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What We Use and What We Have:
Ecological Footprint and Ecological Capacity

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Summary:

The Ecological Footprint is an ecological accounting tool to document how much regenerative capacity of the biosphere is occupied by given human activities. It can be applied to track human demand on nature at the global, national, regional, organizational or individual level. This brief summarizes the underlying concepts, accounting methods, basic results and applications.

The Footprint measures human impact on nature

Because people consume the products and services of nature, every one of us has an impact on the Earth. This is not problematic as long as the human load stays within the ecological capacity of the biosphere. But does it?

The "Ecological Footprint" concept has been designed to answer this question and estimate people's demand on the environment. It does this by measuring how much nature people use today to support themselves.[1]

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 measured as a corresponding biologically productive area that are required to maintain these flows. Thus, the Ecological Footprint of any defined population (from a single individual to a whole city, country, or humanity as a whole) is expressed as the area of the biologically productive land and water required to produce the resources a population consumes, and to assimilate the wastes it generates, using prevailing technology. As people use resources from all over the world and pollute far away places with their wastes, Ecological Footprints add up the extent of these biologically productive areas wherever they may be located on the planet.

Hence, Ecological Footprint accounts allow us to monitor human use of the living natural capital and provide guidance for sustainability. Making Ecological Footprints smaller than the available biocapacity is a necessary condition for 'strong sustainability,' i.e., the postulation that maintenance of natural capital is a condition for preserving people's well-being.[2] To fully meet this condition, uses of the areas occupied by the Footprint must also not degrade their regenerative ability.

Others have argued that 'strong sustainability' is too stringent a condition since other assets such as technology and increased knowledge may compensate for the loss in ecological assets.[2] While the judgment is still out on whether lost ecological assets can be compensated by other kinds of assets, managing for 'weak sustainability' also requires reliable monitoring of all assets. Therefore, accounts like the Ecological Footprint that measure the overall supply of, and human demand on, regenerative capacity are indispensable tools, whether the goal is to manage for 'weak' or 'strong' sustainability. In either case they are needed for tracking progress, setting targets and driving policies for sustainability.

The American Footprint ...

National Ecological Footprints compare the annual demand on nature with nature's regenerative capacity. Estimates for the year 1999, for example, which are based on the most recent publicly accessible United Nations statistics,[3] show that the average American required approximately 9.6 global hectares[4] (or 24 acres) to provide for his or her consumption expressed in the common unit of 'bioproductive space with world average productivity'—hence global hectares. These 9.6 global hectares (24 acres) correspond to 96,000 square meters (960 times 100 meters) or 10 soccer fields (24 football fields). How big is yours? Visit our Web site to find out.[5] In comparison, the average Canadian lived on a Footprint that was nearly one-third smaller (6.9 global hectares or 17 acres), while the average Italian lived on a Footprint that was less than half the size (3.8 global hectares or 9 acres). Since we assume optimistic yield figures for our calculations and still do not include all uses of nature, these figures likely underestimate the biologically productive areas truly necessary to sustain these people. Since individuals in these countries have vastly diverging personal footprints, Redefining Progress has developed a 15-question web calculator for estimating one's personal Footprint.[6]

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... compared to the available bio-capacity

Dividing all the biologically productive land and sea on this planet by the number of people inhabiting it results in an average of 1.8 hectares (4.5 acres) existing per person in the year 2002. This capacity per capita is less than one-fifth of what is necessary to accommodate the 9.6 hectares (24 acres) Footprint of an average American. Of these 1.8 hectares (4.5 acres) per person, 1.5 hectares (3.7 acres) are land based natural and managed ecosystems such as forests, pastures and crop land; 0.3 hectares (0.8 acres) are ecologically productive fishing grounds most of which are located on continental shelves.[7]

However, there is a slight complication. People should not use all the 1.8 hectares (4.5 acres) per capita since we are not alone on this planet. We share it with over 10 million other species - most of whom are excluded from the spaces we occupy for human purposes. For example, industrial agriculture calls "weed" any species that is not exploitable, and urbanization paves over much of the most fertile land. How much of the bio-productive area should we leave relatively untouched for these other 10 million species? How much would be fair? How much would you feel is necessary to secure an ecologically stable world?

Having personally asked many people, I have met only a few who think we should leave less than one third of the eco-capacity for the many other species whom we typically exclude through our practices. To be even more generous to the human species and make sure that our analysis does not exaggerate ecological scarcity, we follow the politically courageous, but ecologically insufficient[8] suggestion by the Brundtland Report: *Our Common Future* (1987). Its authors invited the world community to protect 12 percent of the biologically productive space for preserving the other 10 million species with whom we share this planet.

Obviously, this 12 percent needs to be distributed strategically around the world. In some regions that people have intensively occupiedfor centuries, such as Europe or coastal China, reducing the intensity with which we farm the land may already provide significant possibilities for biodiversity preservation. In other regions that are still wild and by nature more fragile, such as the Amazon rain forest, large areas need to be left untamed, and successful biodiversity protection can only tolerate minimal human intervention. Also, this bioprotection is more likely to last if humanity shares the burden of this effort, rather loading it on those who live in critical habitats. Using this conservative number of 12 percent, the available bio-productive space per person shrinks from 1.8 hectares (4.5 acres) to just under 1.6 hectares (4 acres).

Even though the average Footprint of humanity is 2.3 global hectares (5.6 global acres) per person, it still exceeds the biocapacity of the planet.[9] If we put aside 12 percent for the other species, then we exceed the Earth's capacity by 45 percent. Ecologists call this transgression of the earth's carrying capacity "overshoot." In other words, humanity consumes more than what nature can regenerate, thereby depleting the globe's stock of natural capital. The sustainability challenge then becomes: "*how can all have a satisfying life, recognizing the average global budget of 1.6 hectares (4 acres) per person or less*?" If humanity wants to live sustainably, this is the most significant question we face in research, business and politics.[10]

How is the Footprint calculated?

The Ecological Footprint is an accounting framework that aggregates human demand on the biosphere into one number: the bioproductive space occupied exclusively by a given human activity. It does this by adding up human uses of ecological services in a way that is consistent with thermodynamic and ecological principles. For example, it recognizes the ecological interactions of ecological functions by only adding up mutually exclusive services of nature such as food production or CO_2 sequestration. It also incorporates thermodynamic thinking by distinguishing between energy qualities and differentiating between abilities of ecological spaces to produce biomass. Since the method builds on the assumption that the limiting factor for human life on this planet is the regenerative capacity of the biosphere, the accounts capture human use of nature in as far as it impacts this capacity. This means that the Footprint incorporates the use of non-renewable resources such as oil or copper ores to the extent that it limits nature's integrity and productivity.

Some activities are inherently unsustainable (such as spreading plutonium or PCB into the biosphere, since there exists no significant absorptive capacity for those substances; systematic degradation of soils; biodiversity loss; or salinization of cropland). These activities need to be phased out for a sustainable world. Footprint accounts include only those aspects of human activities that have the potential to be sustainable. At the same time, Footprint thinking allows to distinguish inherently unsustainable activities from potentially sustainable ones. While Footprint accounts aggregate all renewable uses of nature, inherently unsustainable activities need to be tracked separately.

Among a variety of compatible methods to calculate people's Footprints, there are two basic approaches — compound Footprinting and component-based Footprinting. The former produces more robust results, but less resolution than the latter. In order to have robust results with more detail about which activities are occupying which part of the overall Footprint, a hybrid approach is used.

Compound Footprinting

The most robust and comprehensive approach is 'compound Footprinting.' Applied at the national level, it traces all the resources a nation consumes and the waste it emits. The nation's consumption is calculated by adding imports to, and subtracting exports from, the domestic production. To put it in mathematical terms: *consumption = production – exports + imports*. This balance is calculated in approximately 60 primary categories, including as cereals, timber, and tubers. Each primary category captures a primary resource (such as raw timber or milk) and the manufactured products that are derived from them (such as paper or cheese). Resource use is expressed in terms of area by dividing the total amount consumed by the respective resource yield. Likewise, the area of waste equals the quantity of waste divided by the corresponding capacity to absorb waste.

For the Living Planet Report 2002, accounting procedures have been refined. Now accounts reflect:

- country-specific efficiencies for transforming primary inputs of resources into final products;
- a detailed crop-use analysis based on FAO's Food Balance Sheets;
- a more detailed forest analysis with data on plantation type, coverage and yield, forest growth rates; and protected and economically inaccessible forest areas;
- a refined analysis of the grazing Footprint by assessing the percentage of livestock living on crop feed, and estimating each nation's grassland and pasture productivity;
- a fish analysis that reflects the trophic level of fish catch as well as the productivity differences of various fishing grounds;
- productivity potential of land is now based on International Institute for Applied Systems Analysis (IIASA) and UN Food and Agriculture Organization' s (FAO) Global Agro-Ecological Zoning (GAEZ) model land-use data.

To increase the consistency and robustness of the results, each component is screened for double-counting. Since double-counting could exaggerate the Footprint, secondary ecological functions that are accommodated on the same space are not added to the Footprint. For example, honey produced from a pasture for dairy cattle would not add to the Footprint. Neither would the collection of mushrooms in a forest credited with timber production or CO_2 absorption.

To provide results in comparable units of measure, all components are adjusted for their biological productivities ('global hectares' or 'global acres'). This means that land with higher than average productivities would appear larger in Footprint accounts. The same is done on the capacity side when a region or nation's ecological capacity to accommodate Footprints is analyzed.

The sum of adjusted components equals the total Footprint. The analysis provides both a number for the overall Footprint and overall biological capacity. If the Footprint exceeds the capacity, the region has an ecological deficit. If the per person Footprint exceeds the global average, the magnitude of the person's contribution to the global ecological deficit is clarified.

The advantage of compound Footprinting is that it automatically captures many indirect effects of consumption, which are hard to measure, because this approach does not require knowing what each consumed resource is used for. For example, it is irrelevant for the accounting whether the consumed energy powers vehicles, heats homes, produces cars sold in the country, or is merely wasted. Since there are robust statistics on overall energy consumption but much less accurate data on exact use of the energy, the overall assessment of compound Footprinting makes the accounts more reliable.

Component-Based Footprinting and Combinations

The second accounting approach, 'Component-based Footprinting,' adds up the Footprint of each category of consumption. Even though this approach is more instructive and more flexible for calculating Footprints of individuals or organizations, it is more prone to errors since reliable data for assessing indirect consumption components, such as embodied energy and materials in goods and services, is scarce. Still, sometimes sufficient data from life cycle analyses is available to develop reasonably good estimates at the product level.[11]

For the calculations of Footprints for populations smaller than a nation, but larger than a household, the most effective method is a hybrid of these two approaches. For regions or municipalities, their Footprint is assessed by extrapolating from the national Footprint using the relative differences in the consumption pattern of the region and the nation. Both the individual and the regional Footprint assessments are made more accurate by calibrating them with the national accounts.

Limitations of Ecological Footprint accounts

The Ecological Footprint accounts do not answer all questions relevant to sustainability. Rather, they provide answers to very specific research questions. Namely: how much of the regenerative capacity of the planet is necessary to maintain the present resource throughputs of a given entity, using prevailing technology? And how much regenerative capacity does a given region offer?

But even for answering these particular questions, the tool has limitations. One is the availability of data. The reliability of local Footprint accounts depend on what is available, not only for the local analysis, but also globally in order to ensure the global hectares represent most accurately global overall capacity. Also, demands on ecological services that do not require additional capacity but are provided by areas already accounted for are not included in the accounts. This makes the accounts insensitive to improvements in those areas. For instance, acid rain absorption is not included in our standardized national accounts since its absorption occurs on areas that may already be used for farming or forestry. Therefore, current accounts would not capture a reduction in acid rain.

Also, activities which are systematically unsustainable are not included in Footprint accounts since they need to be phased out. For those activities separate accounts are needed.

One of the most discussed aspects of the Ecological Footprint is its inclusion of energy. For some aspects of energy consumption, conversion into area is straightforward (example: hydropower), but for others it is more complicated. Particularly in the case of fossil fuel, various calculation approaches would be possible. Our current method interprets the research question from the perspective of how much bigger the capacity of the planet would need to be in order to absorb the waste (permanent sinks for the excess CO_2 emitted by fossil fuel). Other methods that include energy replacement lead to even larger Footprint areas.

In summary, Footprint result provide significant overall information, but will most likely underestimate human demand on nature.

Box 2: Existing Footprint applications

By providing clear ways to assess potential tradeoffs, the Ecological Footprint becomes a yardstick for measuring the ecological bottom-line of sustainability — a precondition for satisfying lives. The tool has provided the stimulus and foundation for many courses and thesis projects at universities all over the world.[12] More importantly, it has informed discussions and debates from the global level to the local scale by national governments, UN meetings, research institutes, and municipal green plan initiatives[13] to name a few.[14] Global and national studies have compared countries' overall consumption to their eco-capacities or analyzed the ecological capacity embodied in trade.[15] Municipal Footprints have been computed and sustainability strategies evaluated with the Footprint tool.[16] At the household scale, the individual impacts have been assessed with a variety of calculators, including software programs explicitly designed for adoption in school curricula. The ecological demands of specific products or the cumulative effects of consumer items have also been compared using the Footprint method.[17] And there is more to come.[18]

Connecting Footprint accounts to sustainability interventions

To move towards sustainability requires improving people's quality of life while reducing humanity's Footprint. Impossible? No. Three complementary strategies can reduce Footprints without compromising our quality of life. We can:

(i) Improve the bio-productivity of nature sustainably. We can extend the bioproductive areas through reforestation or soil conservation. Also, we can increase harvests and services per hectare. Examples include: permaculture, agricultural infrastructure such as terraces on mountain slopes or careful irrigation, reforestation or installing solar panels on unutilized roof areas;

(ii) Use the harvested resources better by using less input to produce the same output, as in energy efficient lamps or heat pumps, recycling, or climate adapted architecture; and

(iii) Consume less by consuming less per person and by lowering the population size of future generations by reducing fertility below mortality. One of the most cost-effective strategies, which at the same time increases people's quality of life and their future possibilities, is to meet the demand for safe, effective and affordable family planning. Consumption can be reduced in many ways. For instance compact urban design discourage car-dependent lifestyles, or environmental tax reforms can make the production of disposable products more costly and resource efficient products more affordable. At the same time, reduced consumption my allow people to save money and afford themselves more leisure time. In the long term, reducing consumption and waste per capita can succeed in reducing the total human Footprint only if the human population does not continue to increase.

Moving sustainability forward becomes far more likely if strategies are chosen that both improve people's quality of life and reduces the size of humanity's Footprint.

Conclusion

Ecological Footprint accounts can help policy planners assess a population's ecological impact and compare this impact to nature's capacity to regenerate. In other words, Footprints contrast human load with nature's carrying capacity. These analyses give us a benchmark for today's ecological performance, identify the challenges for lightening people's ecological load, and allow us, members of society and managers of the public and private sectors, to document gains as a country, region, city or company moves toward sustainability. In this way, the Ecological Footprint becomes a tool for weighing the merits of potential policies and developing effective strategies and scenarios for a sustainable future.

For more background information, applications and links to other projects, visit the Redefining Progress Web site (http://www.RedefiningProgress.org), which contains descriptions and resources of Footprint projects. Alternatively, contact Mathis Wackernagel at Wackernagel@RedefiningProgress.org.

Notes

[1] Mathis Wackernagel and William E. Rees, 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth.* New Society Publishers, Gabriola Island, BC. For details on the book, see http://www.newsociety.com/oef.html. Translations exist in Italian (Milan: Edizioni Ambiente 1996), German (Basel: Birkhäuser 1997), French (Montréal: Les Éditions Écosocieté 1999), Spanish (Lom, Santiago de Chile 2001), Latvian, Mandarin and Hungarian. Also consult: Nicky Chambers, Craig Simmons and Mathis Wackernagel, 2000. *Sharing Nature's Interest: Ecological Footprints as an Indicator for Sustainability*, Earthscan, London (see http://www.ecologicalfootprint.com). For more details on the footprint method and its applications, visit Redefining Progress at http://www.RedefiningProgress.org or http://www.EcologicalFootprint.org as well as the Anáhuac University of Xalapa's Centre for Sustainability Studies in Mexico (web site under construction).

[2] If the per capita value of these assets declines, economists conclude that future social well-being will be less than current well-being—a development path that is not sustainable. Pearce *et al.* call this *weak* sustainability. While this represents the core of sustainability, this requirement is limited in practice by the difficulty of determining the values of these assets. Monetary values can be assigned for assets traded on a market such as timber or cereals. But for other natural assets, determining an accurate price can be elusive. More importantly, even if values can be determined for natural capital assets, they may not signal that certain ecological limits are being breached in an irreversible manner, with serious consequences for human welfare. Hence Pearce *et al.* offer a way out of this conundrum by introducing the concept of *strong* sustainability. *Strong* sustainability recognizes that there are natural assets (which are frequently global) that do not have substitutes—for example the ozone layer—whose loss would entail serious harm to human beings and nature. *Strong* sustainability therefore requires that critical non-substitutable natural capital be preserved, independent of any increases in value of other social or physical assets. David Pearce, Anil Markandya and Edward

Barbier, 1989. *Blueprint for a Green Economy*. Earthscan Publications, London.

[3] The original study of national footprints was: Mathis Wackernagel, Larry Onisto, Alejandro Callejas Linares, Ina Susana López Falfán, Jesus Méndez García, Ana Isabel Suárez Guerrero, Ma. Guadalupe Suárez Guerrero, 1997. *Ecological Footprints of Nations: How Much Nature Do They Use? How Much Nature Do They Have?* Commissioned by the Earth Council for the Rio+5 Forum. International Council for Local Environmental Initiatives, Toronto. The methods are also described in Mathis Wackernagel, Larry Onisto, Patricia Bello, Alejandro Callejas Linares, Ina Susana López Falfán, Jesus Méndez García, Ana Isabel Suárez Guerrero and Ma. Guadalupe Suárez Guerrero, "National Natural Capital Accounting with the Ecological Footprint Concept." *Ecological Economics* (Vol. 29 No. 3 June 1999). The updates for 1993 and 1995 are available. In addition, the update for 1996, in collaboration with the Union Bancaire Privée and the World Wildlife Fund International (WWF), was completed in April 2000 and includes 150 countries. The results are published in WWF's *Living Planet Report 2000* (visit http://panda.org/livingplanet/lpr00/). The 1999 updates, using a far more detailed methodology, are presented in the upcoming WWF's *Living Planet Report 2002* (visit http://panda.org/livingplanet/lpr02/), to be launched on July 17th, 2002.

[4] By using bioproductive space with world average productivity as the common unit of measure, all the results across the world become directly comparable to each other. One hectare = 2.471 acres.

[5] To calculate your own Footprint, visit http://www.earthday.net or http://www.MyFootprint.org. Developed in partnership with Earth Day Network, it allows participants in over 60 countries and in 6 different languages to estimate their demand on nature. A more detailed version of the calculator, based on 70 consumption categories is available through Redefining Progress.

[6] To calculate your own Footprint, visit http://www.earthday.net or http://www.MyFootprint.org. Developed in partnership with Earth Day Network, it allows participants in over 60 countries and in 6 different languages to estimate their demand on nature. A more detailed version of the calculator, based on 70 consumption categories is available through Redefining Progress.

[7] Here, these areas are given in terms of their physical extension. Once these areas are adjusted for their productivities, less than 0.04 hectares per person of the total are sea space. Note that the adjusted global spaces as well as the ones given in terms of their true physical extension add up to the same total.

[8] Today, about three percent of the biologically productive space is put aside as protected parks, worldwide. However, conservation biologists believe that, independent of interspecies fairness, it may require far more merely for the utilitarian goal of biodiversity preservation. For example, wildlife ecologist and scientific director of the Wildlands Project, 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. These projections all assume 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 neighboring regions (Reed F. Noss and Allen Y. Cooperrider, 1994. *Saving Nature's Legacy - Protecting and Restoring Biodiversity*. Washington DC: Island Press).

[9] Mathis Wackernagel, Niels B. Schulz, Diana Deumling, Alejandro Callejas Linares, Martin Jenkins, Valerie Kapos, Chad Monfreda, Jonathan Loh, Norman Myers, Richard Norgaard, & Jørgen Randers, "Tracking the ecological overshoot of the human economy," Proc. Natl. Acad. Sci. USA, Vol. 99, Issue 14, 9266-9271, July 9, 2002.

[10] With the anticipated global population of 10 billion for the year 2050 or before, the available space will be reduced to 1.2 hectares, including the sea space.

[11] Best Foot Forward in Oxford, for example, was asked by the Danish government to compare the footprint of a variety of bottling options for drinks. They did this by using data from different existing life cycle analyses. While the life cycle analyses did not produce the same absolute footprint results, the relative ranking these assessments produced with each life cycle assessment was the same.

[12] In at least the following countries, we have had direct contact with academics using the Footprint concept in their teaching or their research projects: Argentina, Australia, Austria, Canada, Chile, China, Columbia, Costa Rica, Denmark, Ecuador, France, Finland, Germany, Guernsey, Greece, Hong Kong, Ireland, Italy, Japan, Lithuania, Mexico, the Netherlands, New Zealand, Norway, Philippines, Portugal, Scotland, Singapore, Spain, Sweden, Switzerland, Taiwan, Turkey, Uruguay, the United Kingdom, and the US. Many academic papers analyzing the Footprint concept or applying it to the researchers' own region have been published. Robert Costanza has hosted a special forum on Footprints in *Ecological Economics* (Vol.32, No.3, March 2000). *National Geographic* featured the Ecological

Footprint in their July 2001 issue. Also, many high school curriculums are incorporating Footprints. The Footprint has become a part of the official school curriculum in the Province of Ontario, Canada.

[13] Outside the US, these municipal green plan initiatives are known under the name of 'Local Agenda 21.' These local agendas represent the municipal responses to the 'Agenda 21' unveiled at the 1992 Earth Summit of Rio de Janeiro.

[14] Many Agenda 21 initiatives have used Ecological Footprints in their communications of the sustainability challenges. For example, the municipality of The Hague in the Netherlands has developed an engaging pamphlet on Footprints. Governments have also begun to refer to the Footprint in their documents. For instance, the Japanese government released a white-paper that includes the Footprint. The Dutch Environmental Minister Jan Pronk (who has mentioned Footprints in many of his speeches) has asked his advisory committee to identify the policy implications of Footprints for Holland, with a resulting report that was published. Footprint studies were also commissioned by the European Parliament, the European Commission, and the OECD Roundtable on Sustainable Development. Footprints have stimulated the discussion with other initiatives to promote sustainability such as the Natural Step. See John Holmberg, Ulrika Lundqvist, Karl-Henrik Robèrt and M. Wackernagel, 1999. "The Ecological Footprint from a Systems Perspective of Sustainability," *The International Journal of Sustainable Development and World Ecology*, Vol. 6 p17-33.

[15] For example, Detlef van Vuuren, E.M.W. Smeets and H.A.M. de Kruijf, 1999, The Ecological Footprint of Benin, Bhutan, Costa Rica and the Netherlands, RIVM report 807005004. Bilthoven, the Netheralnds: National Institute of Public Health and the Environment (RIVM), Wackernagel *et al*., 1997, see above; Andreas Sturm, Mathis Wackernagel and Kaspar Müller, *Die Gewinner und die Verlierer im globalen Wettbewerb: Warum Öko-Effizienz die Wettbewerbsfähigkeit stärkt: 44 Nationen im Test*, Verlag: Rüegger, Chur/Zürich 1999, and *The Winners and Losers in Global Competition: Why Eco-efficiency Reinforces Competitiveness: A Study of 44 Nations*, Rüegger, Chur/Zürich, 2000; Mathis Wackernagel, Lillemor Lewan and Carina Hansson, "Evaluating the Use of Natural Capital with the Ecological Footprint: Applications in Sweden and Subregions," *Ambio*, Vol 28 No. 7, pp604-612.

[16] Latest local Footprint calculations of Redefining Progress were prepared for Sonoma County and presented in Ann Hancock's report *Sonoma County Ecological Footprint Project: Time to Lighten Up?* (May 2002). Earlier attempts include: Mathis Wackernagel, 1998. "The Ecological Footprint of Santiago de Chile," *Local Environment* Vol.3 No.1 (Feb); Gavin Davidson and Christina Robb, 1994. The Ecological Footprint of the Lions Gate Bridge. School of Resource Management, Simon Fraser University, Burnaby, British Columbia. Carollo engineering company used the Footprint to evaluate the sustainability of sewage treatment facilities that they were designing for Petaluma, CA.

[17] Yoshihiko Wada, 1993. *The Appropriated Carrying Capacity of Tomato Production: The Ecological Footprint of Hydroponic Greenhouse versus Mechanized Open Field Operations*. M.A. Thesis. School of Community and Regional Planning, University of British Columbia, Vancouver. Nils Kautsky, H. Berg, Carl Folke, J. Larsson, and Max Troell, 1997. Ecological Footprint for assessment of resource use and development limitations in shrimp and tilapia aquaculture. *Aquaculture Research.* 28 (10). Oct., 1997. 753-766. See also Best Foot Forward's example of Footprinting Danish beverage systems.

[18] Wackernagel, Mathis and J. David Yount. 2000. "Footprints for Sustainability: The Next Steps." *Environment, Development and Sustainability.* 2: 21–42.