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COMMENTARY

Measuring sustainable development — Nation by nation

Daniel D. Moran[a,b], *Mathis Wackernagel*[a,*], *Justin A. Kitzes*[a], *Steven H. Goldfinger*[a], *Aurélien Boutaud*[c]

[a]*Global Footprint Network, 312 Clay Street, Suite 300. Oakland, CA 94607-3510, USA*
[b]*LUMES, Lunds Universitet, Sölvegatan 10, Lund SE221-00, Sweden*
[c]*Ecole des Mines de Saint-Etienne, 158 cours Fauriel — F42023 Saint-Étienne Cedex 2 France*

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ABSTRACT

Sustainable development represents a commitment to advancing human well-being, with the added constraint that this development needs to take place within the ecological limits of the biosphere. Progress in both these dimensions of sustainable development can be assessed: we use the UN Human Development Index (HDI) as an indicator of development and the Ecological Footprint as an indicator of human demand on the biosphere. We argue that an HDI of no less than 0.8 and a per capita Ecological Footprint less than the globally available biocapacity per person represent minimum requirements for sustainable development that is globally replicable. Despite growing global adoption of sustainable development as an explicit policy goal, we find that in the year 2003 only one of the 93 countries surveyed met both of these minimum requirements. We also find an overall trend in high-income countries over the past twenty five years that improvements to HDI come with disproportionately larger increases in Ecological Footprint, showing a movement away from sustainability. Some lower-income countries, however, have achieved higher levels of development without a corresponding increase in per capita demand on ecosystem resources.

1. Introduction

The foundations of international development were laid after the end of World War II with the goals of alleviating poverty, reducing inequality, and improving the global standard of living (Truman, 1949). In 1987, the UN-mandated World Commission on Environment and Development (the Brundtland Commission) responded to an emerging recognition that the human economy was stressing global ecosystems. The Commission affirmed the importance of development which "extends to all the opportunity to fulfil their aspirations for a better life." At the same time, it emphasized that this development must be "within the bounds of the ecologically possible," or what they call within "the world's ecological means." They called for sustainable development "that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCSD, 1987).

An action plan for sustainable development, called Agenda 21, was launched in 1992 at Rio's Earth Summit (World Summit on Environment and Development), and more recently, the UN Millennium Development Goals, adopted in 2000,

* *Corresponding author*. Fax: +1 510 251 2410.
E-mail address: mathis@footprintnetwork.org (M. Wackernagel).

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called on all countries to integrate the principles of sustainable development into national policies and programs.

How can a country that has accepted the sustainability challenge determine if it is making progress toward sustainable development? Measurements are needed. These indicators must not only reflect changes in quality of life, but must also show if these changes are compatible with the planet's current ecological limits. While a precise and complete definition of sustainability may be elusive (Carter, 2001), it is possible to define measurable bottom-line conditions for both human development and ecological sustainability. Following Boutaud (2002) in this study we use the UN Human Development Index (UNDP, 2005) (HDI) as an indicator of development and the Ecological Footprint (Rees, 1992; Rees and Wackernagel, 2004; Wackernagel and Rees, 1996; Wackernagel et al., 2002, 2005) as an indicator of sustainable consumption. Using a pair of indicators which a) are based on specific research questions (rather than more general or subjective indices) and b) separately evaluate ecological sustainability and human development offers a potentially more meaningful evaluation of progress and trade-offs than would be possible using either the HDI or Footprint on their own. This approach also improves upon using any single indicator, such as the Environmental Sustainability Index (Esty, 2005), which attempts to measure both factors together by applying yet a third set of criteria.

This analysis of sustainable development using the HDI and the Ecological Footprint highlights the reality of the limited biological carrying capacity of the planet. This is a real constraint not often emphasized in other development assessments. The neoclassical paradigm for sustainable development, as advanced by figures such as Lomborg (2001), tends to treat natural resources as limitless and advances a version of 'weak' sustainability in which manmade capital can fully substitute for natural capital. The Millennium Development Goals strongly emphasize human development but do not directly address how a growing global population with growing resource demands will share the planet's finite resources. The Ecological Footprint and HDI represent strict, yet widely accepted, metrics for ecological sustainability and human development.

2. Methods

We examine sustainable development in terms of its two dimensions. We assess progress in development with the UN Human Development Index (HDI) because it is one of the most widely used overall measures of human well-being. The other dimension of sustainable development is the commitment to develop within the ecological capacity of planet Earth. This can be measured with the Ecological Footprint, a resource accounting tool that assesses how much of the regenerative capacity of the biosphere is occupied by human activities. We compare the changes in these two indicators between 1975 and 2003.

2.1. *Human development index*

The UNDP Human Development Index (HDI), a widely used measure of national development, captures how conducive conditions are for residents of a country to enjoy long, healthy, and creative lives. The HDI is a widely referenced and globally available proxy metric for progress toward human development goals, as reflected for example in the Millennium Development Goals. A country's HDI is a composite of four sub-indicators: life expectancy at birth, adult literacy rate, gross school enrolment ratio, and GDP per capita (UNDP, 2004). This measure is often used as a complementary metric along with more traditional indicators such as GDP, which reflects purely economic development.

An HDI value of 1.0 implies that a country has achieved the maximum value for each sub-index, and a value of zero implies that the country is at or below the minimum value for all sub-indices. The United Nations Development Programme (UNDP) defines an HDI score of 0.80 as the limit between medium and high human development. In 2003, countries with an HDI of 0.80±0.02 included Mexico, Brazil, Libya, Romania, and the Russian Federation. Nearly all OECD countries have HDIs above 0.8, and it is unlikely that any high-income nation, or urban professionals anywhere, would welcome an HDI less than 0.80 as an acceptable standard of living. Table 1 shows the HDI of selected nations, including those with the highest and lowest scores in 2003.

Table 1 – HDI and ecological footprint of selected countries (2003 data)

Country	HDI	Ecological demand per capita	
		Ecological footprint (gha/cap)	Footprint to global biocapacity ratio [a]
Norway [b]	0.96	5.9	3.2
UAE [c]	0.85	11.9	6.5
Panama	0.80	1.9	1.0
India	0.60	0.8	0.4
Bangladesh [c]	0.52	0.5	0.3
Niger [b]	0.28	1.1	0.6

[a] This ratio shows how much larger the per capita demand on resources is as compared to the per capita biocapacity available worldwide. It represents the number of planet Earths that would be required to support the current population at that country's level of consumption (assuming no biological productivity is reserved for the use of for wild species.).
[b] Highest and lowest HDI score of reported countries.
[c] Highest and lowest ecological footprint per capita of reported countries.

2.2. *Ecological footprint and biocapacity*

Humans are part of the biosphere and use resources and services from it. A necessary condition for sustainability is that society metabolizes resources into waste no faster than the biosphere can convert this waste back into resources. If humanity overtaxes the biosphere's regenerative capacities, natural capital is being liquidated and wastes accumulate. Development and resource use can therefore be sustainable only if, over time, their demand on nature stays within the regenerative capacity of the planet. The recent Millennium Ecosystem Assessment (2005) found that human use is degrading 60% of the planet's ecosystem services. Avoiding ecological overshoot is a minimum, not a sufficient, condition for ecological sustainability.

The Ecological Footprint measures how much of the regenerative capacity of the biosphere is used by human

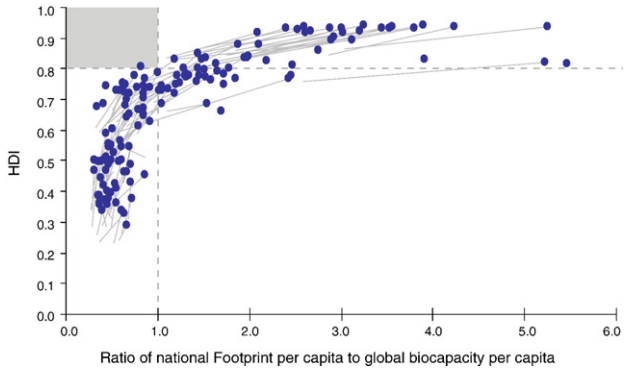

Fig. 1 – National Trends in Sustainable Development, 1975–2003. National development (HDI) versus resource demand (Footprint to biocapacity ratio, or more precisely the ratio of national per capita Ecological Footprint to globally available per capita biocapacity). Points indicate values for 2003, and grey trailing lines show trends from 1975 to 2003. The shaded box represents a domain where both points meet our suggested minimum criteria for 'sustainable development' (HDI≥0.8, Footprint to biocapacity ratio≤1.0).

activities. It does so by calculating the amount of biologically productive land and water area required to support a given population at its current level of consumption and resource efficiency (Ceballos et al., 2005; Monfreda et al., 2004).[1] A country's Footprint is the total area required to produce the food, fibre and timber that it consumes, absorb the waste it generates, and provide area for its infrastructure. Ecological Footprint accounting looks only at present or historical consumption. Future reductions in resource use (by any means, both efficiency improvements and reduced consumption) will shrink the per capita Footprint, while rising consumption and more extensive land use will expand it. In contrast to the Footprint, which addresses demand on ecosystems, biocapacity describes the supply side—the productive capacity of the biosphere and its ability to provide a flux of biological resources and services useful to humanity.

A large body of literature exists examining the strengths and shortcomings of the Ecological Footprint approach (Chambers, 2001; Costanza, 2000; Kitzes et al., 2007; Rees, 2006). Yet despite acknowledged limitations, judging from the vast number of references on websites, government reports and academic publications, the Ecological Footprint remains a leading biophysical accounting tool for comparing present aggregate human demand on the biosphere with the Earth's gross ecological capacity to sustain human life. Ecological Footprint accounts are built primarily on UN statistics, and where necessary complemented with publicly available data sets. The accounts do not attempt to correct these data.

Both Footprint and biocapacity are measured in global hectares (gha). A global hectare represents a hectare of land with world average bioproductivity. In 2003, the global per capita Footprint was 2.2 gha, and the per capita Footprint of nations with available data ranged from 0.5 gha/cap in Bangladesh to 11.9 gha/cap in the United Arab Emirates. In 2003, globally available biocapacity was 1.8 gha/cap. This represents a significant decrease from 3.4 gha/cap of available biocapacity in 1961. This decline has been largely driven by population growth, which leaves less bioproductive area available per person as world population grows.

Comparing Footprint to biocapacity can provide a useful indicator of ecological sustainability. We calculate the ratio of national per capita Ecological Footprint to globally available per capita biocapacity. This measures the minimum number of Earth-equivalent planets that would be required to support the current human population if the given country's level of consumption were universal. The number of Earth-equivalents increases with rising global population and per capita consumption and decreases with growth in resource efficiency and total available biocapacity (Ehrlich and Holdren, 1971).

An Earth-equivalents ratio above 1 indicates global overshoot, a condition in which ecological goods and services are consumed at a rate beyond the biosphere's regeneration rate. The ecological deficits resulting from overshoot will, if continued, erode the natural capital providing these resources. At a minimum, sustainability requires the avoidance of global overshoot, or a Footprint to biocapacity ratio no greater than 1. Thus a ratio ≤1 is a necessary minimum condition for sustainability. Local degradation is still possible at ratios below 1, and some research recommends that 11% to 50% of the biosphere be set aside for biodiversity reserves (Ceballos et al., 2005; Wilson, 2002).

According to Footprint calculations, humanity as a whole entered overshoot in the mid-1980's, and the worldwide ratio between humanity's Footprint and global biocapacity in 2003, the most recent year complete data is available, was 1.25.

We calculate the Earth-equivalents ratio for all nations for which data are available in 1975 (the earliest year for which HDI data are mostly available) and 2003. We compare this with

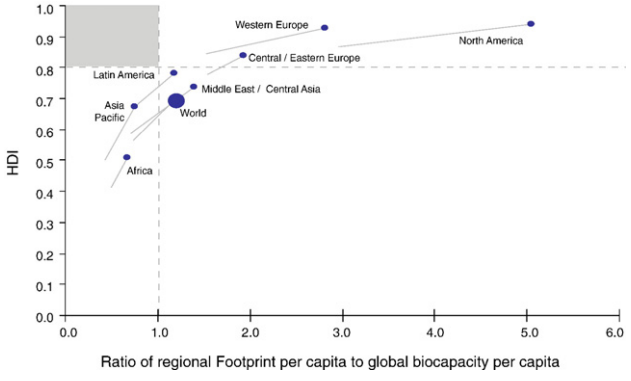

Fig. 2 – Global and Regional Trends in Sustainable Development. Regional and world development (HDI) versus resource demand (Footprint to global biocapacity ratio). Points indicate values for 2003, and grey trailing lines show trends from 1975 to 2003. The shaded box represents a domain where both points meet our suggested minimum criteria for 'sustainable development' (HDI≥0.8, Footprint to biocapacity ratio≤1.0).

[1] Ongoing methodological improvement and data updates are coordinated though Global Footprint Network (www.footprintnetwork.org) which is also facilitating the development of standards (www.footprintstandards.org).

HDI data from 2003 and from 1975 (except in the cases when HDI for 1975 is not reported, in which case we use the earliest reported HDI result). By comparing the HDI and Footprint and their changes over time we can capture how effectively countries are approaching sustainability. Historical HDI results are normalized by UNDP so that direct inter-year comparison is valid. Comparing national Footprints with global biocapacity does not presuppose a judgement about equal sharing of planetary resources, but rather indicates which nations have achieved consumption patterns that could be extended worldwide without leading to global overshoot.

3. Results

Fig. 1 illustrates the trends in HDI and the Earth-equivalents ratio between 1975 and 2003 for the 93 countries for which data are available. Countries for which data are available only for 2003 are depicted without trend lines. The full graph with identifiable data points for each country is available online (see Supplementary Information). Fig. 2 repeats this analysis at the regional and global level. Regional HDIs represent the population-weighted averages of the countries' HDIs.

Specifying an HDI$\geq$0.8 and a Footprint to biocapacity ratio $\leq$1 as thresholds for development and ecological limits, respectively, we find that in 2003, based data reported to the UN, only one country of the 93 surveyed (Cuba) met the two specified minimum requirements for development within a consumption pattern that could be extended globally without entering overshoot (Fig. 1). While we do not claim that the domain bounded by 0.8 HDI and 1.0 Footprint to biocapacity ratio represent sufficient conditions for sustainable development, we do propose that they are necessary conditions, i.e., that, at least as a global average, sustainable development must lie somewhere within this domain, not outside of it.

4. Discussion

Five factors determine the gap between the Footprint and biocapacity. Biocapacity is composed of the bioproductive area times the productivity of each hectare. One possibility is to increase, or at least maintain, biocapacity. This means protecting soil from erosion and degradation, and preserving cropland for agriculture. It involves protecting river basins, wetlands, and watersheds to secure freshwater supplies, and maintaining healthy forests and fisheries. It includes taking action to protect ecosystems from climate change and eliminating the use of toxic chemicals that degrade ecosystems.

The Footprint is a function of three factors: resource intensity in the production of goods and services; consumption of goods and services per person; and population size. If all else is held constant, increasing factor productivity or reducing either per capita consumption or population will shrink the Footprint and help reduce overshoot.

Efficiency gains can increase the amount of goods and services that can be produced from a given amount of ecological resources. On the other hand, the potential for reducing per person consumption depends in part on the person's income level. People living at or below subsistence may need to increase their absolute consumption level to move out of poverty. Wealthy individuals with large Footprints, however, could cut their consumption of goods and services without seriously compromising the quality of their lives. Further, population growth can be reduced and eventually reversed by supporting measures that lead to families choosing to have fewer children. Offering women better education, economic opportunities and health care is one proven approach. These factors can be used when analyzing each country individually to determine what have been driving factors in a country's ecological performance.

Overall, countries with the highest HDI currently have the highest Footprint to biocapacity ratios, and high income countries tend to show smaller increases in HDI with greater increases in Footprint to biocapacity ratio relative to lower income countries. This diminishing returns pattern is expected due to the bounded nature of the HDI index; the pattern also suggests that high income countries direct consumption toward improvements in quality of life not captured by HDI.

Between 1975 and 2003, only one out of 33 countries with an HDI greater than 0.8 decreased its Footprint to biocapacity ratio, suggesting that those high income nations have not been successful in moving their consumption patterns toward ones within ecological limits during this time frame. From 1975 to 2003, high income countries increased their Earth-equivalents ratio from 1.9 to 3.7.

At a larger scale, all regions showed increases in both average HDI and Footprint to biocapacity ratios between 1975 and 2003. In 2003, Asia Pacific and Africa met the minimum criteria for ecological sustainability, and Western Europe, Central and Eastern Europe, and North America met the minimum requirement for socioeconomic development. No region, however, met both criteria for sustainable development, and no regions showed a decrease in the Footprint to biocapacity ratio during this time period. The world as a whole entered ecological overshoot, as measured by the Ecological Footprint, during the time period surveyed here.

Only five countries (Burundi, Congo, Côte D'Ivoire, Malawi, and Uruguay) increased their HDI without increasing their Footprint to biocapacity ratio during this time period. Many low income countries, however, made significant improvements in their human development over the past quarter decade while maintaining a Footprint to biocapacity ratio smaller than one. Caution should be exercised when drawing lessons from countries with populations under one million people, as they are more likely to report incomplete data to the official datasets upon which the Ecological Footprint accounts are based.

In many cases, increasing affluence has worked against the aims of ecological sustainability. This phenomenon is particularly significant in light of a rapidly growing consumer class around the world (Myers and Kent, 2003). However, increasing affluence is by no means intrinsically incongruous with the goal of maintaining the health of the biosphere. Transitioning out of fossil fuels, encouraging resource efficient urban infrastructure, and providing support for people who are choosing to have smaller families are three demonstrated steps which can help make development sustainable (Myers and Kent, 2001). Further analysis of the drivers behind the observed development and sustainability trends is an area of

active yet insufficient research. Further analysis of the findings in this paper can serve as a next step in clarifying the challenges faced by the sustainable development agenda. One example of how this information can be broken down at the country level can be seen in Global Footprint Network's "Africa Factbook." (2006).

5. Conclusion

Measurable outcomes rather than intentions ultimately determine whether or not humanity follows a sustainable path. Quantitative measurements of human development and ecological sustainability are possible with currently available indicators. Contrary to claims that sustainable development is an evasive concept, this analysis shows that (a) minimum conditions for sustainable development can be measured, (b) overall, the sustainable development challenge, as defined by minimum conditions that are necessary but not sufficient, is not currently being met, and (c) national and regional trends are almost all moving away from sustainable development. These findings are obviously incongruent with current national and international sustainability goals.

While both metrics employed are approximations and do not cover the full spectrum of either human development or human pressure on the biosphere, they paint a clear picture. Some lower income countries are experiencing gains in human development without enlarging their Ecological Footprint. High income countries have exhibited the opposite trend, away from sustainability. While the world has achieved much socioeconomic development over the past thirty years, we find that much of this development has been fuelled by increasing demands on the biosphere.

Certainly, more complete indicators for measuring progress toward sustainable development are necessary. Still, the currently available indicators can track progress regarding social and ecological minimum conditions for sustainable development. They point out that a combination of ecologically sound development in low income countries and strong efforts to reduce demands on the biosphere in high income countries will be needed for humanity to secure people's well-being now and in the future, and they can monitor to what extent policies are producing these outcomes.

Appendix A. Supporting online material

A full dataset of results is available online at http://www.footprintnetwork.org/hdief.html.

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