


CALCULATION METHODOLOGY FOR THE NATIONAL FOOTPRINT ACCOUNTS, 2008 EDITION

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Calculation Methodology for the National Footprint Accounts, 2008 Edition (Version 1.1)

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ABSTRACT

Human demand on ecosystem services continues to increase, and there are indications that this demand may be outpacing the regenerative and absorptive capacity of the biosphere. The productivity of natural capital may increasingly become a limiting factor for the human endeavour. Therefore, metrics tracking human demand on, and availability of, regenerative and waste absorptive capacity within the biosphere are needed. The Ecological Footprint is one such metric; it measures human appropriation of ecosystem products and services in terms of the amount of bioproductive land and sea area needed to supply these services. The area of land or sea available to serve a particular use is called biocapacity, and represents the biosphere's ability to meet human demand for material consumption and waste disposal. The Ecological Footprint and biocapacity accounts cover six land use types: cropland, grazing land, fishing ground, forest land, built-up land and carbon uptake land (to accommodate the Carbon Footprint). For each component, the demand for ecological services is divided by the yield for those ecological services to arrive at the Footprint of each land use type. Ecological Footprint and biocapacity are scaled with yield factors and equivalence factors to convert this physical land demanded to world average biologically productive land called global hectares. This allows for comparisons between various land use types with differing productivities. The National Footprint Accounts calculate the Ecological Footprint and biocapacity of individual countries and of the world. According to the 2008 edition of the National Footprint Accounts, humanity demanded the resources and services of 1.31 planets in 2005. This situation, in which total demand for ecological goods and services exceeds the available supply, is known as overshoot. On the global scale, overshoot indicates that stocks of ecological capital are depleting or that waste is accumulating.

INTRODUCTION

Humanity relies on ecosystem products and services including resources, waste absorptive capacity, and space to host urban infrastructure. Environmental changes such as deforestation, collapsing fisheries, and CO_2 accumulation in the atmosphere indicate that human demand may well have exceeded the regenerative and absorptive capacity of the biosphere. Careful management of human interaction with the biosphere is essential to ensuring future prosperity. This requires reliable metrics for tracking the regenerative and waste absorptive capacity of the biosphere. Such metrics are essential in assessing current ecological supply and demand, setting goals, identifying options for action, and tracking progress toward stated goals.

Providing such a metric is the goal of Ecological Footprint Accounts. In 1997, Mathis Wackernagel and his colleagues at the Universidad Anáhuac de Xalapa started the first systematic attempt to assess the Footprint and biocapacity of nations (Wackernagel et al. 1997). Building on these assessments, Global Footprint Network initiated its National Footprint Accounts in 2003 with the most recent edition being issued in 2008. The National Footprint Accounts quantify annual supply of and demand for ecosystem products and services in a static, descriptive accounting framework. The 2008 edition of the National Footprint Accounts calculate the Ecological Footprint and biological capacity of 201 countries and the world from 1961 to 2005 for which complete data sets are available through UN statistics (Global Footprint Network 2008). The intent behind the National Footprint Accounts is to provide scientifically robust and transparent calculations that allow for comparisons of countries' demands on global regenerative and absorptive capacity.

The Ecological Footprint calculates the demand that populations and activities place on the biosphere in a given year, with the prevailing technology and resource management of that year. The Ecological Footprint uses the yields per unit area of primary product flows to calculate the area necessary to support a given activity. The supply created by the biosphere is called the biological capacity, or biocapacity. Biocapacity is a measure of the amount of biologically productive land and sea area available to provide the ecosystem services that humanity consumes. The land uses captured in the Ecological Footprint are assumed to be mutually exclusive.

This paper describes the methodology for calculating the Ecological Footprint and biocapacity at the national level. Since global data sets on production and trade are generally only available at the national level, the National Footprint Accounts are the foundation for sub-national, organizational, and product Footprint analyses. This paper provides the fundamental calculations and principles utilized in the 2008 edition of the National Footprint Accounts. It provides researchers and practitioners with information that will deepen their understanding of the calculation methodology for the Ecological Footprint, biocapacity, yield factors, equivalence factors, and the specific land use types included in the Ecological Footprint: Cropland, grazing land, fishing ground, forest land, carbon uptake land, and built-up land.

The calculations in the National Footprint Accounts are based primarily on international data sets published by the Food and Agriculture Organization of the United Nations (FAO ResourceSTAT Statistical Database 2007), the International Energy Agency (IEA 2006), the UN Statistics Division (UN Commodity Trade Statistics Database – UN Comtrade 2007), and the Intergovernmental Panel on Climate Change (IPCC 2006). Other data sources include studies in peer-reviewed science journals and thematic collections. Of the 201 countries analyzed in the National Footprint Accounts, 150 had populations over one million and were covered consistently by the UN statistical system.

The actual implementation of the National Footprint Accounts through database-supported templates is described in the *Guidebook to the National Footprint Accounts 2008* (Kitzes et al. 2008). These accounts are maintained and updated by Global Footprint Network with the support of more than 100 partner organizations.

FUNDAMENTAL ASSUMPTIONS OF ECOLOGICAL FOOTPRINT ACCOUNTING

Ecological Footprint accounting is based on six fundamental assumptions (Wackernagel et al. 2002):

- The majority of the resources people consume and the wastes they generate can be tracked.
- Most of these resource and waste flows can be measured in terms of the biologically productive area necessary to maintain flows. Resource and waste flows that cannot be measured are excluded from the assessment, leading to a systematic underestimate of humanity's true Ecological Footprint.
- By weighting each area in proportion to its bioproductivity, different types of areas can be converted into the common unit of global hectares, hectares with world average bioproductivity.
- Because a single global hectare represents a single use, and all global hectares in any single year represent the same amount of bioproductivity, they can be added up to obtain an aggregate indicator of Ecological Footprint or biocapacity.
- Human demand, expressed as the Ecological Footprint, can be directly compared to nature's supply, biocapacity, when both are expressed in global hectares.
- Area demanded can exceed area supplied if demand on an ecosystem exceeds that ecosystems regenerative capacity (e.g., humans can temporarily demand more biocapacity

from forests, or fisheries, than those ecosystems have available). This situation, where Ecological Footprint exceeds available biocapacity, is known as overshoot.

FOOTPRINT AND BIOCAPACITY CALCULATIONS

The Ecological Footprint represents appropriated biocapacity, and biocapacity represents the availability of bioproductive land. For any land use type, the Ecological Footprint *EF* of a country, in global hectares, is given by

$$EF = \frac{P}{Y_N} \cdot YF \cdot EQF \qquad \text{(Eq. 1a)}$$

where *P* is the amount of a product harvested or waste emitted, Y_N is the national average yield for *P*, and *YF* and *EQF* are the yield factor and equivalence factor, respectively, for the land use type in question.

A country's biocapacity *BC* for any land use type is calculated as follows:

$$BC = A \cdot YF \cdot EQF \qquad \text{(Eq. 2)}$$

where *A* is the area available for a given land use type.

Secondary Products

Summing the Footprints of all primary harvests and waste absorptive capacity of ecosystem services yields the total Footprint of a country's domestic production. However, in some cases it is necessary to know the Ecological Footprint of products derived from the primary flows of ecosystem goods. Primary and derived goods are related by product specific extraction rates. Primary and derived goods are related by product specific extraction rates. The extraction rate for a derived product, $EXTR_D$, is used to calculate its effective yield as follows:

$$Y_D = Y_P \cdot EXTR_D \qquad \text{(Eq. 3a)}$$

where Y_P and Y_D are the yield for the primary product and the effective yield for the derived product, respectively.

Usually, $EXTR_D$ is simply the mass ratio of derived product to primary input required. This ratio is known as the technical conversion factor for the derived product, denoted TCF_D below. There are few cases where multiple derived products are created simultaneously from the same primary product. Soybean oil and soybean cake, for example, are both extracted simultaneously from the same primary product, in this case soybean. Summing the primary product equivalents would lead to double counting, so the Footprint of the primary product must be shared between the simultaneously derived goods. The extraction rate for a derived good *D* is given by

$$EXTR_D = \frac{TCF_D}{FAF_D} \qquad \text{(Eq. 3b)}$$

where FAF_D is the Footprint allocation factor. This allocates the Footprint of a primary product between simultaneously derived goods according to the TCF-weighted prices. The prices of derived goods represent their relative contributions to the incentive for the harvest of the primary product. The equation for the Footprint allocation factor of a derived product is

$$FAF_D = \frac{TCF_D V_D}{\sum TCF_i V_i} \quad \text{(Eq. 3c)}$$

where V_i is the market price of each simultaneous derived product. For a production chain with only one derived product, then, FAF_D is 1 and the extraction rate equals the technical conversion factor.

NORMALIZING BIOPRODUCTIVE AREAS – FROM HECTARES TO GLOBAL HECTARES

Average bioproductivity differs between various land use types, as well as between countries for any given land use type. For comparability across countries and land use types, Ecological Footprint and biocapacity are usually expressed in units of world-average bioproductive area. Expressing Footprints in world-average hectares also facilitates tracking the embodied bioproductivity in international trade flows.

Yield Factors

Yield factors account for countries' differing levels of productivity for particular land use types. The yield factor provides comparability between various countries' Ecological Footprint or biocapacity calculations. In every year, each country has a yield factor for cropland, grazing land, forest land, and fishing grounds. As a default, the yield factor for built-up land is assumed to be the same as that for cropland since urban areas are typically built on or near the most productive agricultural lands. Natural factors such as differences in precipitation or soil quality, as well as management practices, may underpin differences in productivity.

Yield factors weight land areas according to their relative productivities. For example, the average hectare of pasture in New Zealand produces more grass than a world average hectare of pasture land. Thus, in terms of productivity, one hectare of grassland in New Zealand is equivalent to more than one world average grazing land hectare; it is potentially capable of supporting more meat production. Table 1 shows the yield factors calculated for several countries in the 2008 edition of Global Footprint Network's National Footprint Accounts.

	Cropland	Forest	Grazing Land	Fishing Ground
World average yield	**1.0**	**1.0**	**1.0**	**1.0**
Algeria	0.6	0.9	0.7	0.9
Guatemala	0.9	0.8	2.9	1.1
Hungary	1.5	2.1	1.9	0.0
Japan	1.7	1.1	2.2	0.8
Jordan	1.1	0.2	0.4	0.7
New Zealand	2.0	0.8	2.5	1.0
Zambia	0.5	0.2	1.5	0.0

Table 1: Sample Yield Factors for Selected Countries, 2005.

The yield factor is the ratio of national- to world-average yields. It is calculated in terms of the annual availability of usable products. A country's yield factor YF_L, for any given land use type L, is given by

$$YF_L = \frac{\sum_{i \in U} A_{W,i}}{\sum_{i \in U} A_{N,i}} \qquad \text{(Eq. 4a)}$$

where U is the set of all usable primary products that a given land use type yields, and $A_{W,i}$ and $A_{N,i}$ are the areas necessary to furnish that country's annually available amount of product i at world and national yields, respectively. These areas are calculated as

$$A_{N,i} = \frac{P_i}{Y_N} \text{ (Eq. 5a) and } A_{W,i} = \frac{P_i}{Y_W} \qquad \text{(Eq. 5b)}$$

where P_i is the total national annual growth of product i and Y_N and Y_W are national and world yields, respectively. Thus $A_{N,i}$ is always the area that produces i within a given country, while $A_{W,i}$ gives the equivalent area of world-average land yielding i.

Most land use types in the Ecological Footprint provide only a single primary product, such as wood from forest land or grass from pasture land. For these, the equation for the yield factor simplifies to

$$YF_L = \frac{Y_N}{Y_W} \qquad \text{(Eq. 4b)}$$

For land use types yielding only one product, combining Eqs. 4b and 1a gives the simplified formula for the Ecological Footprint, in global hectares:

$$EF = \frac{P}{Y_W} \cdot EQF \qquad \text{(Eq. 1b)}$$

In practice, cropland is the only land use type for which the extended form of the yield factor calculation is employed.

Equivalence Factors

In order to combine the Ecological Footprints or biocapacities of different land use types, a second scaling factor is necessary. Equivalence factors convert the actual areas in hectares of different land use types into their global hectare equivalents. Equivalence and yield factors are applied to both Footprint and biocapacity calculations to provide results in consistent, comparable units.

Equivalence factors translate the area supplied or demanded of a specific land use type (i.e. world average cropland, grazing land, forest land, fishing grounds, carbon uptake land, and built-up land) into units of world average biologically productive area: global hectares. The equivalence factor for built-up land is set equal to that for cropland and carbon uptake land is set equal to that for forest land. This reflects the assumptions that infrastructure tends to be on or near productive agricultural land, and that carbon uptake occurs on forest land. The equivalence factor for hydro area is set equal to one, which assumes that hydroelectric reservoirs flood world average land. The equivalence factor for marine area is calculated such that a single global hectare of pasture will produce an amount of calories of beef equal to the amount of calories of salmon that can be produced by a single global hectare of marine area. The equivalence factor for inland water is set equal to the equivalence factor for marine area.

In 2005, for example, cropland had an equivalence factor of 2.64 indicating that world-average cropland productivity was more than double the average productivity for all land combined. This same year, grazing land had an equivalence factor of 0.40, showing that grazing land was, on average, 40 per cent as productive as the world-average bioproductive hectare. Equivalence factors are calculated for every year, and are identical for every country in a given year.

Area Type	Equivalence Factor (gha/ha)
Primary Cropland	2.64
Forest	1.33
Grazing Land	0.50
Marine	0.40
Inland Water	0.40
Built-up Land	2.64

Table 2: Equivalence Factors, 2005.

Equivalence factors are currently calculated using suitability indexes from the Global Agro-Ecological Zones model combined with data on the actual areas of cropland, forest land, and grazing land area from FAOSTAT (FAO and IIASA Global Agro-Ecological Zones 2000 FAO ResourceSTAT Statistical Database 2007). The GAEZ model divides all land globally into five categories, based on calculated potential crop productivity. All land is assigned a quantitative suitability index from among the following:

- Very Suitable (VS) – 0.9
- Suitable (S) – 0.7
- Moderately Suitable (MS) – 0.5
- Marginally Suitable (mS) – 0.3
- Not Suitable (NS) – 0.1

The calculation of the equivalence factors assumes the most productive land is put to its most productive use: the most suitable land available will be planted to cropland, the next most suitable land will be under forest land, and the least suitable land will be grazing land. The equivalence factors are calculated as the ratio of the average suitability index for a given land use type divided by the average suitability index for all land use types. Figure 1 shows a schematic of this calculation.

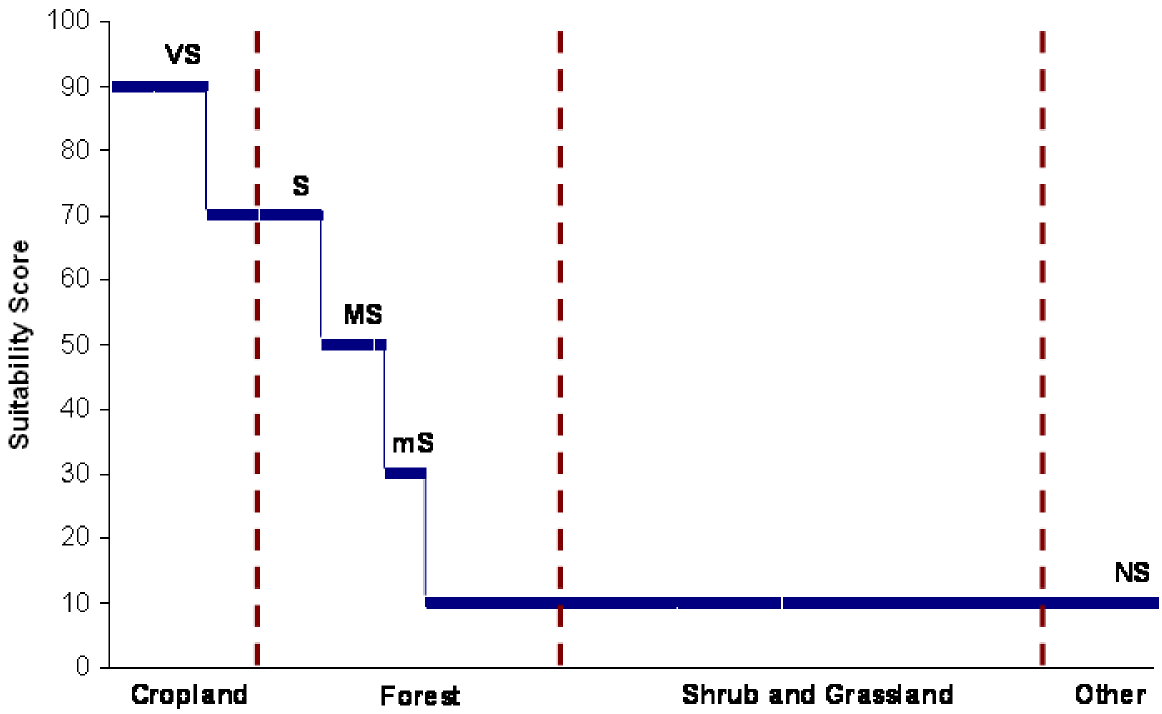

Figure 1 *Schematic Representation of Equivalence Factor Calculations*. The total number of bioproductive land hectares is shown by the length of the horizontal axis. Vertical dashed lines divide this total land area into three land types (cropland, forest, and grazing land). The length of each horizontal bar in the graph shows the total amount of land available with each suitability index. The vertical location of each bar reflects the suitability score for that suitability index, between 10 and 90.

TRADE

All manufacturing processes rely on the use of biocapacity, to provide material inputs and remove wastes at various points in the production chain. Thus all products carry with them an embodied Footprint, and international trade flows in fact represent flows of appropriated biocapacity.

Most Ecological Footprint assessments aim to measure appropriation of biocapacity by final demand, but the Footprint is tallied at the point of primary harvest or waste uptake. Thus, tracking the embodied Footprint in derived products is essential in assigning the Footprint of production to the end uses it serves. One of the advantages of calculating Ecological Footprints at the national level is that detailed trade data allow the Footprints of goods and services to be properly allocated to consumers. The National Footprint Accounts calculate the Footprint of apparent consumption, as data on stock changes for various commodities are generally not available. The Footprint of consumption, EF_C, is the Footprint of all goods and services produced in a country, plus the Footprint of goods and services imported, less the Footprint of goods and services exported, as given by the formula

$$EF_C = EF_P + EF_I - EF_E \qquad \text{(Eq. 6)}$$

where EF_p is the Ecological Footprint of production, and EF_I and EF_E are the Footprints embodied in imported and exported commodity flows, respectively.

A country in which demand for ecological goods and services exceeds domestic supply is an ecological debtor; it must either rely on external biocapacity through imports, demands on the global commons, or draw down of its domestic ecological capital. Conversely, an ecological creditor has a net biocapacity surplus. This is not in itself a criterion for sustainability. It simply means that the country's demand for the particular services included in the Footprint could have been met by its domestic supply in that particular year.

Figure 2 shows ratios of Footprint to biocapacity for debtor countries, or the ratio of biocapacity to Footprint for creditor countries, in 1961 and 2005, as calculated in the 2008 National Footprint Accounts. While some countries remain ecological creditors in 2005, the world as a whole has gone into overshoot. Debtor countries' demand for ecosystem goods and services beyond what their domestic ecological capital can provide now exceeds the available supply from the remaining creditor countries.

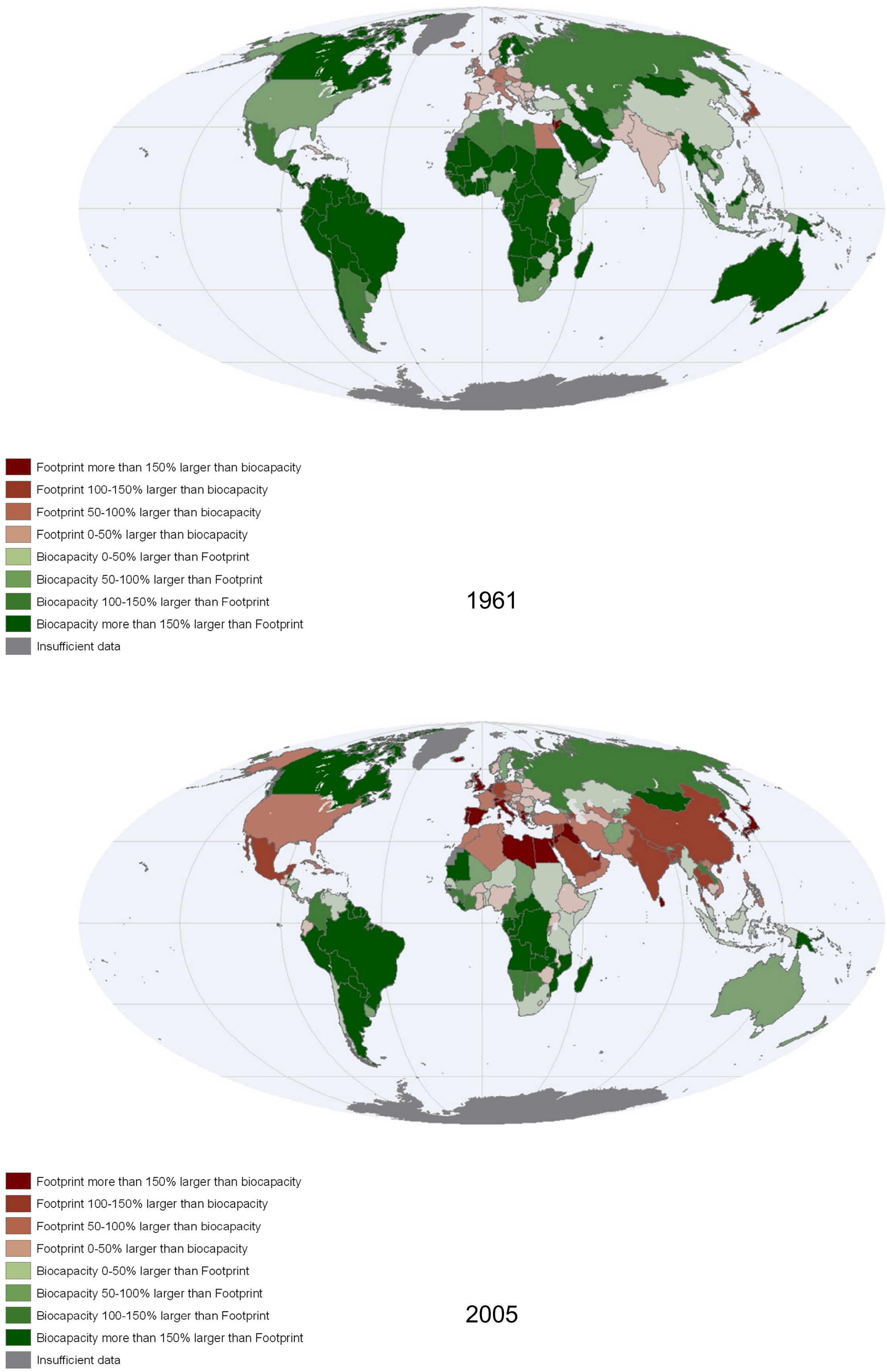

Figure 2: Ecological creditor and debtor countries, 1961 and 2005.

LAND USE TYPES IN THE NATIONAL FOOTPRINT ACCOUNTS

The Ecological Footprint and biocapacity accounts are comprised of six land use types: cropland, grazing land, forest land, fishing grounds, carbon uptake land, and built-up land. With the exception of carbon uptake land, each of these land use types is assigned a corresponding biocapacity. The Footprint represents demand for ecosystem products and services in terms of these land use types, while biocapacity is the supply of land available to serve each use.

In 2005, the area of biologically productive land and water on Earth was approximately 13.4 billion hectares. World biocapacity was also 13.4 billion global hectares, since the total number of average hectares equals the total number of actual hectares. However, after multiplying by the equivalence factors, the relative area of each land use type expressed in global hectares differs from the distribution in actual hectares as shown in Figure 3.

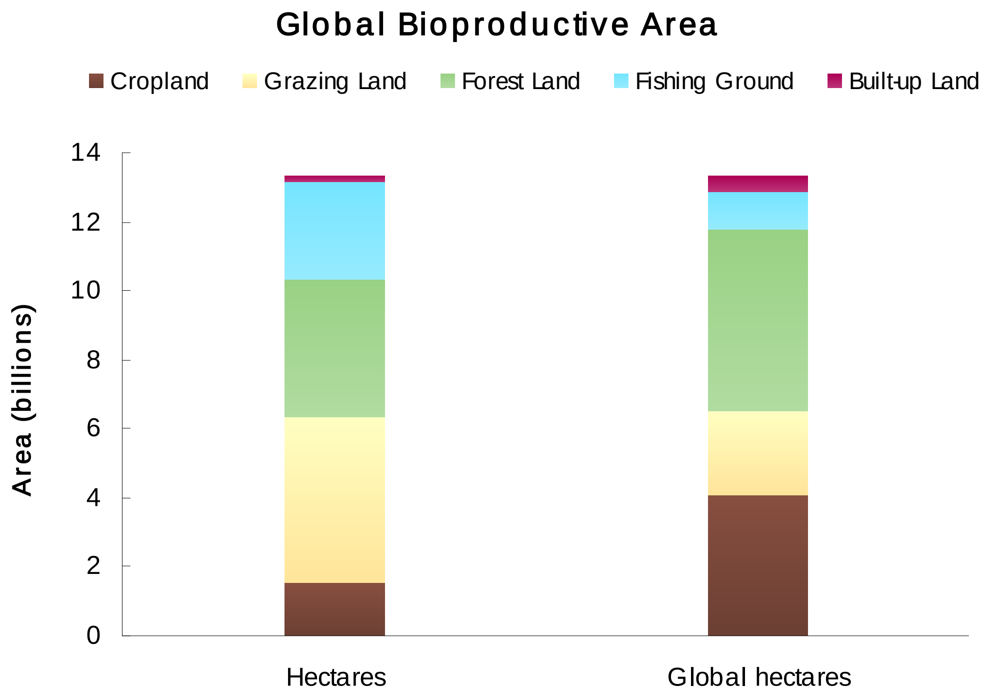

Figure 3. Relative area of land types worldwide in hectares and global hectares, 2005.

Figure 4 shows humanity's Ecological Footprint as calculated in the 2008 edition of the National Footprint Accounts, in relation to the Earths' regenerative and waste absorptive capacity in each year. The various land use types are stacked to show the total Footprint. Humanity's Ecological Footprint in 2005 consisted of 24% cropland, 10% grazing land, 9% forest land, 3% fishing ground, 52% carbon uptake land, and 2% built-up land. The Ecological Footprint to biocapacity ratio has increased from 0.54 to 1.31 planets from 1961 to 2005. In 2005, humanity demanded the resources and services of at least 1.31 planets, meaning it would take approximately a year and 4 months, at least, to regenerate what humanity used in 2005. As explained later, the accounts are specifically designed to yield conservative estimates of global overshoot. They consistently underestimate Footprint and overestimate biocapacity wherever data is inconclusive or issues are insufficiently documented.

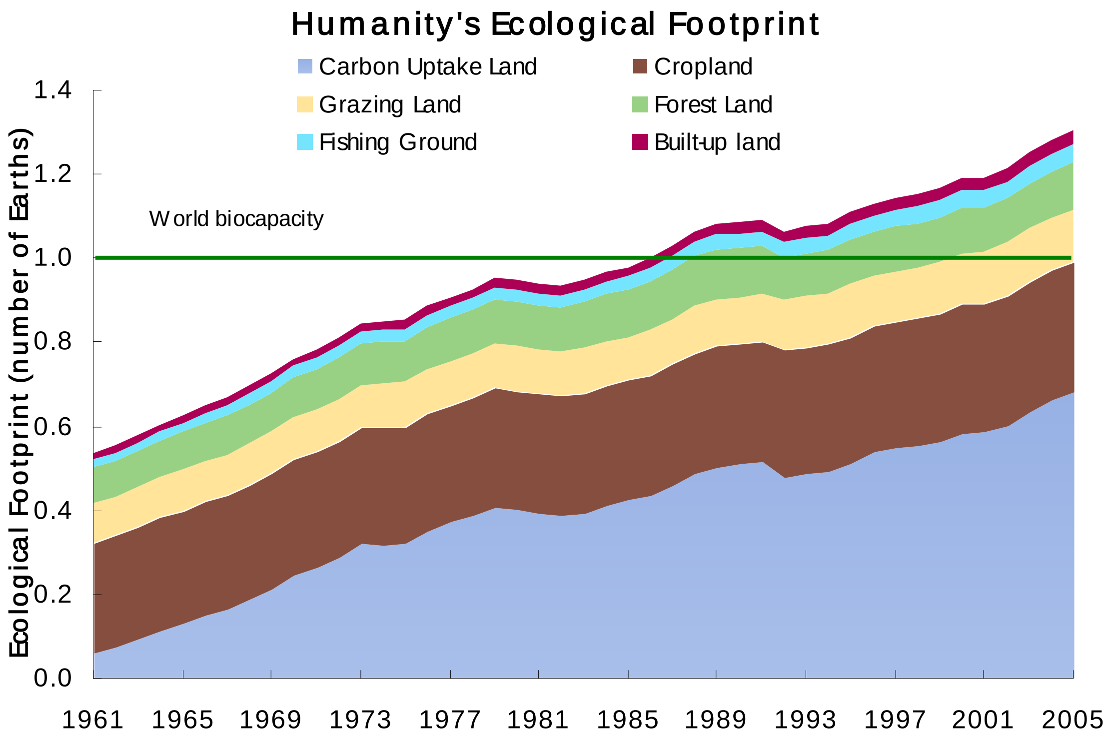

Figure 4: World overshoot according to the 2008 edition of the National Footprint Accounts. Humanity's Ecological Footprint, expressed in number of planets demanded, has increased significantly over the past 45 years.

Cropland

Cropland is the most bioproductive of all the land use types and consists of the area required to grow all crop products, including livestock feeds, oil crops and rubber. Agriculture typically uses the most suitable and productive land areas, unless they have been urbanized. Thus, cropland affords biological services of greater utility to humans than the same physical area of other land use types. This is reflected in that the number of global hectares of cropland is large compared to the physical number of cropland hectares, as shown in Figure 3.

Worldwide in 2005 there were 1.6 billion hectares designated as cropland (FAO ResourceSTAT Statistical Database 2007). The National Footprint Accounts calculate the Footprint of cropland according to the production quantities of 195 different crop categories. The Footprint of each crop type is calculated as the area of cropland that would be required to produce the harvested quantity at world-average yields. In the 2008 edition of the National Footprint Accounts, cropland is the only land use type which yields more than one primary product and thus uses Eq. 4a to calculate a national yield factor.

Locally, cropland can be in deficit when countries consume more crops or embodied cropland in livestock than they have the biocapacity to produce themselves. However, on a global scale cropland biocapacity represents the combined land area devoted to growing all crops, which the cropland Footprint cannot exceed.

Grazing Land

The grazing land Footprint measures the area of grassland necessary in addition to crop feeds to support livestock. Grazing land is comprised of grassland and sparsely wooded land and is used to feed livestock for meat, dairy, hide, and wool products. In 2005, there were 4.8 billion hectares of land worldwide classified as grazing land or other wooded land. Other wooded land is defined to encompass areas that contain a low overall percentage of canopy cover, scattered trees and shrubs, and is treated as grazing land area in the National Footprint Accounts (FAO ResourceSTAT Statistical Database 2007). The grazing Footprint is calculated following Eq. 1, where the yield is average above-ground NPP for grassland. The demand for grazing land productivity, T_{GR}, is the amount of biomass required by livestock after cropped feeds are accounted for, following the formula

$$P_{GR} = TFR - F_{Mkt} - F_{Crop} - F_{Res} \qquad \text{(Eq. 7)}$$

where *TFR* is the calculated total feed requirement, and F_{Mkt}, F_{Crop} and F_{Res} are the amounts of feed available from general marketed crops, crops grown specifically for fodder, and crop residues, respectively.

Since the yield of grazing land represents the amount of above-ground primary production available in a year, overshoot is not physically possible over extended periods of time for this land type. For this reason, a country's grazing land Footprint of production cannot exceed its biocapacity. Global Footprint Network has significantly improved the calculation of the grazing land Footprint in the 2008 edition of the National Footprint Accounts over that employed in the 2006 edition, with the help of researchers at the Social Ecology Institute of University of Klagenfurt in Vienna (Haberl et al. 2007; Krausmann et al. 2007).

Locally, grazing land can be in deficit when countries consume more embodied grazing land in livestock than they have the biocapacity to produce themselves. However, on a global scale demand may not overshoot supply for this land use type because grasses are annual plants and thus it is assumed that there are no stocks from previous years to draw down.

Fishing Grounds

The fishing grounds Footprint is calculated based on the amount of annual primary production required to sustain a harvested aquatic species. Marine yields are calculated as the primary production equivalent of the estimated global sustainable catch for a representative set of fish species, distributed according to local rates of primary production. Biocapacity is based on estimates of sustainable fish harvests, in primary production equivalents, rather than on fish stock levels.

The annual primary production embodied in a quantity of fish is determined by multiplying the wet weight of fish by its primary production requirement, denoted *PPR*. This *PPR* is the mass of annual primary production required to sustain a fish of a given trophic level, per unit of fish biomass (Pauly and Christensen 1995). It is calculated as

$$PPR = CC \cdot DR \cdot \left(\frac{1}{TE}\right)^{(TL-1)} \qquad \text{(Eq. 8)}$$

where *CC* is the carbon content of wet-weight fish biomass, *DR* is the discard rate for bycatch, *TE* is the transfer efficiency of biomass between trophic levels, and *TL* is the trophic level of the fish species in question.

In the National Footprint Accounts, *DR* is assigned the global average value of 1.27 for all fish species, meaning that for every tonne of fish harvested, 0.27 tonnes of bycatch are also harvested (Pauly and Christensen 1995). This bycatch rate is applied as a constant coefficient in the PPR equation, embodying the assumption that the trophic level of the bycatch is the same as that of the primary catch species. These approximations are employed for lack of higher resolution data on bycatch. *TE* is assumed to be 0.1 for all fish, meaning that 10% of biomass is transferred between successive trophic levels (Pauly and Christensen 1995).

The estimate of annually available primary production used to calculate marine yields is based on estimates of the sustainable catches of various fish species (Gulland 1971). These quantities are converted to primary production equivalents, using Eq 8 and the sum of these is taken to be the total primary production equivalent which global fisheries may sustainably harvest. Thus the total sustainably harvestable primary production equivalent, PP_S, is calculated as

$$PP_S = \sum \left(Q_{S,i} \cdot PPR_i\right) \qquad \text{(Eq. 9)}$$

where $Q_{S,i}$ is the estimated sustainable catch for species *i*, and PPR_i is the primary production equivalent of species *i*, in tons of carbon PP per ton of fish biomass. This total harvestable primary production is allocated across the continental shelf areas of the world to produce biocapacity estimates. Thus the world-average marine yield Y_M is given by

$$Y_M = \frac{PP_S}{A_{CS}} \qquad \text{(Eq. 10)}$$

where PP_S is the global sustainable harvest, calculated as the primary production equivalent of the estimated sustainable fish harvest and A_{CS} is the total area of the world continental shelf. Marine yield factors are calculated based on countries' average rates of NPP within their exclusive economic zones.

Fishing grounds can enter overshoot if the area demanded for sustainable extraction of the fish exceeds actual area available.[1]

Forest Land

The forest land Footprint is calculated based on the annual harvests of fuelwood and timber to supply forest products consumed by a country and includes all forested area. The yield is simply the net annual increment of merchantable timber per hectare. In 2005 there were 3.95 billion hectares of forest land area in the world – they also include the carbon uptake land, but due to data limitation, current accounts do not distinguish between forests for forest products, for long-term carbon uptake or for biodiversity reserves. Estimates of timber productivity from the UNEC and FAO "Forest Resource Assessment," the FAO "Global Fiber Supply" and the Intergovernmental Panel on Climate Change give a world average yield of 2.36 m^3 of harvestable wood per hectare per year (UNEC, 2000, FAO 2000, FAO 1998, IPCC 2006).

Forest land Footprint can be in overshoot locally as well as globally. When this occurs, forest stocks decreased over time due to the over consumption of forest products.

Carbon Uptake Land

Carbon uptake land represents the amount of forest land needed to uptake anthropogenic carbon emissions. It is the biocapacity that accommodates the Carbon Footprint. Since most terrestrial carbon uptake in the biosphere occurs in forests, carbon uptake land is assumed to be forest land. For this reason it could be considered to be a subcategory of forest land. Therefore,

[1] In spite of wide acknowledgment of global overfishing, the current data set and method in the National Footprint Accounts do not show that demand exceeds supply in this component. Therefore, further research in this area is needed to clarify the way fish demand is being accounted for. Global Footprint Network is currently engaged in such research.

in the 2008 edition, forest for timber and fuelwood is not separated from forest for carbon uptake.[2]

Carbon uptake land is the only component of the Ecological Footprint which is exclusively dedicated to tracking a waste product: carbon dioxide. The carbon Footprint is calculated as the amount of forest land required to uptake anthropogenic emissions, which stem primarily from fossil fuel combustion. Carbon uptake land is the largest contributor to humanity's current total Ecological Footprint and increased more than tenfold from 1961 to 2005. However, particularly in lower income countries the carbon Footprint is not always the dominant contributor to the overall Ecological Footprint.

Analogous to Eq. 1b, the formula for the carbon Footprint EF_c is

$$EF_C = \frac{P_C \cdot (1 - S_{Ocean})}{Y_C} * EQF \qquad \text{(Eq. 11)}$$

where P_C is annual emissions (production) of carbon, S_{Ocean} is the percentage of anthropogenic emissions sequestered by oceans in a given year and Y_C is the annual rate of carbon uptake per hectare of world average forest land.

Currently, carbon uptake land is in overshoot globally as well as for many countries. In other words, the forest Footprint combined with the carbon Footprint exceeds the entire forest biocapacity. This has caused an accumulation of carbon dioxide in the biosphere and atmosphere.

Built-Up Land

The built-up land Footprint is calculated based on the area of land covered by human infrastructure — transportation, housing, industrial structures and reservoirs for hydroelectric power generation. In 2005, the world contained 165 million hectares of built-up land area. The 2008 edition of the National Footprint Accounts follows the 2006 edition in assuming that built-up land occupies what would previously have been cropland, unless we have specific evidence that this assumption does not hold true. This assumption is based on the observation that human settlements are generally situated in highly fertile areas with the potential for producing high yielding cropland (Wackernagel et al. 2002).

For lack of data on the areas and types of land inundated, all hydroelectric dams are assumed to flood land with global average productivity and to cover areas in proportion to their rated generating capacity.

Built-up land has a biocapacity equal to its Footprint since both quantities capture the amount of bioproductivity lost to encroachment by physical infrastructure.

CONCLUSION

In an increasingly resource constrained world, accurate and effective resource accounting tools are needed if nations, cities and companies want to stay competitive. The Ecological Footprint is one such resource accounting tool that tracks human demand on the regenerative and absorptive capacity of the biosphere.

[2] Global Footprint Network has not identified yet reliable global data sets on how much of the forest areas are dedicated to long-term carbon uptake. Hence, the accounts do not distinguish which portion of forest land is dedicated to forest products and how much is permanently set aside to provide carbon uptake services. Also note that other kind of areas might be able to provide carbon uptake services.

In 1961, the first year for which the National Footprint Accounts are available, humanity's Ecological Footprint was approximately half of what the biosphere could supply—humanity was living off the planet's annual ecological interest, not drawing down its principal. However, in the 1980s human demand exceeded the planet's biocapacity. Overshoot has continued to increase, reaching 31% in 2005. As these annual deficits accrue into an ever larger ecological debt, ecological reserves are depleting, and wastes such as carbon dioxide are accumulating in the biosphere and atmosphere.

This paper has described the fundamental principles and calculations utilized in the 2008 edition of the National Footprint Accounts. To learn more about the structure and results of the 2008 edition of the National Footprint Accounts, please visit Global Footprint Network's website to download the *Guidebook to the National Footprint Accounts: 2008 Edition* and *The Ecological Footprint Atlas 2008*. They are available at www.footprintnetwork.org/atlas.

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