological capacity are endowed with an ecological remainder -- the difference between capacity and footprint. Today in many cases, this remainder is occupied by the footprints of other countries (through export production). See also "ecological deficit".

embodied energy of a commodity is the energy used during its entire life cycle for manufacturing, transporting, using and disposing.

hectare is 10,000 square meters or 100 times 100 meters. One hectare contains 2.47 acres.

locally available capacity is the part of the locally existing ecological capacity that is available for human use. The remaining part should be left untouched for preserving biological diversity. In this report, we calculate the available capacity by subtracting 12 percent from the existing capacity, as suggested by the Brundtland Report.

locally existing capacity refers to the total ecological production that is found with in the country's territories. It is expressed in hectares with world average productivity.

natural capital refers to the stock of natural assets that yield goods and services on a continuous basis. Main functions include resource production (such as fish, timber or cereals), waste assimilation (such as CO_2 absorption, sewage decomposition) and life support services (UV protection, biodiversity, water cleansing, climate stability).

overshoot, according to William Catton, is "growth beyond an area's carrying capacity, leading to crash."

photosynthesis is the biological process in chlorophyll-containing cells that convert sunlight, CO_2, water, and nutrients into plant matter (biomass). All food chains which support animal life -- including our own -- are based on this plant matter.

productivity is measured in biological production per year and hectare. A typical indicator of biological productivity is the biomass accumulation of an ecosystem.

waste factors (used in the round wood calculations) give the ratio of cubic meter of round wood used per cubic meter (or tonne) of product.

yield adjusted area refers to the biologically productive space expressed in world average productivity. It is calculated by multiplying the physically existing space by the yield factors.

yield factor is the factor by which the country's ecosystems are more productive than world average. A yield factor of 0.5 indicates that local productivity is only half of the global average. The footnotes in "ef-world.xls" explain how each is calculated.

NOTES

[1] Additional copies can be obtained from the *Earth Council* in Costa Rica, e-mail: eci@terra.ecouncil.ac.cr, fax: (++506) 255-2197.

[2] United Nations Development Programme (UNDP), annual. *Human Development Report*. New York: Oxford University Press. World Resources Institute (WRI) *et al*., bi-annual. *World Resources*. New York: Oxford University Press. Worldwatch Institute, annual. *Vital Signs* and *State of the World*, New York: W.W. Norton.

[3] Mathis Wackernagel and William E. Rees, 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth*. Gabriola Island, BC: New Society Publishers, ISBN 1-55092-521-3. Also available in Italian through Edizioni Ambiente, Milan, and in German through Birkhäuser Verlag, Basel.

[4] Two countries of the World Economic Forum's *Global Competitiveness Report 1996* are missing in our analysis: Luxembourg and Taiwan as they do not appear in UN statistics.

[5] For information consult: Howard Odum, 1994. *Ecological and General Systems*, revised edition. Boulder: University of Colorado Press. John Holdren and Paul Ehrlich, 1974. "Human Population and the Global Environment." *American Scientist*. Vol.62. p282-292., ; Donella Meadows, Denis Meadows, Jørgen Randers and W. Behrens, 1997. *Limits to Growth*, New York: Universe Books. Donella Meadows, Denis Meadows, and Jørgen Randers, 1992. *Beyond the Limits*. Toronto: McClelland & Stewart Inc., Toronto. Meadows 1972/1992, Robert H. Whittaker, 1975. *Communities and Ecosystems*. New York: MacMillan Publishing. Helmuth Lieth and Robert Whittaker (eds.), 1975. *The Primary Productivity of the Biosphere*. New York: Springer. S. Abel, A. Braunschweig and R. Müller-Wenk, 1990. Methodik für Ökobilanzen auf der Basis ökologischer Optimierung (Methodology for life cycle analysis based on ecological optimization). Bern: Bundesamt für Umwelt, Wald und Landschaft. Schriftenreihe Umwelt, Vol. 133). Sustainable Netherlands, Friends of the Earth. Peter Vitousek *et al*.. MIPS (Friedrich Schmidt-Bleek and the Wuppertal Institute), Christian Krotscheck and Michael Narodoslawsky, 1996. "The Sustainable Process Index: A New Dimension in Ecological Evaluation". *Ecological Engineering*, Vol.6 p241-258. Carl Folke *et al.*, 1996. "Renewable Resource Appropriation by Cities." in Robert Costanza et al., 1996. *Getting Down to Earth*. Washington DC: Island Press.

[6] Listing the ecological space for CO_2 absorption separately from biodiveristy preservation and forests does not imply double counting. For absorbing large quantities of CO_2, recently reforested areas or immature forests are necessary. Older forests only absorb significantly less CO_2. These "new" forests, in contrast, do not have the "old" biodiversity. Also, CO_2 absorbing forests can not be used for timber production, as this would release the gases again. However, these CO_2 absorbing spaces can provide other simultaneous functions such as water regulation, soil building and erosion prevention.

[7] David and Marcia Pimentel, 1996. *Food, Energy and Society*, revised edition. Niwot, Colorado: University Press of Colorado. p. 293.

[8] David and Marcia Pimentel, 1996, (see above).

[9] Yoshihiko Wada, 1993. *The Appropriated Carrying Capacity of Tomato Production: The Ecological Footprint of Hydroponic Greenhouse versus Mechanized Open Field Operations*. Vancouver: M.A. Thesis at the UBC School of Community and Regional Planning.

[10] George Cox and Michael Atkins, 1979. *Agricultural Ecology: An Analysis of World Food Production Systems*. W.H. Freeman: San Francisco, p. 571. Daniel Pauly and Villy Christensen, 1995. "Primary production required to sustain global fisheries." *Nature*. Vol.374. Yoshihiko Wada, 1996. "The Concept of Ecological Footprints and Its Application to Japan: Is Japanese Consumption Sustainable?" *Manuscript for a presentation at the Spotlight on Asia Symposium.* Vancouver, B.C., Canada. Yoshihiko Wada, 1995. "Ecological Footprint of Consumption of an Average Japanese -- (Aquatic Area)", University of British Columbia, unpublished.

[11] The World Commission on Environment and Development. *Our Common Future*. Oxford: Oxford University Press, 1987. p.147, p.166.

[12] Many ecologists believe that a much larger percentage of the world's ecosystems needs to be preserved in order to secure biodiversity. For example, in 1970 ecologist Eugen Odum recommended in the case of the state of Georgia that 40 percent of the territory remain as natural area, while 10 percent be ceded to urban-industrial systems, 30 percent to food growing and 20 percent to fibre production (1970). Wildlife ecologist and scientific director of the Wildlands Project, Reed Noss, hypothesised that about 50% of an average region needs to be protected as wilderness (or equivalent core reserves and lightly used buffer zones) to restore populations of large carnivores and meet other well recognised conservation goals (1991a, 1991b). Reed Noss and Allen Cooperrider, after reviewing several studies, concluded that most regions will need protection of some 25 to 75 percent of their total land area in core reserves and inner buffer zones. All that assuming that this acreage is distributed optimally with regard to representation of biodiversity and viability of species, and well connected within the region and to other reserve networks in neighbouring regions (1994). For perspective, the United States claims

that 10 percent of the land area is in specially-protected areas, of which 90 percent is in national parks. When areas of moderate to high human activity is eliminated from this figure, the area of protected land drops to less than 3 percent. The areas referred to above include a system of core areas of minimal human activity and surrounding buffer zones of progressively greater human activity. For more detailed discussion see Reed F. Noss, 1991a. "From endangered species to biodiversity", pages 227-246, in K.A. Kohm, ed., 1991. *Balancing on the Brink of Extinction: The Endangered Species Act and Lessons for the Future*. Washington, DC: Island Press. Reed F. Noss, 1991b. "Sustainability and wilderness." *Conservation Biology*: p120-121. Reed F. Noss and Allen Y. Cooperrider, 1994. *Saving Nature's Legacy - Protecting and Restoring Biodiversity*. Washington DC: Island Press. Eugene P. Odum, 1970. "Optimum population and environment: A Georgia microcosm." *Current History* 58:355-359.

[13] Based on 1993 world population, there existed 2.07 hectares biologically productive area per person worldwide (For details consult the spreadsheet file "ef-world.xls" on the attached disk. This file calculates the ecological footprint of all humanity). With the 1997 world population and assuming optimistically the same biologically productive area, there is only 1.94 hectares per capita left today. Subtracting from this 12 percent for biodiversity preservation, we get ((1 - 0.12) x 1.94 =) 1.71 hectares per capita that are available for human use.

[14] By the time this report appears, 1994 data should be available. Typically, there is a time lag of over two years until UN data is published. For a few countries, only 1992 data was available. Also a few subcategories in the calculations use 1992 data.

[15] All the main sources used in this document stem from United Nations documents. The codes in the spreadsheets' reference columns point to the documents used. The first number of the reference code indicates the data source, the second the page and the third the classification number within the data source. The data sources are (1): United Nations, 1995. *1993 International Trade Statistics Yearbook*. Vol. 1. New York: Department for Economic and Social Information and Policy Analysis, Statistical Division. (2): United Nations Conference on Trade and Development (UNCTAD), 1994. *UNCTAD Commodity Yearbook 1994*. New York and Geneva: United Nations. (3): Food and Agriculture Organization of the United Nations (FAO), 1995. *FAO Yearbook: Production 1994, Vol. 48*. Rome: FAO. (4): Food and Agriculture Organization of the United Nations (FAO), 1994. *FAO Yearbook: Trade 1993, Vol. 47*. Rome: FAO. (5): Food and Agriculture Organization of the United Nations (FAO), 1995. *FAO Yearbook: Forest Production 1993*, Rome: FAO. (WRI): World Resources Institute, 1996. *World Resources 1996-1997*. Washington DC: World Resources Institute, UNEP, UNDP, The World Bank. Food and Agriculture Organization of the United Nations (FAO), 1995. *State of the World's Forests*, Rome: FAO. "-est" means that the number is estimated, either by extrapolating from subcategories, or by using price/weight ratios from other countries.

[16] The report includes a DOS compatible 3.5 inch disk with the compressed spreadsheet files of all these calculations in Excel format Version 4.0. Each country is presented in its own file. Instructions for decompressing the files can be found in "read.me" on the same disk.

[17] In the line description, capitalized names stand for main categories. Line description with a dot (".") in front indicate subcategories. Two dots ("..") means sub-subcategory. Where ever possible, the most general categories were used. These categories and subcategories are identified by **bold** print.

[18] Most world average productivities are taken from: Food and Agriculture Organization of the United Nations (FAO), 1995. *FAO Yearbook: Production 1994, Vol. 48*. Rome: FAO. Productivity of animal products are calculated from FAO world production figures, and weighed according to their conversion efficiencies. The world average productivity of forests we estimated from various FAO publications and studies. Both animal and forest productivities are explained in the footnotes of the spreadsheet file "ef-world.xls". For rubber and jute we extrapolated Vietnamese data (Government of Vietnam, http://www.batin.com.vn/10years/indplant/). Cotton productivity is taken from Nick Robins *et al*., 1995. *Citizen Action to Lighten Britain's Ecological Footprints*, London: International Institute for Environment and Development, p64. Cocoa productivity is taken from Mexican yields. As explained in Wackernagel and Rees (1996, see above) fossil fuel is translated into land areas at the rate of 100 Gj/ha/year (CO_2 absorption), hydroelectricity at 1,000 Gj/ha/year (occupied land by dams and power lines).

[19] Please note that the files use the 1993 population, while Table 1 lists the 1997 population of each country.

[20] The calculation of each yield factor is explained in the footnotes of the Excel file "ef-world.xls" on the attached disk. Please note that the yield factors probably overestimate the biological productivity of industrialized countries with heavy fertilizer use. The yield factor for the sea remains 1 for all nations, as due to the international nature of the world's oceans we allocated sea space equally to all nations' citizens. For built-up land, the yield factor is equal to the one of arable land, as settlements are typically located on such land.

[21] In earlier publications (such as Wackernagel and Rees 1996), we compared the footprint to locally existing space, without adjusting it for its productivity. As also mentioned in these publications, this exagerates the ecological deficit for biologically highly productive countries.

[22] Population figures are taken from the World Resources Institute, 1996. *World Resources 1996-1997 Database*, Washington D.C.: WRI. file "hd16101.wk1".

[23] For both India and Pakistan, their terrestrial ecological capacity is only about 50 to 60 percent of their footprint on the land.

[24] Ernst Ulrich von Weizsäcker, Amory Lovins, Hunter Lovins. 1997. *Factor Four.* London: Earthscan.

[25] Wouter van Dieren (editor), *Taking Nature into Account*, Club of Rome Report, New York: Springer Verlag.

[26] United Nations Development Programme (UNDP), 1994. *Human Development Report 1994*. New York: Oxford University Press. p164-165.

[27] COED Communications, 1997. *Ecoquest: Reducing Our Ecological Footprint*. Toronto: Lever - Ponds and COED Communications. Mark DiMaggio, 1996. *The Ecological Footprint: a curriculum unit designed for high school students who wish to move their school and community towards a sustainable future* (to be published by the New Society Publishers, Gabriola Island). Various environmental courses in the US, Canada and Switzerland have started to measure their household's ecological footprint.

[28] See for example: Maria Buitenkamp, Henk Venner and Theo Wams (editors), 1992. *Action Plan Sustainable Netherlands.* Amsterdam: Friends of the Earth Netherands.

[29] Lester Brown *et al*., 1997. *State of the World*. New York: W.W. Norton.

[30] Herman Daly, 1993. "The Perils of Free Trade". *Scientific American*. Vol.269 No.5 (November 1993), p.56.

[31] Jeffrey Sachs and Andrew Warner, 1996, "Why Competitiveness Counts", in World Economic Forum, 1996. *The Global Competitiveness Report 1996*, World Economic Forum, Geneva. p.12.

[32] Robert Kaufmann, 1992 "A Biological Analysis of Energy", in: *Ecological Economics*, Vol.6 No.1 (1992): 35-56; Charles A. S. Hall, Cutler J. Cleveland and Robert Kaufmann, 1986. *Energy and Resource Quality*, New York: John Wiley & Sons.

[33] William Rees and Mathis Wackernagel, 1994. "Ecological Footprints and Appropriated Carrying Capacity: Measuring the Natural Capital Requirements of the Human Economy." in AnnMari Jansson *et al.* (ed.), 1994. *Investing in Natural Capital*. Washington D.C.: Island Press.

[34] One dollar buys in the US about one gallon of gas, which contains 135 Megajoules or 0.135 Gigajoule of energy. With the conversion factor of 100 Gj/ha/year, this translates into (10,000 m^2/ha x 0.135 Gj / 100 Gj/ha/year =) 13.5 square meters for one year.

[35] John Holmberg, Karl-Henrik Robèrt and Karl-Erik Eriksson, 1996. "Socio-Ecological Principles for a Sustainable Society," in: Robert Costanza, Olman Segura and Juan Martinez-Alier (editors), *Getting Down to Earth: Practical Applications of Ecological Economics*, Washington D.C.: Island Press 1996.

[36] Karl Polanyi, 1948. *The Great Transformation*, Boston: Beacon Press.

[37] Hazel Henderson, 1981. *Politics of the Solar Age*, Chapter 8, Doubleday, 1981; TOES books, 1988.

[38] Cambridge, Massacusetts; Harvard University Press, 1971.

[39] See Herman E. Daly, "On Nicholas Georgescu-Roegen's Contribution to Economics", *Ecological Economics*. (June, 1995), p. 149.

[40] Hazel Henderson, 1996 "What's Next in the Great Debate About Measuring Wealth and Progress?" *Challenge*, Vol.39 No.6.

[41] See, for example, Robert H. Frank and Philip J. Cook, *The Winner Take All Society*, Free Press, 1995.

[42] *The Economist* (January 25, 1997), p. 18.