ECOLOGICAL FOOTPRINT OF NATIONS

2005 UPDATE

SUSTAINABILITY INDICATORS PROGRAM

Redefining Progress
1904 Franklin Street
Oakland, California 94612
(510) 444-3041
www.RedefiningProgress.org

Primary Authors and Analysts

Dr. Jason Venetoulis, Progressive Consulting
Email: jason@TheProgressiveConsultant.com

Dr. John Talberth, Redefining Progress
Email: Talberth@rprogress.org

ECOLOGICAL FOOTPRINT OF NATIONS

2005 UPDATE

OVERVIEW

Ecological footprints measure a population's demands on nature in a single metric: area of global biocapcity. By comparing humanity's ecological footprint with the Earth's available biological capacity, ecological footprint analysis (EFA) suggests whether or not our use of crop lands, forest lands, pasture lands, fisheries, built space, and energy lands can be sustained. In previous *Footprint of Nations* reports, Redefining Progress (RP) documented that humanity's ecological footprint has breached the limits of environmental sustainability. We revealed that nature has been utilized beyond its capacity to renew and regenerate indefinitely, a finding consistent with an extinction rate estimated to be as great as 1000 times the natural level, a runaway greenhouse effect, widespread degradation of forest and crop land, collapsing fisheries, and increasing scarcity of all natural resources.

"…at present rates of consumption, we would need 1.39 Earths to insure that future generations are at least as well off as we are now."

The footprint provides an excellent framework for measuring the extent (area) of humanity's use or appropriation of natural resources and services within in the context of sustainability. The originators, and fellow global leaders in the field, have done much in the way of making continuous advances to EFA (Wackernagel et al. 2005). This report presents a new EFA methodology, Footprint 2.0. Our hope is that Footprint 2.0 contributes the process of improving EFA by adding to the depth of the concept and subtleties to the methodology.

Footprint 2.0 (EF 2.0) was developed by a team of researchers at RP. In summary, EF 2.0 differs from EF 1.0 by: (a) including the entire surface of the Earth in biocapacity estimates; (b) reserving a portion of biocapacity for other species; (c) changing assumptions about carbon sequestration rates; and (d) using net primary productivity (NPP) as the basis for footprint equivalence factors.

Using Footprint 2.0, RP's 2005 edition of *Footprint of Nations* indicates that the situation is significantly worse than what EF 1.0 has shown. For the first time, we have found that footprints associated with crop land, built space, marine and inland fisheries are not sustainable. EF 1.0 shows sustainability on all these accounts. We also found that on a global level, humanity is exceeding its ecological limits by 39%—nearly double the amount of ecological overshoot found in our 2004 report using the old approach. This suggests that at present rates of consumption, we would need 1.39 Earths to insure that future generations are at least as well off as we are now.

At the country level, United Arab Emirates, Kuwait and United States of America exceeded their biological capacities by the most. On a continental basis, Western Europe and North America had the greatest ecological footprints and ran negative ecological balances (footprint–biocapacity) while Africa, Latin America, and other less consumptive regions had relatively smaller footprints and ran positive ecological balances. Footprint 2.0 also appears to be more sensitive to carbon cycle overshoot and increased built space. We found that nations with higher shares of their energy met by fossil fuels and a more urbanized land base are contributing the most to global ecological deficits.

In addition to introducing the new approach, describing the latest *Footprint of Nations* results using EF 2.0, this report offers some thoughts for future research that may prove fruitful in EFA's ongoing development.

WHAT IS ECOLOGICAL FOOTPRINT ANALYSIS?

Pioneered by William Rees and Mathis Wackernagel in 1996, the ecological footprint approach has become one of the most widely referenced sustainability analysis tools around the globe. Ecological footprint analysis (EFA) is used to calculate the land area needed to sustain human consumption and absorb its ensuing wastes. Comparing the footprint of a given population in a discrete area with the amount of biologically productive space available to that population provides a way to estimate whether or not a population's consumption is sustainable.

When a population's footprint is smaller than available biocapacity it is sustainable. When it is larger, that population is said to be engaging in unsustainable ecological overshoot or running a negative ecological balance. In addition to its heuristic value, the power of EFA lies not in the absolute values it yields, but in its ability to compare resource demands of different populations in a common currency of global productivity (Ferguson, 1999).

To calculate a nation's footprint, we use official statistics tracking consumption and translate that into the amount of biologically productive land and water area required to produce the resources consumed and to assimilate the wastes generated on an annual basis. Because people use resources from all over the world, and affect faraway places with their pollution, the footprint is the sum of these areas wherever they are on the planet. Ecological footprint calculations are based on five assumptions:

1. It is possible to keep track of most of the resources people consume and many of the wastes people generate. Much of that information can be found in existing official statistics.
2. Most of these resource and waste flows can be converted into the biologically productive area that is required to maintain these flows.
3. These different areas can be expressed in the same unit (hectares or acres) once they are scaled proportionally to their biomass productivity. In other words, each particular acre can be translated to an equivalent area of world-average land productivity.
4. Since each standardized acre represents the same amount of biomass productivity, they can be added up to a total representing humanity's demand.
5. This area for total human demand can be compared with nature's supply of ecological services, since it is also possible to assess the area on the planet that is biologically productive.

Ecological footprints and biocapacity are expressed in "global acres." Each unit corresponds to one acre of biologically productive space with "world average productivity."

THE FOOTPRINT 2.0 APPROACH

Because the footprint embodies a vast amount of information in a single quantitative measure and attempts to operationalize well known concepts of carrying capacity and sustainability, its popularity is burgeoning in academic, government, non-profit, education, and business circles. At its simple best, the footprint has great heuristic value that resonates with people's conception of ecological sustainability.

Beyond the ideal, footprint analysis still has a number of serious shortcomings, such as not including water, toxins, other species, or 2/3 of the Earth, and counting carbon emissions as forest area, when the carbon cycle includes the entire planet. Critiques of EFA's assumptions, methods, and data have been well presented in the literature (van den Bergh and Verbruggen, 1999). These and other independent insights, and the rising need and demand for accurate sustainability analysis tools provided much of the impetus for development of Footprint 2.0. Though not addressing all the possible shortcomings, we would suggest that the new approach makes several intuitive steps that improve footprint analysis conceptually and methodologically. It is offered here for your consideration and feedback.

Footprint 2.0 was developed by Jason Venetoulis, Christopher Gaudet, Karl Tupper, Dahlia Chazan, and Christen Cutil at RP in 2004/05. An initial draft of proposed changes were reviewed by independent academics before the results herein were tabulated.[1] For a full discussion of the new approach see Venetoulis and Talberth (2006).

In summary, Footprint 2.0: includes the entire surface of the Earth in biocapacity estimates. EF 1.0 only includes about 1/3. Other species have been given thoughtful consideration in the footprint literature (Chambers et al. 2000), yet EF 1.0 does not provide a corresponding algorithm. In contrast, Footprint 2.0 deducts 13.4% of biocapacity for the needs of other species. Footprint 2.0 also incorporates new carbon sequestration model results. Last, but not least, the basis of the EFA equivalence factors are changed from potential of land to provide food for humans to the relative net primary productivity.

> *"EF 1.0 has failed to capture the world's biological diversity crisis, indicating that lands we use to meet our demands for food, fiber, timber, and fish are all managed sustainably…"*

Net primary productivity (NPP) is the amount of energy left after subtracting the respiration of primary producers from the total amount of energy that is fixed biologically. NPP provides the basis for maintenance, growth, and reproduction of all consumers and decomposers. NPP is a measure of the "total food resource" available on the planet (Vitousek et al., 1986). Because human beings appropriate NPP to fuel production and consumption activities and because these activities, in turn, affect NPP availability in the future, NPP is particularly relevant in sustainability analyses. In fact, it has been suggested that human appropriation of NPP is "a more explicit measure of the intensity of human pressure on ecosystem use than the ecological footprint, which focuses more explicitly on demand" (UNEP, 2005). Drawing from both, the combination of NPP and footprinting provide the basis for the significant changes represented in EF 2.0. Allow us to elaborate.

EF 1.0 uses potential agricultural productivity as estimated by the Global Agricultural Ecological Zone (GAEZ) suitability indices as a basis for making final biocapacity estimates. GAEZ excludes portions of the Earth where productivity is assumed to be negligible – de facto nil. Footprint 2.0 takes a first step toward including these areas in EFA by adding them to biocapacity estimates. Footprint 2.0 also shifts the basis of biocapacity estimates from agricultural potential to NPP by using NPP as measured by Amthor et al. (1998) as the basis (denominator) for equivalence factors.

Footprint 2.0 estimates the equivalence factors for each biome using the ratio of NPP for major biomes to the global average. FP 2.0's equivalence factors for each biome as well as biocapacity estimates are presented on the following page. We would suggest that using NPP as a basis for equivalence factors has three main advantages over agricultural productivity: (a) all of the Earth's surface can now be included in EFA; (b) NPP better matches the relative ecological values of various terrestrial and aquatic ecosystems (i.e. crop land is now more valuable then built space) and (c) NPP provides a basis for real time mapping of biocapacity through satellite based measurements.

[1] A draft manuscript was presented to outside academic reviewers from Stanford University, Claremont Colleges, University of California, Berkeley, Illinois University, University of Texas, Austin, and Illinois Natural History Survey. There feedback was given due consideration in the final analysis. The findings have been submitted for peer review consideration in an academic journal.

Footprint 2.0 also attempts to take a first step towards making formal accommodation for other species. As noted elsewhere, EF 1.0 takes an explicit anthropocentric stance. As a consequence, the portion of the Earth's biocapacity needed to sustain the diversity of non-human life is not removed from the realm of sustainable human appropriation. The unintended result is that footprinting has failed to adequately capture the world's biological diversity crisis, indicating that lands we use to meet our demands for food, fiber, timber, and fish are all managed sustainably, while all remaining lands are ignored, suggesting that they have no ecological significance.

As a first, tentative step toward addressing this concern, Footprint 2.0 formally sets aside a portion of the planet's biocapacity (NPP) for needs of non-human species and, more broadly, non-human ecosystem functions. While there are a number of techniques—some involving high resolution satellite mapping—available for estimating the location and amount NPP that should be reserved for other species, our second change takes an easier route and simply removes from biocapacity a fixed amount of the Earth's surface based on global gap analysis. Existing gap studies suggest that if approximately 13.4% of the terrestrial land on Earth were protected, 55% of all species that are significantly threatened with extinction would meet targets for survival (Rodrigues et al., 2003). In regions "with high levels of species richness and endemism…larger percentages of their territory [require protection]" (Ibid.).

"Footprint 2.0 formally sets aside a portion of the Earth's net primary productivity for needs of non-human species . . ."

We use the gap estimate as a starting point and deduct 13.4% of each EFA biome from biocapacity. We would suggest that this is a conservative estimate of the amount of aquatic and terrestrial space actually needed to ensure the wellbeing of present and future generations of all life. Nonetheless, it is an adjustment that

World Biocapacity Estimates for EF 2.0
(All figures in global hectares per capita, 2001 data)

Biome	Area (ha/cap)	Equivalence Factor	Other Species (-13.4%)	Biocapacity (global ha/cap)
Crop land	14.80	2.12	0.22	0.46
Forest land	36.10	3.29	0.54	1.77
Pasture land	29.80	2.42	0.49	1.20
Built space	2.00	0.50	0.04	0.02
Less productive land	66.10	1.04	0.75	0.78
Marine and inland fisheries	21.30	2.67	0.33	0.87
Open ocean	343.60	0.48	4.85	2.34
Energy land	8.27	n/a	n/a	8.27
Average	-	2.00	-	-
Total	16.60	-	7.21	15.71

recognizes the critical importance of providing space for other species within the EFA framework.

The final change, incorporated in the new footprint approach, concerns the largest portion, and only unsustainable factor reported by EF 1.0 – energy.

For every ton of carbon emitted, EF 1.0 apportions a 1.05 hectare footprint based on the carbon uptake potential of relatively young forests in 1980 and 1990. On the biocapacity side of the footprint equation, no energy land is presented in final accounts. As such, EF 1.0 fails to acknowledge the role that the most of the Earth plays in the carbon cycle. Footprint 2.0 offers changes that we hope can begin address these concerns.

According to global carbon models, the total combined carbon sequestration of Earth is estimated to be 3.0 gigatons of carbon (Gt C) annually with oceans sequestering an estimated 2.3 Gt C (IPCC, 2004). Net terrestrial uptake is estimated to be 0.7 Gt C annually. Terrestrial uptake potential is actually higher, but land use changes (e.g. deforestation) have decreased this potential. Of the Earth's 51 billion hectares, oceans cover about 36.7 billion and land covers 14.4. The footprint per tonne of carbon estimate used in Footprint 2.0 is the weighted average of net sequestration potential of the land and sea or 0.06 tonnes of carbon per hectare per year.

The result is that Footprint 2.0 adds 8.27 hectares to the final global biocapacity estimates by including the entire earth in energy footprint calculations and increases the footprint per unit of energy. For every tonne of carbon emitted EF 2.0 assigns a footprint of 16.65 hectares. EF 1.0 reports 1.05 t/ha/yr footprint and no biocapacity. An extended discussion of the changes is presented in Venetoulis and Talberth (2006).

> *"Footprint 2.0 adds 8.27 hectares to the final global biocapacity estimates by including the entire earth in energy footprint calculations and increases the footprint per unit of energy."*

THE RESULTS: FOOTPRINT 1.0 AND 2.0\

The combined changes to the standard footprint approach discussed in the previous section affect biocapacity estimates, size of the footprint, and, for the first time, show a footprint that exceeds biocapacity in other categories besides energy. The table below summarizes our results and provides a comparison with EF 1.0.

Global Footprint Accounts: EF 1.0 and EF 2.0
(All figures in global hectares per capita, 2001 data)

	Biocapacity		Footprint		Ecological Balance	
Biome	**EF 2.0**	**EF 1.0**	**EF 2.0**	**EF 1.0**	**EF 2.0**	**EF 2.0**
Crop land	0.461	0.527	0.521	0.527	-0.060	0.000
Forest land	1.775	0.833	0.464	0.189	1.311	0.644
Pasture land	1.197	0.267	0.470	0.091	0.726	0.176
Built space	0.020	0.100	0.046	0.100	-0.026	0.000
Less Productive Land	0.779	-	0.000	-	0.779	-
Marine and inland fisheries	0.873	0.132	1.045	0.138	-0.173	-0.006
Open ocean	2.337	-	0.000	-	2.337	-
Energy land	8.265	-	19.357	1.142	-11.092	-1.142
Total	15.707	1.859	21.903	2.187	-6.197	-0.328

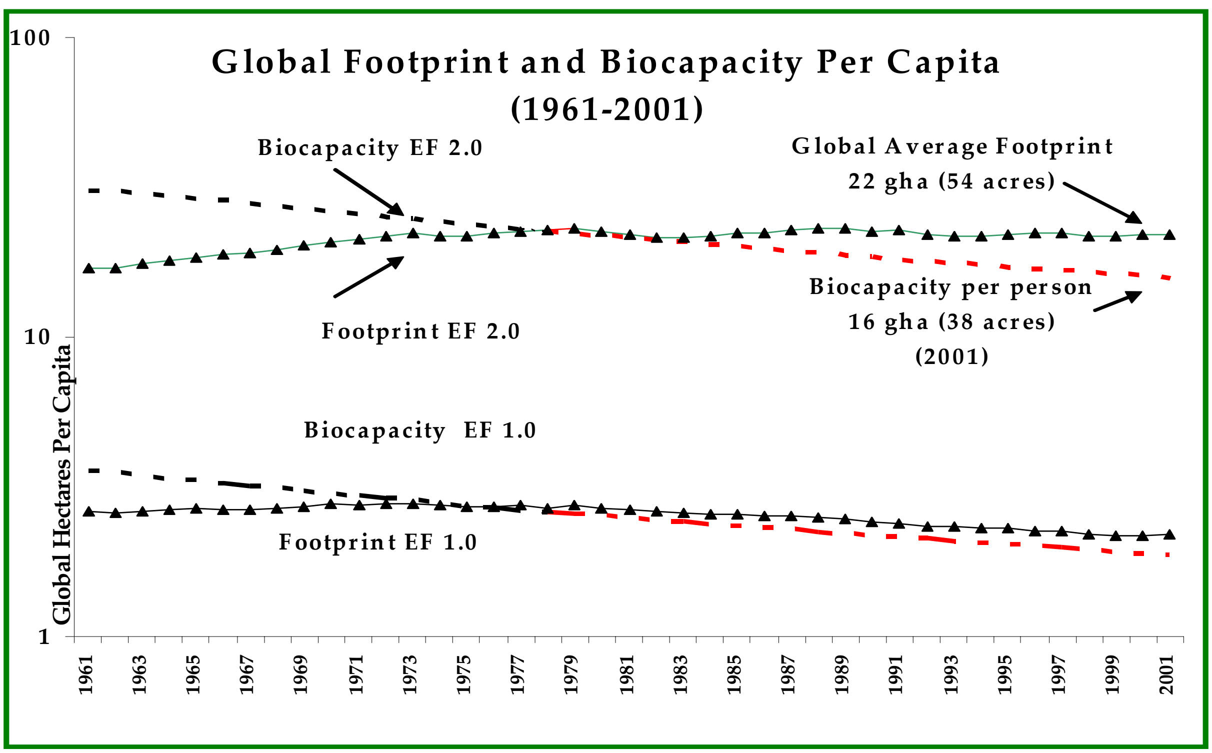
Biocapacity estimates rise from about 1.9 global hectares (gha) per capita under EF 1.0 to 15.71 gha under EF 2.0. As compared with EF 2.0, energy land is the greatest addition (8.27 gha per capita) since EF 1.0 assigns no biocapacity to this function. EF 2.0 also adds 3.11 gha per capita to biocapacity for less productive lands and open oceans where EF 1.0 assigns none. Footprint 2.0 increases the size of the average ecological footprint, as well as the share attributable to each biome. EF 2.0 indicates a footprint of nearly 22 gha per person – over 10 times the footprint size calculated by EF 1.0. EF 2.0 also has significantly larger footprints associated with forest land, pasture land, and marine and inland fisheries. The new equivalence factors explain most of this difference. Conversely, EF 2.0 shows a smaller built space footprint because built space is relatively less productive based on NPP estimates.

> *"This is the first time global footprint analysis has been able to capture unsustainable use of crop land, built space, and marine and inland fisheries."*

Both approaches show a negative ecological balance, or overshoot. EF 2.0: -6.20 gha per capita; EF 1.0: -0.33. On a per planet basis, if you will, EF 1.0 shows a footprint of 1.18 planets. That is, humanity's ecological footprint would require biocapacity the size of another planet that is 18% the size of Earth (at average biocapacity levels) to be sustainable. EF 2.0 shows a footprint of 1.39 planets, a 21% increase over EF 1.0.

While the global footprint accounts are dominated by energy, EF 2.0 also reveals ecological overshoot for crop land, built space, and marine and inland fisheries.

This is the first time global footprint analysis has been able to capture unsustainable use of these biomes. Fisheries in past EFA studies have been reported to be at the maximum, but sustainable, i.e. fish footprint equaled 0.14 gha/capita as does biocapacity associated with fisheries. EF 2.0 shows the footprint associated with fisheries at 1.04 gha/capita in 2001, which is about 16% larger than the sustainable rate. This appears to better correspond with research in the field (Pauly et al., 2001). Built space and crop land are also reported in deficit using Footprint 2.0, where EF 1.0 show sustainability.



While these changes may mark improvements in EFA, we still see the need for improvement in the use of sustainability criteria in EF 2.0. For example, both approaches do not fully capture precipitous declines in the world's forests over the last 100 years. And because EF 2.0 has not yet assigned a footprint to open oceans and less productive lands, our use of these biomes also appears to be within ecological limits. The differences between approaches are still worth further consideration in that they may represent the best measure, to date, of our ecological footprint.

On a per capita basis, and as illustrated by the chart on the previous page, EF 2.0 and EF 1.0 footprints diverge to a considerable extent. With EF 1.0, there is a rise in the footprint (from 2.61 to 2.79) between 1961 and 1973, then a fairly steady decline through 2001 (from 2.79 to 2.19). This could be due to several factors, including rising population or increases in yield factors. EF 2.0 shows per capita footprint increasing over the first twenty years and then becoming fairly stable within the range of 21 to 23 gha per capita thereafter. In the final tally, Footprint 2.0 shows humanity overshot sustainable biocapacity levels by about 8 global hectares per capita. Overshoot of renewable biocapacity suggests a draw down in natural capital to fill the gap. In the ensuing years, this means that there could be less natural capital (to provide renewable biocapacity services) for more people without changes in policy, markets, consumption patterns, and technology.

"Footprint 2.0 shows that humanity overshot sustainable biocapacity levels by about 6 global hectares (13 acres) in 2001 . . . "

In terms of global totals, both EF 1.0 and EF 2.0, show similar results in biocapacity through the period. Global ecological footprints have risen steadily under both approaches, but more steeply under EF 2.0. Ecological overshoot began in the late 1970s. Thereafter, overshoot has increased to about 18% with EF 1.0 and 39% with EF 2.0

Footprint 2.0 also appears to be more sensitive to carbon emissions overshoot and levels of built space. We found that those nations with higher shares of their energy met by fossil fuels and a more urbanized land base are contributing the most to global ecological deficits. Nations with more modest consumption, on the other hand and greater shares of their land base in forests, pasture, crop land, or fisheries tended to have smaller over all footprints with a higher percentage dedicated to food.

EF 2.0 footprint and biocapacity accounts for 138 nations and six regions are shown in Appendix 1. In general, under EF 2.0, nations that use relatively less fossil fuel energy, have larger land masses, and have greater shares of their biological capacity in pasture, forest, or marine and inland fisheries have smaller footprints and are more likely to run positive ecological balances and those with relatively higher fossil fuel use and greater shares of biological capacity devoted to built space are more likely to have larger footprints and run negative ecological balances. This is because EF 2.0 appears to be sensitive to the footprint associated with carbon emissions, puts greater emphasis on the ecological value of pasture land, forest land, and marine and inland fisheries and deemphasizes the ecological value of built space.

African, Asian-Pacific, Latin American, and Caribbean regions tend to fall into the former group and, as a whole, run positive ecological balances, as show in the Appendix. In these regions, the footprint is smaller than biocapacity, indicating that resource use may be sustainable. In contrast, nations in the Middle Eastern, Central Asian, North American, and European regions tend to fall into the latter group and, as a whole, run negative ecological balances. Here, footprints are generally larger than biocapacity indicating that resource use has overstepped ecological limits.

The five nations with the largest per capita ecological deficits (negative ecological balances) are the United Arab Emirates (-213), Kuwait (-146), the United States (-89), Belgium & Luxembourg (-62) and Netherlands (-56). Nations with the largest per capita ecological surpluses (positive ecological balances) are

Mongolia (163), Nambia (97), Gabon (96), Mauritania (68) and Papua New Guinea (65).

As was noted in the 2004 *Footprint of Nations* report, wealthier nations tend to run negative ecological balances, largely because of the high degree of correlation between affluence (expenditures) and fossil fuel consumption. In regions with more modest energy consumption, on the other hand, a higher percentage of their footprint is associated with food. The figures in Appendix 2 illustrate this fact. In the Asia Pacific, African, Latin American, and Caribbean regions, the energy footprint is 80% or less, while in Europe, North America, the Middle East, Europe and Central Asia the energy footprint share is 90% or greater.

Differences between regions are also revealed by comparing the breakdown of the footprint, excluding energy. In Central Europe the footprint associated with crop land is the largest of all categories, while in the rest of Europe fisheries appears to be taking up the largest percentage. In North America and Latin America, the extraction of forests makes up the largest footprint category.

Wealthier countries (despite technological advantages), were found to have larger footprints on a per capita basis as compared to their fellow global citizens that consume less. For example, footprints per capita in Africa in 2001 were 7 ½ gha (18.5 acres). In North America the average was 95 gha (234 acres). In the UAE the average footprint was 235 gha (578 acres). The amount of biocapacity available per person on a sustainable basis globally estimated with EF 2.0 is about 16 gha (30 acres).

FUTURE REFINEMENTS TO ECOLOGICAL FOOTPRINT ANALYSIS

The footprint provides an excellent framework for measuring the extent (area) of humanity's appropriation of natural resources and services within the context of sustainability. Since its inception, there has been continuous valuable advances in footprinting (Wackernagel et al. 2005). Our hope is that Footprint 2.0 adds to the concept and methodology on its way to becoming a genuine, scientifically robust, sustainability research tool.

While not yet having the opportunity to consider unforeseen problems with EF 2.0, we would suggest that the most important improvements in EFA still needed are: 1) establishing and incorporating sustainable thresholds; 2) refining the technique to better account for other species and land not included; and 3) developing a theoretical basis and methodology for dealing with water, other climate changing gases, and toxins. These are discussed at length in Venetoulis and Talberth (2006).

Additional refinements to EFA now being explored by RP include calculating the footprint of additional greenhouse gases, addressing the effects of environmental toxins, modeling the footprint of water consumption, and establishing sustainability criteria for fisheries, forests, and water.

While carbon dioxide makes up the largest share of climate changing gasses from anthropogenic sources, analyses that link methane (CH4), nitrous oxide (N2O), and fully fluorinated compounds (PFCs, HFCs and SF6) to appropriation of biocapacity would represent a significant step forward in making EFA more comprehensive and meaningful with respect to the effects of climate change.

At first glance, it appears very difficult, if not impossible, to convert the impacts associated with uranium, lead, arsenic, mercury, and other toxics into an area-based measure such as footprint. Footprinting is, after all, a quantitative indicator, not qualitative. Still, the relationship between concentrations of these toxins in a biome and its NPP may shed light on techniques to expand the scope of EFA to address these critical environmental concerns. Likewise, developing a defensible footprint for water consumption that captures aquifer depletion, loss of ecologically sustainable in-stream flows and degradation of water quality would represent a significant improvement in accounting for vital ecosystem services performed by lakes, rivers, streams, and underground water reserves. RP is seeking support and partners to continue to refine EFA to address these critical issues over the next year, in anticipation of its *Footprint of Nations 2006* report.

REFERENCES

Amthor, J.S. (team leader): 1998, Terrestrial Ecosystem Responses to Global Change: A Research Strategy, *ORNL Technical Memorandum 1998/27*, Ecosystems Working Group of the Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Chambers, N., Simmons, C., and M. Wackermenagel: 2000, *Sharing Nature's Interest: Using Ecological Footprints as an Indicator of Sustainability*. Earthscan, UK.

Ferguson, Andrew R.B.: 1999, 'The logical foundations of ecological footprints,' *Environment, Development, and Sustainability* 1, 149-156, 1999.

Ferng, Jiun-Jiun: 2005, 'Local sustainable yield and embodied resources in ecological footprint analysis-a case study on the required paddy in Taiwan,' *Ecological Economics* 53, 415-430.

Haberl, H. et al.: 2004, 'Human appropriation of net primary production and species diversity in agricultural landscapes,' *Agriculture, Ecosystems, and Environment* 102(2), 113-118.

Intergovernmental Panel on Climate Change (IPCC): 2004, 'Inter-annual and decadal variability of atmospheric CO2 concentrations", in *The Special Report on Land Use*, *Land-Use Change, and Forestry*, http://www.grida.no/climate/ipcc/land_use/020.htm#table1-2.

Lélé, Sharachchandra and Norgaard, R.B.: 2005, 'Practicing interdisciplinarity,' *Bioscience* 55(11), 967-975.

Pauly, D., and Watson, R.: 2001, 'Systematic distortions in world fisheries catch trends,' Nature 414, 534-536.

Rodrigues, et al.: 2003, 'Global Gap Analysis: towards a representative network of protected areas,' Advances in Applied *Biodiversity Science* 5, 73-74.

van den Bergh, J.C.J.M. and Verbruggen, H.: 1999, 'Spatial sustainability, trade and indicators: an evaluation of the ecological footprint,' *Ecological Economics* 29(1), 61-72.

United Nations Environmental Program (UNEP), *Convention on Biological Diversity: 2005, Indicators for Assessing Progress Towards the 2010 Target: Ecological Footprint and Related Concepts*.

Venetoulis, Jason and Talberth, John.: 2006, 'Net Primary Productivity as the Basis for Ecological Footprint Analysis,' submitted, Jan. 2006.

Vitousek, P.M., Ehrlich, P.R., Ehrlich, A.H., and Matson, P.A.: 1986, 'Human appropriation of the products of photosynthesis,' *Bioscience* 36, 368-373.

Rees, W. and Wackernagel, M.:1996. *Our Ecological Footprint*. New Society Publishers, Gabriola Island.

Wackernagel, M., Monfreda, C., Moran, D., Wermer, P., Goldfinger, S., Deumling, D., and Murray, M.: 2005, National Footprint and Biocapacity Accounts 2005: The Underlying Calculation Method, Global Footprint Network, Oakland, California.

Wright, D.H.: 1990, 'Human impacts on the energy flow through natural ecosystems and implications for species endangerment,' *Ambio*: A Journal of the Human Environment 19, 189-194.

Appendix 1
Ecological Footprint and Ecological Balance Per Capita in Global Hectares (2001 data)

	Cropland	Pasture	Forests	Fisheries	Built Space	Energy	Total FP	Biological Capacity	Ecological Balance (2.0)	Ecological Balance (1.0)	Difference
World	0.52	0.47	0.46	1.05	0.05	19.36	21.91	15.71	-6.20	-0.33	-5.87
Africa	0.45	0.80	0.38	0.73	0.04	5.07	7.48	27.51	20.03	2.05	17.98
Algeria	0.64	0.49	0.18	0.13	0.03	13.73	15.21	20.11	4.91	-1.09	6.00
Angola	0.32	0.38	0.22	0.79	0.02	4.68	6.41	44.71	38.30	7.74	30.56
Benin	0.41	0.29	0.49	0.55	0.04	1.28	3.06	10.24	7.18	0.19	6.99
Botswana	0.36	1.91	0.31	0.20	0.02	13.62	16.42	63.61	47.19	2.37	44.82
Burkina Faso	0.57	1.31	0.50	0.11	0.07	0.49	3.05	12.46	9.42	0.44	8.98
Burundi	0.29	0.14	0.62	0.19	0.03	0.23	1.50	7.36	5.86	-0.03	5.89
Cameroon	0.62	0.74	0.37	0.80	0.05	1.85	4.43	18.66	14.23	3.14	11.09
Central African Rep	0.63	1.89	0.45	0.49	0.04	0.69	4.19	47.40	43.21	6.12	37.09
Chad	0.47	1.74	0.46	1.26	0.04	0.24	4.21	32.96	28.75	0.60	28.15
Congo	0.22	0.12	0.31	1.61	0.05	1.15	3.46	55.90	52.44	13.11	39.33
Cote Divoire	0.48	0.20	0.43	0.50	0.06	2.17	3.84	14.52	10.68	1.57	9.11
Egypt	0.48	0.13	0.21	1.14	0.19	10.15	12.30	9.25	-3.05	-0.93	-2.12
Eritrea	0.25	0.84	0.28	0.30	0.04	1.08	2.79	13.63	10.83	0.60	10.24
Ethiopia	0.26	0.14	0.68	0.03	0.04	0.42	1.56	8.53	6.97	-0.24	7.22
Gabon	0.67	0.16	0.24	2.54	0.03	20.43	24.06	120.20	96.15	31.22	64.92
Gambia	0.54	0.73	0.31	0.89	0.04	1.28	3.78	10.64	6.86	0.08	6.78
Ghana	0.42	0.12	0.54	0.87	0.05	1.24	3.23	10.78	7.54	0.39	7.16
Guinea	0.31	0.84	0.73	0.68	0.05	0.90	3.51	21.10	17.59	2.17	15.42
Guinea-Bissau	0.42	1.08	0.32	0.62	0.02	1.20	3.65	28.60	24.95	3.13	21.82
Kenya	0.22	1.51	0.37	0.04	0.04	1.69	3.87	12.70	8.83	0.74	8.09
Lesotho	0.25	1.25	0.45	0.00	0.02	0.75	2.72	12.41	9.69	0.57	9.11
Liberia	0.23	0.06	0.72	0.56	0.04	0.59	2.20	20.39	18.19	2.88	15.31
Libya	0.89	0.37	0.12	0.57	0.03	37.51	39.50	71.09	31.60	-2.20	33.79
Madagascar	0.28	1.54	0.28	0.59	0.04	0.73	3.46	23.85	20.39	2.08	18.30
Malawi	0.29	0.08	0.25	0.48	0.05	0.71	1.86	8.50	6.64	0.24	6.40
Mauritania	0.37	4.32	0.24	0.46	0.04	5.84	11.28	79.77	68.49	0.81	67.67
Mauritius	0.57	0.40	0.23	2.01	0.08	19.02	22.31	58.41	36.11	-0.93	37.04
Morocco	0.51	0.32	0.08	0.56	0.03	4.73	6.22	10.65	4.43	-0.14	4.56
Mozambique	0.23	0.10	0.47	0.18	0.02	0.48	1.49	23.99	22.50	2.83	19.68
Namibia	0.99	1.93	0.00	3.40	0.07	3.28	9.67	106.96	97.30	3.18	94.11
Niger	0.70	0.34	0.16	0.14	0.04	0.54	1.92	26.84	24.91	-0.02	24.93
Nigeria	0.56	0.24	0.34	0.63	0.05	4.02	5.84	9.04	3.20	-0.03	3.23
Rwanda	0.33	0.26	0.48	0.11	0.04	0.44	1.65	7.13	5.48	0.01	5.47
Senegal	0.44	1.17	0.37	1.52	0.04	2.43	5.98	14.46	8.48	0.66	7.82
Sierra Leone	0.25	0.25	0.56	1.12	0.04	1.05	3.27	14.15	10.87	0.79	10.08
South Africa	0.65	1.62	0.60	0.51	0.06	37.19	40.62	20.80	-19.81	-0.32	-19.50
Sudan	0.45	1.68	0.33	0.18	0.04	1.56	4.23	18.99	14.76	1.05	13.71
Tanzania	0.24	1.25	0.34	0.96	0.05	0.55	3.39	15.81	12.42	1.34	11.08
Togo	0.59	0.25	0.60	0.49	0.03	1.87	3.83	9.05	5.23	-0.13	5.35
Tunisia	0.84	0.20	0.26	0.86	0.04	8.14	10.35	10.70	0.35	-0.66	1.01
Uganda	0.51	0.35	0.83	1.62	0.05	0.19	3.55	10.00	6.44	0.05	6.39
Zambia	0.52	0.53	0.41	0.77	0.03	0.63	2.89	30.40	27.51	3.77	23.74
Zimbabwe	0.28	1.11	0.39	0.17	0.02	7.06	9.03	16.35	7.32	1.19	6.13
Middle East and Central Asia	0.58	0.55	0.17	0.61	0.05	39.65	41.61	13.55	-28.06	-1.75	-26.32
Armenia	0.38	0.70	0.03	0.05	0.03	4.01	5.20	7.55	2.36	-0.36	2.72
Azerbaijan	0.52	0.96	0.08	0.04	0.03	18.98	20.60	11.64	-8.96	-0.80	-8.17
Georgia	0.41	1.11	0.01	0.04	0.02	6.01	7.60	9.36	1.76	-0.12	1.87
Iran	0.51	0.64	0.04	0.48	0.05	23.65	25.36	12.45	-12.91	-1.04	-11.87
Israel	0.83	0.41	0.50	2.29	0.09	52.30	56.42	6.55	-49.87	-4.14	-45.73
Jordan	0.53	0.28	0.18	0.53	0.06	14.06	15.64	9.06	-6.58	-1.30	-5.29
Kazakhstan	0.71	0.97	0.06	0.04	0.02	33.87	35.66	34.61	-1.05	-0.11	-0.94
Kuwait	0.54	0.35	0.27	0.63	0.15	152.98	154.91	8.41	-146.50	-9.43	-137.06
Kyrgyzstan	0.56	0.85	0.03	0.02	0.03	8.70	10.19	10.19	0.00	8.83	-8.83
Lebanon	0.65	0.24	0.36	0.33	0.07	22.24	23.90	6.33	-17.57	-1.96	-15.62
Saudi Arabia	0.85	0.29	0.22	0.75	0.09	65.89	68.10	23.19	-44.91	-3.31	-41.60
Syria	0.57	0.21	0.06	0.19	0.06	17.27	18.36	7.98	-10.39	-0.85	-9.54
Tajikistan	0.27	0.31	0.02	0.00	0.02	4.02	4.64	9.65	5.01	-0.29	5.30
Turkey	0.82	0.53	0.28	0.56	0.06	14.01	16.25	9.08	-7.17	-0.77	-6.40
Turkmenistan	0.60	0.76	0.01	0.04	0.03	26.42	27.86	25.40	-2.46	-0.59	-1.88
United Arab Emirates	1.18	0.42	0.83	4.22	0.08	226.13	232.86	19.43	-213.43	-13.76	-199.66
Uzbekistan	0.31	0.42	0.01	0.02	0.04	19.78	20.58	20.58	0.00	-1.10	1.10
Yemen	0.28	0.40	0.03	0.68	0.04	3.43	4.87	12.45	7.58	-0.33	7.91

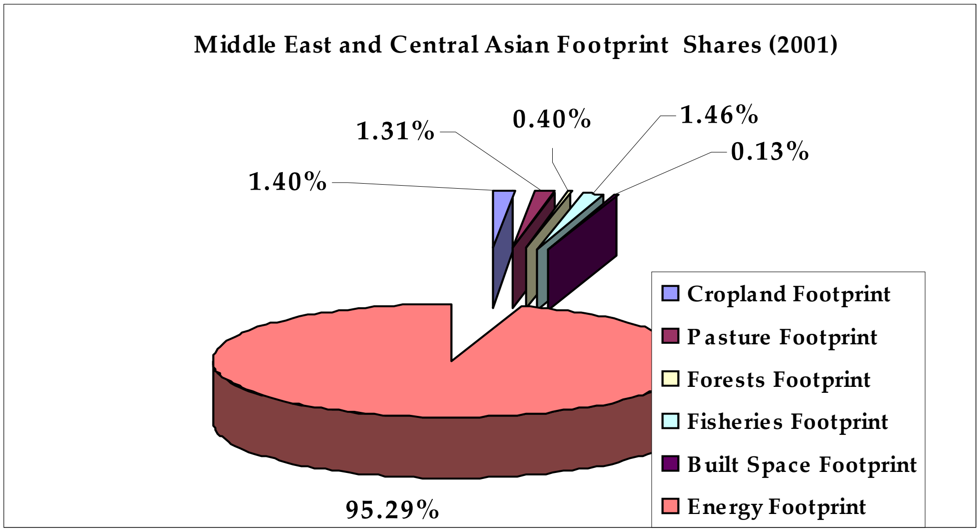
Ecological Footprint and Ecological Balance Per Capita in Global Hectares (continued)

	Cropland	Pasture	Forests	Fisheries	Built Space	Energy	Total FP	Biological Capacity	Ecological Balance (2.0)	Ecological Balance (1.0)	Difference
Asia-Pacific	0.53	1.09	0.51	1.69	0.04	15.55	19.42	29.97	10.55	2.15	8.40
Australia	1.85	1.84	1.57	2.10	0.05	71.63	79.05	110.21	31.16	4.36	26.80
Bangladesh	0.23	0.03	0.10	0.68	0.03	1.27	2.33	6.50	4.17	-0.14	4.31
Cambodia	0.31	0.50	0.34	0.09	0.03	0.24	1.51	10.56	9.05	0.78	8.28
China	0.39	0.12	0.21	1.18	0.04	10.53	12.46	8.36	-4.10	-0.33	-3.77
India	0.29	0.02	0.15	0.19	0.02	4.15	4.83	6.93	2.10	-0.10	2.20
Indonesia	0.32	0.15	0.28	0.87	0.03	6.39	8.03	12.54	4.50	0.93	3.58
Japan	0.48	0.20	0.61	4.09	0.09	47.73	53.21	8.77	-44.44	-3.62	-40.82
Korea DPRP	0.29	0.01	0.20	0.75	0.03	42.66	43.93	9.11	-34.82	-1.76	-33.06
Korea Republic	0.50	0.16	0.46	3.61	0.07	34.89	39.69	9.04	-30.65	-2.57	-28.07
Laos	0.27	0.76	0.58	1.28	0.03	0.34	3.26	23.81	20.55	4.64	15.91
Malaysia	0.59	0.30	0.44	4.04	0.04	30.07	35.48	17.10	-18.38	0.44	-18.82
Mongolia	0.38	15.05	0.26	0.01	0.01	11.05	26.77	189.89	163.12	25.17	137.95
Myanmar	0.41	0.05	0.39	0.73	0.03	0.98	2.58	11.99	9.40	1.06	8.35
Nepal	0.28	0.22	0.31	0.08	0.03	0.68	1.60	7.54	5.93	0.12	5.81
New Zealand	2.91	2.85	2.72	6.45	0.10	33.51	48.54	84.73	36.18	2.47	33.72
Pakistan	0.30	0.02	0.13	0.39	0.02	3.84	4.69	7.07	2.39	-0.29	2.67
Papua New Guinea	0.26	0.18	0.80	2.03	0.03	1.81	5.11	70.08	64.97	14.69	50.28
Philippines	0.27	0.17	0.32	2.13	0.03	5.63	8.55	7.99	-0.56	-0.45	-0.11
Sri Lanka	0.26	0.19	0.23	1.76	0.03	3.58	6.04	8.25	2.21	-0.36	2.57
Thailand	0.31	0.10	0.27	1.89	0.03	13.35	15.95	9.67	-6.27	-0.14	-6.13
Vietnam	0.27	0.06	0.24	1.21	0.05	2.31	4.12	9.14	5.02	0.20	4.82
Latin America & Caribbean	0.49	1.95	0.57	0.64	0.05	13.20	16.90	22.22	5.31	1.67	3.64
Argentina	1.04	3.12	0.28	0.76	0.05	17.81	23.05	39.26	16.20	4.24	11.96
Bolivia	0.40	3.28	0.21	0.10	0.03	6.97	11.00	48.60	37.60	8.63	28.97
Brazil	0.66	2.92	1.02	0.59	0.05	8.88	14.11	29.16	15.05	4.67	10.38
Chile	0.52	1.46	1.85	1.25	0.08	14.28	19.44	39.84	20.40	1.41	18.98
Colombia	0.29	2.70	0.18	0.37	0.05	7.57	11.17	18.57	7.41	1.92	5.48
Costa Rica	0.38	1.42	1.05	0.28	0.08	11.11	14.32	18.85	4.54	0.58	3.96
Cuba	0.59	0.32	0.15	0.40	0.03	11.61	13.10	9.60	-3.50	-0.48	-3.02
Ecuador	0.35	1.59	0.73	1.00	0.04	9.86	13.56	15.92	2.36	1.03	1.33
El Salvador	0.34	0.92	0.55	0.20	0.03	5.53	7.57	7.43	-0.14	-0.59	0.45
Guatemala	0.31	0.87	0.67	0.04	0.05	5.69	7.64	10.33	2.69	0.25	2.44
Haiti	0.26	0.41	0.15	0.12	0.02	1.18	2.15	7.18	5.03	-0.23	5.26
Honduras	0.37	1.38	0.75	0.10	0.04	5.79	8.44	13.54	5.11	0.39	4.72
Jamaica	0.44	0.73	0.48	1.18	0.04	23.02	25.90	11.49	-14.41	-1.72	-12.69
Mexico	0.75	1.58	0.34	0.63	0.04	19.80	23.14	14.34	-8.81	-0.66	-8.15
Nicaragua	0.66	1.25	0.52	0.13	0.04	4.81	7.42	19.41	11.99	2.05	9.93
Panama	0.55	2.01	0.28	0.59	0.04	18.85	22.32	22.84	0.51	1.32	-0.81
Paraguay	0.47	3.34	1.19	0.55	0.04	4.27	9.86	34.37	24.51	5.44	19.07
Peru	0.43	1.20	0.19	1.48	0.05	3.71	7.06	30.11	23.05	5.16	17.89
Trinidad and Tobago	0.47	0.31	0.28	1.35	0.04	59.87	62.31	11.53	-50.78	-3.92	-46.86
Uruguay	0.58	8.12	1.00	1.29	0.04	11.60	22.64	44.42	21.77	4.58	17.19
Venezuela	0.43	2.06	0.14	1.04	0.05	25.08	28.80	19.75	-9.05	0.99	-10.04
North America	1.72	1.01	2.69	1.59	0.15	88.83	95.99	53.16	-42.83	-0.93	-41.90
Canada	1.90	1.06	2.74	1.31	0.12	75.91	83.03	85.95	2.92	3.12	-0.21
United States of America	1.53	0.96	2.65	1.86	0.18	101.76	108.95	20.37	-88.58	-4.99	-83.60
Western Europe	0.98	0.53	1.78	2.87	0.11	54.45	60.70	16.84	-43.86	-2.73	-41.13
Austria	0.82	0.60	1.92	1.04	0.06	46.69	51.13	9.94	-41.19	-3.07	-38.12
Belgium & Luxembourg	0.85	0.44	0.00	2.02	0.13	65.43	68.87	7.19	-61.69	-4.64	-57.05
Denmark	1.26	0.45	3.28	1.69	0.11	55.04	61.84	16.28	-45.56	-2.64	-42.92
Finland	1.03	0.10	5.69	1.98	0.25	35.44	44.48	32.16	-12.33	2.12	-14.45
France	1.13	0.63	1.10	2.51	0.10	60.36	65.82	11.29	-54.54	-3.29	-51.25
Germany	0.73	0.22	0.87	1.22	0.14	49.04	52.21	8.44	-43.77	-2.75	-41.02
Greece	1.16	1.16	0.51	2.43	0.07	62.53	67.85	11.79	-56.06	-3.68	-52.38
Ireland	1.21	0.62	1.19	1.64	0.07	60.69	65.42	27.02	-38.40	-1.48	-36.92
Italy	0.86	0.49	0.69	1.75	0.03	37.68	41.51	8.05	-33.46	-2.65	-30.81
Netherlands	0.93	0.51	0.98	1.39	0.09	65.19	69.09	7.96	-61.13	-4.58	-56.54
Norway	0.76	0.16	2.40	5.91	0.09	83.81	93.13	48.89	-44.24	-2.90	-41.34
Portugal	0.93	0.66	1.02	10.03	0.09	36.47	49.20	16.33	-32.88	-3.58	-29.30
Spain	1.10	0.69	0.84	4.58	0.05	43.42	50.68	10.44	-40.24	-3.19	-37.05
Sweden	1.20	0.34	5.34	2.51	0.24	57.13	66.76	26.38	-40.38	-0.93	-39.45
United Kingdom	0.71	0.81	0.81	2.33	0.09	57.81	62.56	10.45	-52.11	-3.73	-48.38

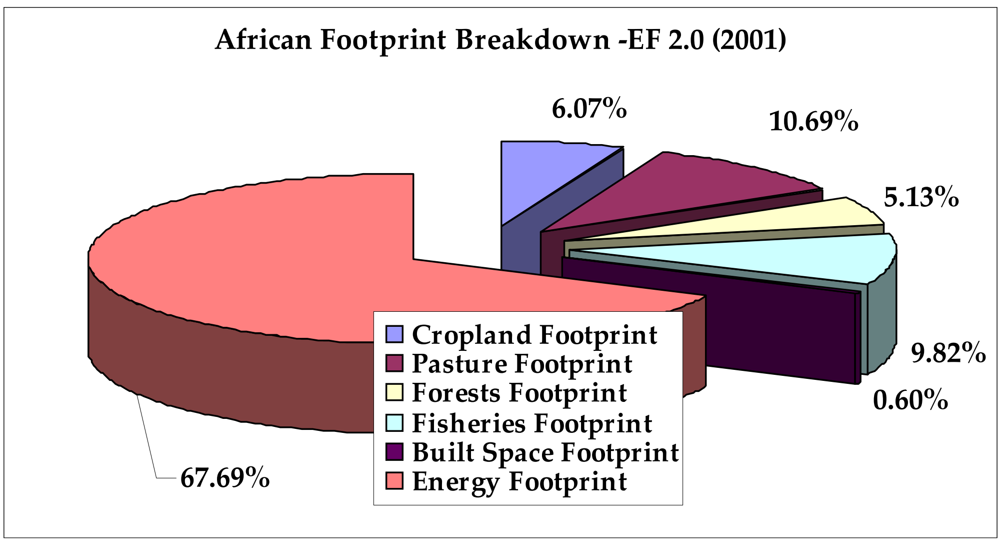
Ecological Footprint and Ecological Balance Per Capita in Global Hectares (continued)

	Cropland	Pasture	Forests	Fisheries	Built Space	Energy	Total FP	Biological Capacity	Ecological Balance (2.0)	Ecological Balance (1.0)	Difference
Central and Eastern Europe	0.96	0.53	0.86	0.67	0.04	28.30	31.36	12.45	-18.91	-0.99	-17.92
Albania	0.65	0.44	0.13	0.20	0.04	8.43	9.90	8.29	-1.61	-0.55	-1.05
Belarus	0.89	0.75	0.45	0.42	0.03	32.62	35.17	12.23	-22.94	-0.79	-22.15
Bosnia Herzegovina	0.59	0.97	0.70	0.26	0.03	18.64	21.20	8.13	-13.07	-1.67	-11.40
Bulgaria	1.07	0.52	0.36	0.19	0.04	31.47	33.65	10.76	-22.88	-1.33	-21.56
Croatia	0.90	0.45	0.71	0.78	0.05	25.75	28.64	12.87	-15.77	-0.80	-14.97
Czech Republic	0.99	0.25	1.29	0.98	0.06	43.67	47.24	9.95	-37.30	-2.09	-35.21
Estonia	1.24	0.51	3.31	1.39	0.04	23.36	29.84	20.97	-8.88	-0.11	-8.77
Hungary	0.73	0.32	0.69	0.51	0.06	32.62	34.93	9.28	-25.65	-1.10	-24.55
Latvia	2.06	0.65	2.66	-0.12	0.03	18.83	24.11	18.75	-5.36	0.63	-6.00
Lithuania	1.40	0.36	0.82	2.33	0.04	32.56	37.51	12.41	-25.10	-1.22	-23.88
Macedonia	0.67	1.05	0.38	0.54	0.03	23.24	25.92	8.32	-17.60	-1.74	-15.86
Moldova Republic	0.64	0.24	0.09	0.15	0.03	8.37	9.52	7.73	-1.79	-0.21	-1.59
Poland	1.00	0.29	0.70	0.88	0.05	31.38	34.31	9.18	-25.13	-1.54	-23.59
Romania	0.78	0.67	0.42	0.19	0.04	26.84	28.94	8.24	-20.71	-1.65	-19.05
Russia	1.28	0.82	0.70	1.87	0.03	43.65	48.35	35.94	-12.42	0.69	-13.11
Slovakia	0.79	0.42	0.95	0.45	0.04	33.56	36.22	10.73	-25.48	-1.19	-24.29
Slovenia	0.70	0.42	0.88	0.48	0.05	36.05	38.57	10.88	-27.69	-1.34	-26.35
Ukraine	0.97	0.42	0.18	0.48	0.04	38.36	40.46	9.52	-30.94	-1.75	-29.19

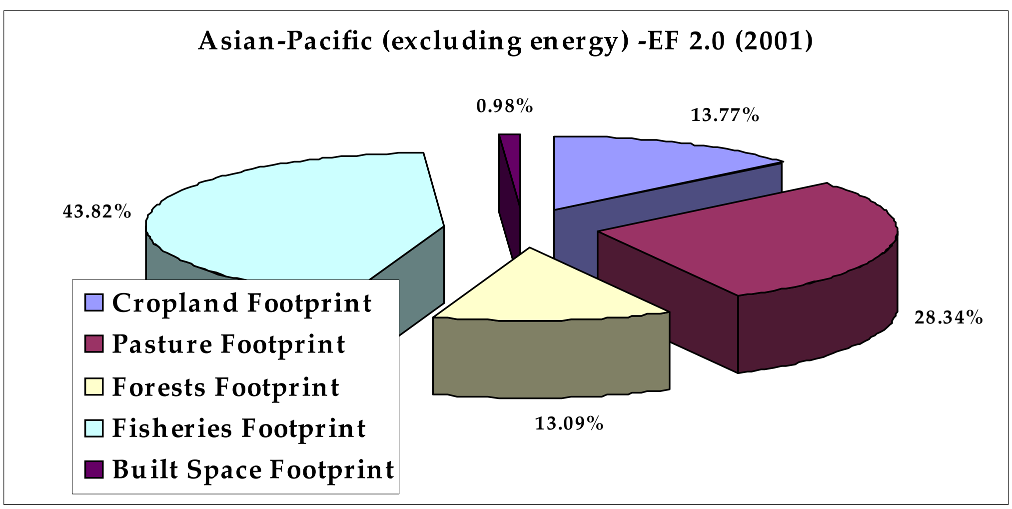
Appendix 2



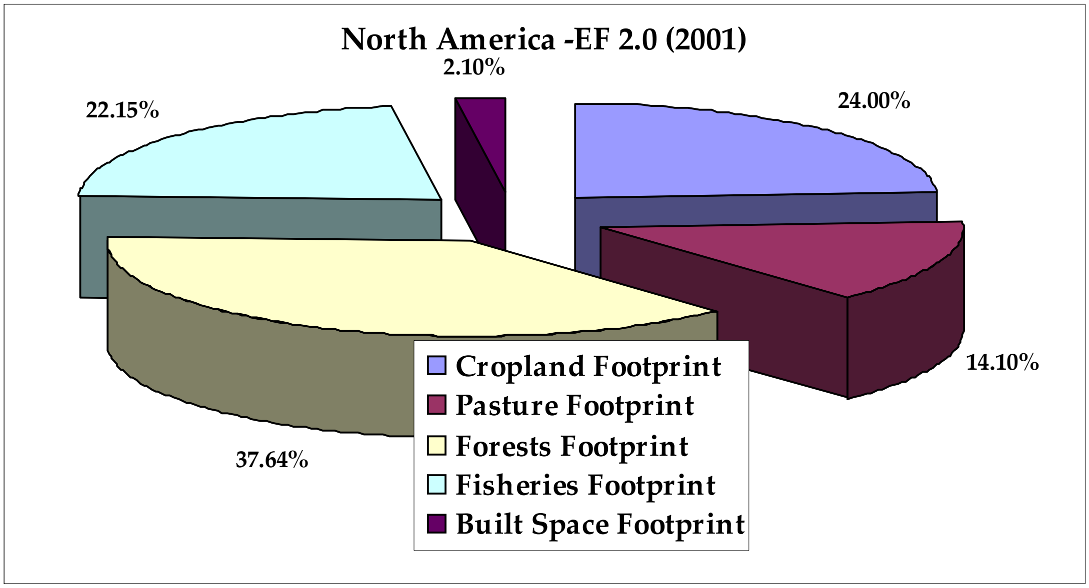
Middle East and Central Asian Footprint Shares (2001)
1.31%
0.40%
1.46%
0.13%
1.40%
95.29%
Cropland Footprint
Pasture Footprint
Forests Footprint
Fisheries Footprint
Built Space Footprint
Energy Footprint

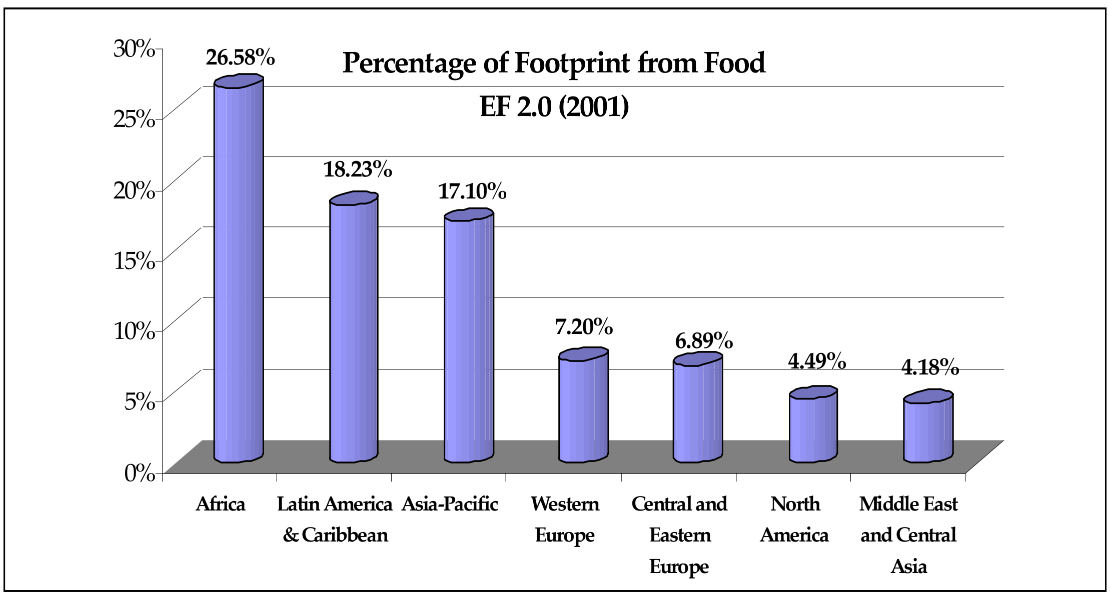


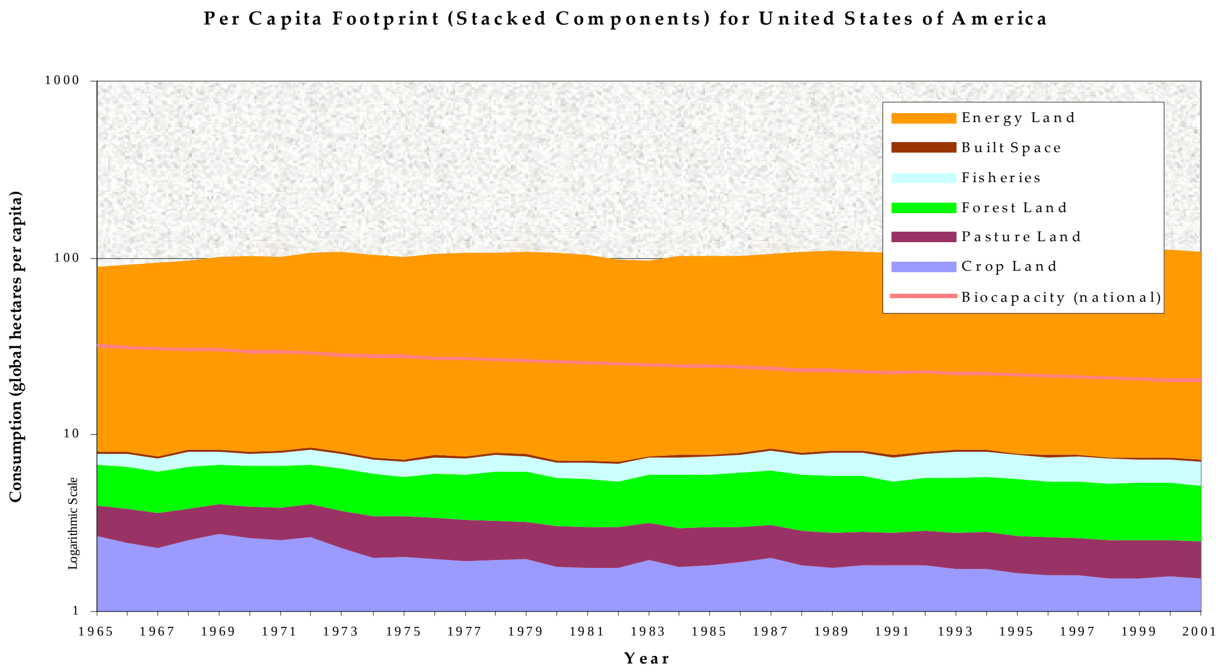
African Footprint Breakdown -EF 2.0 (2001)
6.07%
10.69%
5.13%
9.82%
0.60%
67.69%
Cropland Footprint
Pasture Footprint
Forests Footprint
Fisheries Footprint
Built Space Footprint
Energy Footprint



Asian-Pacific (excluding energy) -EF 2.0 (2001)
0.98%
13.77%
43.82%
28.34%
13.09%
Cropland Footprint
Pasture Footprint
Forests Footprint
Fisheries Footprint
Built Space Footprint


North America -EF 2.0 (2001)
2.10%
22.15%
24.00%
14.10%
37.64%
Cropland Footprint
Pasture Footprint
Forests Footprint
Fisheries Footprint
Built Space Footprint


Percentage of Footprint from Food
EF 2.0 (2001)
30%
25%
20%
15%
10%
5%
0%
26.58%
18.23%
17.10%
7.20%
6.89%
4.49%
4.18%
Africa
Latin America & Caribbean
Asia-Pacific
Western Europe
Central and Eastern Europe
North America
Middle East and Central Asia


Per Capita Footprint (Stacked Components) for United States of America
1000
100
10
1
Consumption (global hectares per capita)
Logarithmic Scale
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
Year
Energy Land
Built Space
Fisheries
Forest Land
Pasture Land
Crop Land
Biocapacity (national)