Proceedings of 2012 Blue Planet Prize Commemorative Lectures

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CONTENTS

Professor William E. Rees (CANADA)

Professor, University of British Columbia,

FRSC (Fellow of the royal Society of Canada)

Dr. Mathis Wackernagel (Switzerland)

President, Global Footprint Network

Selection rationale: Developing and advancing the Ecological Footprint, a comprehensive accounting system for comparing human demand on ecosystems to ecosystems' capacity to self-renew. Their approach measures human carrying capacity and helps assess the risks of overconsumption to planetary stability.

Professor William E. Rees

Education and Academic and Professional Activities

1943	Born in Canada
1966	Graduated from the Department of Zoology, University of Toronto (Canada)
1969	Assistant professor, University of British Columbia (Canada)
1973	Received Ph.D. from the University of Toronto (Ecology and Ethology)
1976	Associate professor, University of British Columbia
1988-90	Founding Member, City of Vancouver Task Force on Atmospheric Change
1990	Professor, University of British Columbia
1994	Founding member, Canadian Society for Ecological Economics
1994-1999	Director, School of Community and Regional Planning (SCARP)
1997-1999	President, Canadian Society for Ecological Economics
2006 -	Founding member, One Earth Initiative (now a continuing Fellow and Member, Board of Directors), Fellow, Post Carbon Institute
2007-2009	Director, Centre for Human Settlements

Major Awards Received

1997	Killam Research Prize
2005	City of Barcelona 2004 Award (Multimedia Category) for the exhibition *Inhabiting the World* (10 February 2005) as member of winning team
2006 -	Fellow of the Royal Society of Canada (FRSC)
2007-2010	Pierre Elliott Trudeau Fellowship and Prize
2012	Honorary Doctorate, Laval University, Québec, (Canada)
	No 13 in the global (En)Rich List – top inspirational individuals whose contributions enrich paths to sustainable futures
	Kenneth Boulding Memorial Award in Ecological economics (jointly with Dr Mathis Wackernagel)

Dr. Mathis Wackernagel

Education and Academic and Professional Activities

1962	Born in Switzerland
1987	Graduated from the Swiss Federal Institute of Technology in Mechanical Engineering
1994	Received Ph.D. from The University of British Columbia (Canada) in Community and Regional Planning
1995-2001	Coordinator, Centre for Sustainability Studies, Anáhuac University, Xalapa (Mexico)

1999-2003	Director, Indicators Program at Redefining Progress (San Francisco)
2003 onwards	Co-Founder and President, Global Footprint Network (with Susan Burns) (Oakland, USA; Brussels, Belgium; Geneva, Switzerland)
2011 onwards	Guest professor, Cornell University

Major Awards Received

2005	Herman Daly Award (Society for Ecological Economics)
2006	World Wide Fund for Nature Award for achievements in environmental conservation
2007	Skoll Award for Social Entrepreneurship (with Susan Burns);Honorary Doctorate, University of Bern
2008	Gulbenkian International Award (with Global Footprint Network)
2011	Zayed International Prize for the Environment
2012	No 19 in the global (En)Rich List – top inspirational individuals whose contributions enrich paths to sustainable futures Kenneth Boulding Memorial Award in Ecological Economics (jointly with Dr William Rees)

William Rees and Mathis Wackernagel are the co-developers of Ecological Footprint analysis, a resource accounting framework for determining human demands for biophysical productivity (biocapacity) relative to the regenerative capacity of ecosystems. They produced the first extensive regional application of the method as part of their participation in the University of British Columbia's Task Force on Healthy and Sustainable Communities—of which Professor Rees was co-Chair—in the early 1990s. (This research program provided the case study for Wackernagel's doctoral dissertation.)

Rees has been continuously involved in refining and applying Ecological Footprint analysis to sustainability analysis throughout most his career at that university. Various graduate students under his tutelage have used integrated material flows analysis and Ecological Footprint analysis to assess the impacts of cities, countries, and numerous individual economic activities from greenhouse vegetable production, through net-pen salmon farming and air transportation to global trade, and have subsequently gone on to establish outstanding academic careers. His current students continue to apply and refine Ecological Footprint analysis in studies of both urban sustainability/vulnerability and the negative biophysical implications of globalization. Prof. Rees has authored or co-authored hundreds of scientific papers, book chapters, and popular articles on Ecological Footprint analysis, human carrying capacity, and related topics. He has lectured by invitation on areas of his expertise in 30 countries around the world. From 1994 to 1999 he served as Director of the School of Community and Regional Planning and led the reorientation of the School's mission statement and curriculum in support of 'planning for sustainability'. He is also a policy and science advisor to Global Footprint Network since its inception in 2003, and has actively supported Global Footprint Network in leading a worldwide effort to make the Footprint an ever-more robust measure of human demand on the biosphere.

Wackernagel completed his Ph.D. research, developing the Ecological Footprint, under Professor Rees in 1994. He then worked in Costa Rica with Maurice Strong's Earth Council and shortly after initiated a centre on sustainability studies at Anáhuac University in Xalapa (Mexico), where he furthered Footprint research. There, in 1997, he for the first time consistently calculated the Footprint and biocapacity for 52 countries using UN data sets. His research attracted a great deal of attention at the Rio+5 Conference in Rio. From 1999 to 2003, Wackernagel was the sustainability director of Redefining Progress, an economic think-tank in California. This experience encouraged him to co-found Global Footprint Network with Susan Burns in 2003 with the goal of raising the profile of Ecological Footprint analysis and making ecological limits central to decision-making. The Network has quickly grown into a major non-governmental organization with offices in Brussels (Belgium) and Geneva (Switzerland), in addition to its California headquarters. In 2012, it was identified as one of the top 100 NGOs in the world.

For the last 10 years, Wackernagel has contributed to WWF's bi-annual flagship publication "The Living Planet Report" which has become a key publication for Ecological Footprint results. The 2012 edition was released in May from the International Space Station, generating the largest media response of any Living Planet Report so far. The latest Global Footprint Network calculations show that humanity's demand for bio-resources exceeds the long-term regenerative capacity of Earth by over 50 percent.

Significance of impact

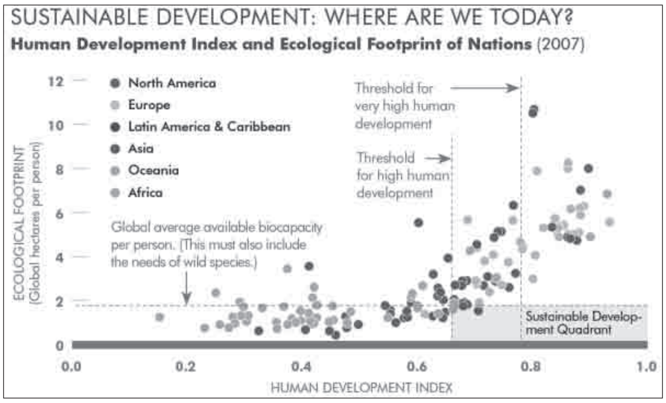
Ecological Footprint accounts enable, for the first time, systematic comparisons of human demand on nature to available supplies of nature's goods and services (i.e., biocapacity). The method can be applied to any population at regional, national or global scales. [1]Ecological Footprint analysts measure both demand and supply in terms of hectares of global average productivity. Hence, a population's Ecological Footprint is *the area of productive land and water ecosystems required, on a continuous basis, to produce the bio-resources that the population consumes and to assimilate its wastes, using prevailing technology*. One significant waste flow is the carbon dioxide from fossil fuel burning. Biocapacity is the productive ecosystem area that exists – in the world or in a region.

The Ecological Footprint is inversely related to carrying capacity: while traditional carrying capacity would ask "how many people could this area support at a specified material standard of living", Ecological Footprint analysis asks "how much area (biocapacity) is required to support this population *wherever on earth the relevant land and water ecosystems may be located.*" This approach accounts for both trade flows and reflects technological sophistication for the time that is being analyzed. As noted, Ecological Footprint analysis enables scientific determination of whether prevailing levels of bio-resource consumption by the particular population (or the entire human enterprise) exceed the long-term productive capacity of supportive ecosystems. In other words, it can reveal whether the population exceeds the carrying capacity of its domestic territory and other ecosystems at its disposal.

Because Ecological Footprint analysis has such serious implications for global development, both the general concept and specific features of the method have long been the subject of discussion and controversy in various academic journals and meetings around the world. For example, *Ecological Economics*, the official journal of the International Society for Ecological Economics, frequently publishes articles and book reviews on Ecological Footprint analysis and has run at least two special fora dedicated to debating the concept. Also the Stiglitz-Sen-Fitoussi commission of French President Sarkozy dedicated 15 pages of its report discussing and evaluating the Footprint.

The influence of Ecological Footprint analysis has, of course, spread far beyond the academic ivory tower. Because Ecological Footprint analysis represents human environmental demands in terms of personal consumption and a corresponding two-dimensional area of land and water, it is easy for the general public to relate to and understand. This has facilitated the application of the method around the world in numerous projects at a variety of spatial scales. In particular, the conceptual simplicity of Ecological Footprint analysis contributes to an increasing appreciation of the impossibility of sustaining ever-increasing material consumption on a finite planet. The notion that there may be biophysical limits to material growth is finally beginning to resonate with governments, international agencies and development-oriented NGOs alike, as it has serious implications for everyone, from the lowest income communities to the

[1] Ecological Footprint analysis can also be adapted to assess the ecological "load" imposed by specific economic activities, industries, or sectors.



Global sustainable development can be assessed by tracking development (or human wellbeing) and sustainability (does it fit within the means of one planet?). These two dimensions can be measured using UNDP's Human Development Index (HDI) as an indicator of human development, and the Ecological Footprint as a measure of human demand on the biosphere. An Ecological Footprint less than 1.8 global hectares per person makes those resource demands globally replicable. Despite growing adoption of sustainable development as an explicit policy goal, most countries do not meet both minimum requirements. Since every country contains different amounts of biocapacity, this analysis can also be adapted to each country. Also note that the world as a whole is outside the Sustainable Development quadrant.

highest net-worth individuals.

It follows that the Ecological Footprint enjoys a special role as a tool in environmental education. Many public and high-school text books feature chapters or illustrations of the method. Students and the general public can also make use of an on-line personal Footprint calculator, (originally produced for Earth Day Network), which is visited by over one million people per year.

Lagging behind the public, government agencies are now beginning to pay serious attention to Ecological Footprint analysis. As previously noted, numerous national governments have commissioned reviews to test the Footprint concept and at least seven, including the United Arab Emirates, Ecuador, Switzerland, Japan, Indonesia and Latvia, have incorporated the Footprint assessment into some of their policies.

Awareness of the Ecological Footprint is certainly spreading within the Japanese government. (Dr. Yoshihiko Wada, a colleague of Wackernagel and Ph.D. student of Rees, has been an active promoter of the concept in Japan and beyond). WWF Japan has published a prominent Ecological Footprint report. There is an Ecological Footprint Japan society. The Japanese Ministry of the Environment shows research results and policy agreements concerning Ecological Footprints in the 1996, 1999, 2001 and 2002 editions of its *Annual Report on the Environment (review);* since September 2000, Ecological Footprint specialists have taken part in a meeting for discussing procedures for trade liberalization and environmental impact assessment, held within the Ministry of the Environment; Ecological Footprint analysis is also cited in the environmental white paper of the Tokyo metropolitan government.

The Ecological Footprint also played a prominent role in the "Beyond GDP" initiative of the European Commission. During the conference in 2007, the commissioners mentioned only three progress measures by name: GDP, Human Development Index, and the Ecological Footprint.

But the Footprint is cited many more international fora, including in the Environmental Commission's report on the North American Free Trade Agreement (NAFTA) and in various United Nations agencies' reports. For instance, UNDP's *Human Development Report* is listing the Footprint as an indicator – as well as The Economist's *Pocket World in Figures*. Also the Convention on Biological Diversity proposes the Footprint as a biodiversity indicator – with plenty of documents on their site pointing to the Footprint.

The Ecological Footprint concept, developed by Drs. William E. Rees and Mathis Wackernagel, continues to gain popularity, momentum and credibility with sustainability analysts everywhere. Of course there is also sometimes resistance on the path, that's part of the program and an indication that the approach challenges people's thinking. Empirical observations on everything from climate change to fisheries collapse confirm daily the reality of the resource limitations and overshoot that have long been highlighted by Ecological Footprint analysis. And a comprehensive approach as proposed by the Footprint help people to make sense out of the complexity and guide action that truly resolve problems, rather than shifting them from one issue to the next.

There is little question that the method has succeeded in helping to re-open the debate on human carrying capacity. The stage is set for a renewed effort by the Global Footprint Network to convince ever more countries to adopt the Ecological Footprint as a key measure of well-being and sustainability. Data for Ecological Footprint assessment may well become as central to nations' national accounting systems as economic data are for GDP calculations today.

Carrying Capacity, Globalization and the Unsustainable Entanglement of Nations

Professor William E. Rees

Introduction: The Precarious State of the Planet

H. sapiens is the dominant species on Earth and the major geological force changing the face of the planet. The basic science of human-induced global change is undeniable – climate change, ocean acidification, fisheries collapses, land/soil degradation, desertification, tropical deforestation and biodiversity loss are just a few symptoms of wide-spread ecosystems degradation resulting from human activities.

The starting point for this presentation is that all such macro-ecological trends, whether characteristic of truly global systems (e.g., climate change, ocean acidification) or merely occurring simultaneously in ecosystems on several continents (e.g., desertification, biodiversity loss) are indicators that humans and their economies have exceeded the long term carrying capacity of Earth. The human enterprise is in a state of 'overshoot.'

This is not just another routine milestone along the road in the extended human journey. Overshoot is potentially catastrophic because systems science makes clear that: a) the behavior of ecosystems under stress is dominated by the complex interplay of positive and negative feedback and is typically non-linear and unpredictable; b) like other complex systems, ecosystems have multiple equilibrium states or stability regimes many of which may not be compatible with human purposes or survival; c) ever-increasing rates of exploitation will eventually force typical ecosystems over some previously unknown threshold (i.e., a 'tipping point') beyond which key components or the entire system may 'flip' into an unfamiliar stability regime; d) there is increasing evidence that such critical transitions or 'state shifts' can (and have) occurred at the planetary scale and; e) once such a shift has occurred it may be difficult or impossible to return the system from its new, potentially hostile stability regime to its previous human-compatible state (Holling 2001, Kay & Regier. 2001, Walker & Salt 2006).

Most significantly, Barnosky *et al*. (2012) argue that human population growth and rising material consumption, habitat transformation/fragmentation, energy production and consumption and climate change constitute global forcing mechanisms that all exceed in rate and magnitude, the forcings apparently responsible for the most recent 'natural' global-scale state shift, the last glacial–interglacial transition. Given the number and intensity of these forcings, they argue that "another global-scale state shift is highly plausible within decades to centuries, if it has not already been initiated" (Barnosky *et al*. 2012, p.57). In other words, human impacts on the ecosphere may well be sufficient to precipitate a whole-system transition that, in turn, could trigger the collapse of global civilization. Techno-industrial society would then suffer on a *global* scale what many earlier societies have brought upon themselves at the regional scale (Tainter 1988, Diamond 2005).

Humanity need not continue living under such a threat. Modern society has the scientific data, technological means and adequate resources to turn things around. These factors, combined with humanity's high intelligence and unique capacity for forward planning should be sufficient for the world community to implement a globally coordinated campaign to rescue civilization from ignominious chaotic collapse.

Is there intelligent life on Earth?

Remarkably, however, nothing of the kind is on the horizon. The world community seems chronically unable to act decisively to employ humanity's unique abilities in the collective interests of our species. On the contrary, the United Nations' Rio+20 Earth Summit (the biggest UN conference ever) ended in June of 2012 with a vapid statement on *The Future We Want* containing little more than a bland renewal of commitment to 'sustainable development' and endless reassurances of international rededication to previously failed initiatives. The statement commits no national government to specific actions or targets on anything and repeatedly equates 'sustainable development' to 'sustained economic growth' (see UN 2012). Environmental journalist George Monbiot accused participating governments of concentrating "not on defending the living Earth from destruction, but on defending the machine that is destroying it." Accordingly, Monbiot declared Rio+20 to be "perhaps, the greatest failure of collective leadership since the first world war" (Monbiot 2012).

The primary drivers of the contemporary economic "machine", designed to deliver "sustained economic growth", are globalization, market liberalization and the liberalization of international markets. The purpose of this paper, therefore, is to make the case that the integration of the global economy and so-called free trade are also instrumental in the destruction of the planet. Using ecological footprint analysis, we can show that: a) globalization and trade enable individual countries vastly to exceed their domestic carrying capacities; b) the aggregate human eco-footprint is excessive by half and; c) material trade is producing an increasingly unsustainable and destabilizing material entanglement of nations. Restructuring this system is essential if the world community is to avoid precipitating a global 'state shift' that could destroy human civilization.

Carrying capacity and does it matter?

> *"Carrying capacity is the fundamental basis for demographic accounting" (Hardin 1991).*

'Carrying capacity' (CC) is the term employed by wildlife and range managers to denote *the average maximum population of a given species that can occupy a particular habitat without permanently impairing the productive capacity of that habitat*.[1] Despite Hardin's confident assertion above, analysts have long contested whether the concept applies to *H. sapiens*.

The Reverend (and economist) Thomas Malthus opened the modern debate on human carrying capacity late in the 18th Century with his famous essay *On the Principle of Population*. Malthus' concern was based on elementary arithmetic. He observed that "population, when unchecked, increases in a geometric ratio, subsistence increases only in an arithmetic ratio" (Malthus 1798). Today we would say: 'population increases exponentially (like compound interest) while food production increases only linearly (in constant increments).' Clearly, Malthus though humanity would forever be pressing up against the earth's limited 'carrying capacity', bringing misery to millions.

While his theory seemed incontrovertible at the time, Malthus' warning was effectively squelched by the

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[1] We say "average maximum" here to recognize that the instantaneous carrying capacity of a habitat constantly fluctuates with the weather/climate, water availability and other factors that affect the productivity of the ecosystem.

growing optimism of the dawning industrial age and the fact that there were whole new continents to be peopled. Those who did remember Malthus would come to dismiss his 'dismal theorem' on grounds that he had not anticipated the ability of technology to keep food production expanding a step ahead of population growth.

And, for a while, the optimists seemed to be right. The good Reverend's geometric multiplier continued to grind away but it was not until the 1960s that the 'Malthusian spectre' remerged in popular discourse (see Ehrlich 1968). It had taken until 1930 – more than a century after Malthus death – for the human population to grow from one to two billion. But the third billion was added by 1960 in just 30 years and the forth in a mere 14 years! By the end of the century, the human population had topped six billion, having doubled since 1960. It had taken two million years for the human population to reach three billion; the second three billion were added in just forty years! (and we have since added the seventh billion – see UNFPA 2011). Such is the power of exponential growth.

Meanwhile, the economy had been expanding even faster than population. By the 1960s, anxiety about urban, industrial, and agricultural pollution, and even resource scarcity, had spawned the so-called 'environmental movement' and added a new dimension to the question of human carrying capacity. Catton (1980) accordingly redefined *human* carrying capacity as the environment's "maximum persistently sustainable load".

The combined impact of the population and industrial juggernauts were predictable on a finite planet. By the early 21st Century, humans had transformed half of the land on Earth – the most productive half – to suit human purposes; were using half the planet's accessible fresh water; contaminated virtually every eco-system; fully- or over-exploited up to three quarters of the world's major fisheries; and accelerated biodiversity loss to hundreds or thousands of times the background rate, all to the detriment of our supportive ecosystems. Meanwhile, to feed our seven billions, humans fix and inject more atmospheric nitrogen into terrestrial ecosystems than do all natural processes combined; land clearing, industrial agriculture and burning fossil energy to keep the human enterprise going has inflated atmospheric carbon-dioxide levels from a pre-industrial 280 to 395 parts per million (40%), the highest level in at least 800,000 and perhaps as much as 15 million years); in response, mean global temperatures have reached record highs for modern times and many places around the world are being pummelled by more frequent and violent extreme weather events.

By 1992, things looked threatening enough that 1,700 of the world's top scientists (including most science Nobel Laureates) issued *The World Scientists' Warning to Humanity* which concluded: "A great change in our stewardship of the Earth and the life on it is required if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated" (UCS 1992) More than a decade later, the authors of the Millennium Ecosystem Assessment echoed this earlier warning, asserting that "human activity is putting such a strain on the natural functions of the Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted" (MEA 2005). Clearly the consensus among natural scientists is that *H. sapiens* is near, or has breached, long-term global carrying capacity and is in danger of crossing a catastrophic tipping-point. They recognize it is physically impossible to sustain the growth of anything real on a finite planet indefinitely, and that to attempt to do so is to invite catastrophe.

Not everyone agrees. According to Lawrence Summers (then Chief Economist, the World Bank):

> There are no... limits to the carrying capacity of the earth that are likely to bind any time in the foreseeable future. There isn't a risk of an apocalypse due to global warming or anything else. The idea that we should put limits on growth because of some natural limit is a profound error and one that, were it ever to prove influential, would have staggering social costs (Summers 1991, cited in McQuillan & Preston 1998).

Traditional economists and other technological optimists (including many politicians) assert that humankind has achieved mastery over the natural world and that, as the global economy expands, trade, technology and increased wealth will enable humanity to compensate for the depletion of natural resources and the loss of life-support services.

The trade argument is relatively straight forward: any human population (e.g., a region or country) that can trade surpluses of resource 'a', for needed supplies of essential resource 'b', need not be restricted in population or economic growth by limited domestic supplies of 'b'. Trade reduces negative feedback, fosters growth and appears to increase *local/national* carrying capacities. More generally, trade in local surpluses that might not otherwise be used enables greater global economic output. This can support greater *per capita* consumption or more people, and thereby effectively increases *global* carrying capacity. Conventional trade theory further argues that we can capture even more efficiencies (i.e., even *greater* net economic output and higher carrying capacity) if each region/country in the global marketplace specializes in those few goods or commodities it can produce most efficiently (goods with the lowest inputs per unit output) and trades for everything else.

But what happens if important globally traded commodities are eventually exhausted? No problem –free markets will come to the rescue. Rising prices will trigger conservation, greater efficiency, and the entrepreneurial search for technological substitutes, thus increasing supplies and, again, *raising* human carrying capacity. Beckerman (1995) puts the economic argument this way: "The finite resources argument is flawed in every respect. It is logically flawed and obviously at variance with the whole of historical experience… It is based on a concept of resources that is static and unimaginative, and an underestimate of the human capacity to make technological progress and adapt to changing conditions."

One can hardly imagine a more confident and assertive rebuttal of scientists' concerns.

The Ecological Footprints of Trade

But that doesn't make it right. The economists' way of thinking originates from simplistic, mechanical, single-equilibrium economic models that have no systemic connection to anything outside of themselves (Daly 1985). These models therefore recognize neither the non-linear biophysical systems within which the economy is embedded nor the similarly complex social systems it supposedly serves.

We can get some understanding of at least the material *connections* between the economy and natural systems using ecological footprint analysis (EFA) (Rees 1996, 2012; Wackernagel and Rees 1996). EFA starts from the premise that the human enterprise is an integral sub-system of the ecosphere and that the human sub-system can grow and maintain itself only by extracting energy and material 'resources' from its host system. People are therefore still very much dependent on ecosystem integrity and 'the land' for survival. The method also explicitly recognizes: a) that whether one consumes locally-produced products or trade goods from afar, the land connection remains intact and; b) that no matter how sophisticated our technology, the production/consumption process requires some land- and water-based ecosystems services.

EFA is closely related to 'carrying capacity.' However, rather than asking how large a population can be supported by a given area, eco-footprinting asks how much productive area is needed to support a specific population, regardless of the location of the land/water or the current state of technology. We therefore define the ecological footprint (EF) of a specified population as *the area of productive land and water ecosystems required by that population, on a continuous basis, to produce the renewable resources it consumes and to assimilate the wastes it produces, wherever on earth the relevant ecosystems may be located.* A complete eco-footprint analysis includes the population's use of domestic ecosystems, plus the *net* ecosystem area it 'occupies' through trade, plus its demands on the global common pool for free eco-systems services (e.g., the carbon sink function).

Three qualities of the eco-footprint are worth underscoring: 1) a population's EF represents much of its demand for global biocapacity; 2) by inverting the standard carrying capacity ratio, EFA captures the effects of trade; the method also reflects whatever technologies are in use at the time of the analysis (i.e., EFA accounts for economists' objections to human carrying capacity); 3) since bio-capacity appropriated by one human population is not available for use by another, human populations everywhere are in competition for the available load-bearing capacity of the earth.

A planet in overshoot

As noted, globalization and trade constitute the engine of the expansionist economy. This is problematic. The argument that trade relieves resource constraints and increases local carrying capacity without limit implicitly assumes each trading region is an open system within an infinite universe. This is a poor representation of reality. In the aggregate, Earth is a materially closed, finite sphere with a limited (even shrinking) productive area. In this *real* world, exchange may result in a one-time increase in the population of trading regions, but it also increases global consumption and total pollution. Moreover, resources imported and consumed by country 'X' are no longer available for consumption in the exporting country 'Y' (and *vise versa*) which may limit future options. Thus, while trade increases the total human load on the planet, *there is no unambiguous increase in total load-bearing capacity*.

Indeed, in some circumstances unfettered trade can lead to a permanent *loss* of carrying capacity. Global trade exposes pockets of scarce resources everywhere to the largest possible market (and demand is still growing because of both population growth and increasing disposable incomes). This subjects even renewable natural capital to ever-greater exploitation pressure, often to the point of depletion or collapse. (Such is the history of trade in fisheries products, for example.) To reiterate, instead of increasing load-bearing capacity, trade simply shuffles it around. This enables local population increases but also accelerates resource depletion and ecosystems degradation which, in turn, ensures that all countries, their economies heedlessly expanding through trade, hit the (now shrinking) limits to growth simultaneously.

How far has globalization led the world down this path? By 2008, the aggregate human footprint had reached 18.2 billion global average hectares on a planet with a total global bio-capacity of only 12 billion gha[2]. Thus, while there are only 1.8 gha of productive ecosystem per person on Earth, the average person already consumes the output of 2.8 gha. The human enterprise has over shot carrying capacity by 50% – it would take the ecosphere 1.5 years to regenerate the renewable resources people consumed and assimilate the carbon dioxide they emitted in 2008 (WWF 2012, see also Rockström *et al*. 2009).[3]

This situation is the very definition of unsustainability – humanity's present consumption is liquidating Earth's *real* material wealth. As long as the human enterprise remains in overshoot, it subsidizes its growth and maintenance by depleting critical natural capital and over-filling essential waste sinks. If it stays its present course, techno-industrial society risks implosion within mere years or decades.

The unsustainable entanglement of nations

EFA enables us to identify which individual countries are most 'responsible' for humanity's ecological predicament and to assess the contribution from trade. First, EFA reveals that the majority of the world's approximately 192 countries is in overshoot. Countries in overshoot depend on trade and exploitation of the global commons to grow or simply maintain current levels of consumption. Just ten nations account for over 60% of the world's biocapacity and only a handful, mostly large low population countries have domestic surpluses of biocapacity.

The world's wealthy minority generally sport the largest eco-footprints, generally ranging from just over 4 gha (e.g., Portugal, New Zealand, Japan) to 7 or 8 gha (e.g., United Arab Emirates, Denmark, United States) *per capita*. It would take the equivalent of two to three planet Earths to support everyone on Earth at the material lifestyles enjoyed by typical Europeans or Japanese. Four Earth-like planets would be needed to support everyone at current US levels of consumption. By contrast, if everyone lived on the 0.9 gha EF of the average Kenyan or Philippino, the human family would be using only *half* of Earth's biocapacity.

These numbers illuminate the gross and growing inequity in the world today. High-income people and nations are able to 'appropriate' vastly more than their equitable share of global biocapacity through trade and by exploiting the global commons. Consequently, many wealthy or densely populated countries exceed their domestic carrying capacities and are running large *ecological deficits* with the rest of the world (Table 1).

Table 1: The Eco-Footprints and Bio-Capacities of Selected Countries (data estimated from WWF 2012)

Country	Per capita Footprint (gha)	Biocapacity per capita (gha)	Overshoot factor (EF/biocapacity)
United Arab Emirates	8.4	0.6	14.0
United States	7.2	3.7	1.9
Canada	6.5	14.9	(.44)
Netherlands	6.2	0.9	6.9
United Kingdom	4.7	1.3	3.6
Japan	4.3	0.6	7.2

NB: An overshoot factor > 1 means an ecological deficit.

[2] To facilitate international comparisons, national eco-footprint estimates are converted to 'global hectares' (gha), i.e., their equivalent in hectares of global average productivity.

[3] The human enterprise first went into overshoot in the 1970s (WWF 2012).

The United Arab Emirates (UAR) is an extreme case – this country depends on 14 times its domestic biocapacity to sustain its population at prevailing material standards. The UAR's demand for carbon sinks comprises over three quarters of the country's total EF, a burden that it imposes on other countries and the global commons. The UAR must also import most of its food and other renewable resources.

The Netherlands and Japan overshoot their domestic carrying capacities by a factor of seven. Again, both countries are trading nations with large ecological deficits. They are highly dependent on other nations and the global commons for food and fiber, which they acquire through trade, and as carbon sinks. The UK with and overshoot factor of 3.6 is perhaps more typical of high-income trade-dependent European countries.

The US is a special and somewhat worrisome case. This nation has overshot domestic biocapacity by 90% (mostly due to its large carbon eco-footprint). Long an agricultural powerhouse and a major net exporter of food, the US balance of trade (dollar value of exports compared to dollar value of imports) in this critical sector has been steadily dropping in recent decades from over as 2:1 in the mid 1970s to 1.4:1 in 2011-12 (see USDA 2012). Kissinger and Rees (2012) show that between 1995 and 2005 both the import share of U.S. consumption and the offshore land area embodied in those imports increased steadily. The US agricultural trade surplus (by weight) shrank by more than 50% during this period; some import commodities such as fruits, vegetables, beef, processed food, already exceed exports. Trade in wood products displays similar trends. Most critically from the perspective of the present analysis, the actual ecosystem area embodied in U.S. imports of agricultural and forest products was equivalent to the area of Germany, Italy, Spain, and the United Kingdom combined (Kissinger and Rees 2010). This is hardly a trivial claim on extraterritorial biocapacity. It seems that even the U.S. is becoming increasingly dependent on external sources of supply and that U.S. consumers now impose a significant burden on terrestrial ecosystems outside the U.S.

Canada is also a special case but for a different reason. Canada is one of only a few countries with an apparent ecological surplus (8.4 gha/cap). Canadians have large average eco-footprints at 6.5 gha, but their relatively small population (33 million) lives at low average density in a huge country. Even though much of the land is cold and unproductive much of the year, the available biocapacity (14.9 gha/cap) dwarfs domestic demand.

Not surprisingly, therefore, Canada is a major food exporter: it is the world's third largest producer of barley, fifth largest producer of wheat, and eighth largest beef producer. Tens of millions of people around the world are at least partially dependent on Canadian agricultural exports.

The Canadian prairies are the nation's agricultural powerhouse with 85% of the arable land in the country. Serving international markets makes significant demands on prairie agro-ecosystems. Kissinger and Rees (2009) found that, on average between 1989 and 2007, Canada effectively 'exported' 51.4% of the agricultural land (65% of cropland) in its prairie provinces and that the total area 'exported' increased from about 20 million actual hectares to 34 million ha in recent years.

Obviously Canada's agricultural exports benefit all partners in the exchange. Millions of people in importing countries acquire essential foodstuffs while Canadian farmers, chronically undercompensated, enjoy the extra income. However, there are both short- and long-term concerns associated with prevailing agricultural practices and trade policy. High-input production agriculture induces soil erosion, destroys native biodiversity, contaminates surface and ground water and generally accelerates the pace of ecological deterioration. In little over a century, conventional agriculture on the Canadian prairies has all but eliminated the natural grassland habitat and the rich flora and fauna associated with it, and has dissipated half the organic matter and natural nutrients that required millennia to accumulate on the post-glacial plains. Soils that only a few decades ago produced high yields of outstanding quality without artificial inputs now need to be fertilized to maintain both quality and quantity. Excess fertilizer, together with pesticides and mechanization, accelerate the degradation of prairie agro-ecosystems in what is arguably an unsustainable downward spiral. These impacts can reasonably be assigned proportionally to production for export and production for domestic consumption (Kissinger and Rees 2009).

Trade plays a similar role in the exploitation of Canada's forest and marine/aquatic ecosystems. Exports accounted for $26 billion of $57.1 billion (46%) in forest sector revenues in 2010 (FPAC 2011); exports of fish and seafood products contributed $3.9 billion to the industry's total revenues of approximately $5 billion, about 80% of the total (AFC 2011).

What these data illustrate is that Canada's apparent surplus of biocapacity (relative to domestic demand) is illusory and the same would be true for any other country with a nominal ecological surplus. In a closed global trading system, the apparent eco-surpluses of a few privileged countries are necessarily absorbed by the growing eco-deficits of net importing countries.[4] In ecological terms, trade on a finite planet is, at best, a zero sum game.

And we are not operating 'at best' – this is a world in overshoot. Trade has become a *negative* sum game. The few national eco-surpluses are insufficient to cover most other countries' eco-deficits. Trade-stimulated economic growth can therefore only accelerate the depletion of critical natural capital. Consider the North Atlantic cod fishery, among the world's greatest fisheries and one oriented largely to export markets. The collapse of cod stocks under Canada's regulatory watch in 1992 was a major ecological and social tragedy and a classic example of a regional ecosystemic 'state shift' attributable to over-exploitation (see Barnosky et al. 2012).

It should also serve as wake-up call to the global community. Hundreds of millions of lives are now dependent on reliable resource flows from distant 'elsewheres'. These people are increasingly vulnerable to the potential disruption of trade flows because of climate change, resource depletion, systems collapse and potential international conflict as geopolitical tensions escalate in a resource-scarce world.

Regrettably, nobody seems to notice. Trade-dependent consumers are blind to the negative ecological effects of distant production processes driven, in part, by their own material demands. People at distance lack the direct 'negative feedback' that might otherwise induce them to behave sustainably (Rees 1994). This, combined with general ignorance of systems behaviour and the ecological consequences of unsustainable resource exploitation, encourages still greater material consumption and trade and hence greater reliance on external supplies (Princen 1997).

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[4] This holds also for any terrestrial carbon sink capacity surplus to domestic requirements. Carbon sinks everywhere are overwhelmed by the excess – and still growing – carbon dioxide emissions of the global economy.

Indeed, the present form of globalization facilitates the increasing growth-driven entanglement of nations in a sticky web of interdependence even as it undermines the ecological foundations of the entire system. This has created a perfect storm of unsustainability. We live in an ecologically over-full world breaching the limits of critical life-support systems whose behaviour provides the vey archetypes of lags, thresholds and multiple equilibria. Should any major system (e.g., global climate) be forced over a previously untested threshold into a hostile stability regime, there may be no recovery on a time-scale relevant to human civilization. Preventative action is inhibited not only by ignorance but also by many people's and nations' short-term economic interests on maintaining the *status quo*.

The Way Ahead

Globalization and trade have enriched millions and improved the lives of billions of people. Nevertheless, there can be too much of a good thing. Global economic integration has produced an increasingly unsustainable and destabilizing entanglement of nations. The ready availability of trade goods encourages nations to run down their own resource stocks and exceed their domestic carrying capacities, oblivious of the risk this poses for themselves and future generations. The aggregate result is a world in gross overshoot, blindly pursuing a growth-based global development strategy that can only erode essential natural capital, undermine global life-support systems, and risk a global-scale state shift that could be fatal to civilization.

As noted at the outset, humans theoretically have the intelligence, knowledge and resources necessary to confront this dilemma.[5] However, any effective international solution will require a true 'paradigm shift', including abandonment of the core values, beliefs and assumptions underpinning prevailing global development policies. The simple fact is that circumstances have changed and global development policies must also change to reflect new realities. The question is whether the global community can muster sufficient political will to *choose* to succeed (see Diamond 2005).

Most critically, the world must act to reduce human demands on global life-support systems and to restore the natural capital base that supports all human activity. To address these goals, the emphasis in international development must shift from growth and efficiency toward a sustainable steady-state with greater social equity (redistribution); competition must be paired with cooperation for the common good; dependent specialization should give way to greater local self-reliance and economic diversity. These are the minimum conditions necessary for the human enterprise to back away from critical systems thresholds and avoid precipitating a potentially catastrophic global-scale state shift.

Consistent with such new goals, the following specific questions flow logically from the forgoing analysis but have largely been ignored in both domestic land/resource planning and international trade negotiations to date (Kissinger and Rees 2009). In a rapidly changing and increasingly unpredictable world:

1. Is it wise for any nation to commit a significant proportion of its agricultural output and land-base to satisfying off-shore demand (i.e., creating dependent populations);
2. Should any population or country allow itself to become significantly dependent on increasingly

[5] This may not be enough. See Rees (2010).

uncertain external sources of essential food and other resources?

3. Should any region or country allow its prime agricultural lands to be paved over or otherwise degraded on the assumption that it can always import basic foodstuffs from elsewhere?
4. Is it not time to resurrect the virtue of greater self-reliance through investment in local natural capital?
5. What strategies can irreducibly import-dependent countries employ to diversify suppliers, enhance the security of existing trade relationships and share in management responsibility for critical ecosystems in other countries?
6. How can trade rules be modified to prohibit the overexploitation of critical forms of natural capital? For example:
7. How might the terms of trade for agricultural, forest, fisheries and other renewable resource products be adjusted to provide the economic surpluses necessary for the maintenance of the productive ecosystems (natural capital) for the long-term benefit of both producers and consumers?

Similarly difficult questions must be asked in virtually every domain of human economic activity.

Obviously, the paradigm shift necessary for global ecological sustainability poses a daunting challenge beyond anything attempted by the international community to date. While not yet fully understood or appreciated, the motivation for such a dramatic shift is actually quite simple: for the first time in human history, long-term individual/national self-interest has converged with humanity's *collective* interests. Failure to recognize this reality and to accept the challenge of designing an cooperative transition to sustainability would be a failure to exercise the very qualities that distinguish modern *H. Sapiens* from all other species: high intelligence (e.g., reasoning from the evidence); the capacity for forward planning; and the ability to exercise moral judgement (Rees 2010). Any such failure would be tantamount to a backward step in human evolution.

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