# HARMONIZING THE NATIONAL FOOTPRINT ACCOUNTS

# WITH THE

# SYSTEM OF INTEGRATED ENVIRONMENTAL AND ECONOMIC ACCOUNTING

Paper prepared by the Global Footprint Network

*(for discussion)*

Global Footprint Network
Advancing the Science of Sustainability

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## 1. Introduction

Historically, environmental statistics have been collected to address unique research questions—thereby creating a patchwork of data that varies in accessibility, classification, timeliness, and quality. This led to the agenda set forth during the Rio Conference in 1992 to create a framework for environmental accounting—analogous to, and linked with, the economic System of National Accounts (SNA)—to provide a "consistent, systematic set of principles, concepts, and methods" for environmental statistics with "common definitions, classifications, and methods" (SEEA 2003). The goal of the SEEA is to provide an information system for the environment that also covers direct links between the economy and the environment.

This concept proposal gives an overview of: the National Footprint Accounts, the methodology of the Ecological Footprint and biocapacity indicators, the necessary steps to synchronize an external accounting framework with the SEEA, and the benefits and limitations of the National Footprint Accounts and its alignment with the SEEA. Harmonizing the National Footprint Accounts with the SEEA aligns the Ecological Footprint and biological capacity (biocapacity) indicators with the SEEA physical flow accounts, as well as with complementary indicators already incorporated into SEEA. The National Footprint Accounts' approach to analyzing sustainable production and consumption flows of biocapacity provides added value to Volume III of SEEA 2013. Future improvements to this analysis could also include discussion on the use of multi-regional input-output analysis within the National Footprint Accounts, and the potential harmonization procedure for linking the National Footprint Accounts with the SEEA hybrid flow accounts.

## 2. National Footprint Accounts

### 2.1 Background

Introduced in the early 1990s (Rees 1992), the Ecological Footprint measures the human appropriation of biologically productive land and water—measured as biocapacity (Wackernagel et al. 1999, 2002). The Ecological Footprint addresses a single research question: "How much of the regenerative capacity of the biosphere—expressed as biocapacity—is demanded by a given human activity" (Kitzes and Wackernagel 2009)?

The Ecological Footprint thus accounts for the pressure humanity places on the planet in terms of the aggregate demand that resource-consumption and the release of $CO_2$ emissions place on ecological assets. The Ecological Footprint is a flows indicator; however, it is measured in terms of the bioproductive land areas needed to generate such flows, and thus is expressed in the unit of *global hectares (gha)*[1]. There is an advantage in expressing demand for flows in terms of bioproductive land appropriation, in that the use of an area better reflects the fact that many basic ecosystem services and ecological resources are provided by surfaces where photosynthesis takes place (bioproductive areas). These surfaces are limited by physical and planetary constraints and the use of gha helps to better communicate the existence of physical limits to the growth of human economies.

Consumption of flows is translated into appropriation of bioproductive lands through a multi-step process, as explained in section 2.3. Harmonizing the National Footprint Accounts with the SEEA framework requires aligning the sole input flows used in the calculation of the Ecological Footprint and biocapacity indicators with the SEEA physical flow accounts.

### 2.2 Methodology

Under the term "Ecological Footprint methodology", two different indicators are actually calculated. The first one, named *Ecological Footprint* is a measure of the demand humans place on the biosphere's regenerative capacity (demand indicator). The second one, named *biocapacity*, is a measure of the regenerative capacity available on the planet, at both local and global levels  (Rees 1992; Wackernagel et al. 1999, 2002).

The biocapacity indicator measures the capacity of ecosystems to produce useful biological materials to absorb waste materials generated by humans, using current management schemes and extraction technologies. "Useful biological materials" are defined as those used by the human economy; hence, what is considered "useful" can change from year to year (e.g. use of corn (maize) stover for cellulosic ethanol production would result in corn stover becoming a useful material, thus increasing the biocapacity of maize cropland).

The biocapacity, *BC*, of each land use type is calculated as

| (1)      BC = A · YF · EQF |
|---|

where *A* is the area available for a given land use type and *YF* and *EQF* are the yield and equivalence factors, respectively.

The Ecological Footprint indicator measures appropriated biocapacity, expressed in global average bioproductive hectares for five biophysical land-use types—cropland, grazing land, forest land, fishing

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[1] Global hectares provide more information than simply weight - which does not capture the extent of land and sea area used - or physical area - which does not capture how much ecological production is associated with that land.

grounds, and built-up land—as well as one indirect land-use type, carbonFootprint. For each land-use type, the Ecological Footprint of consumption ($EF_C$) is derived from domestic and international activities as

**(2)** $\quad EF_C = EF_P + EF_I - EF_E$

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

The Ecological Footprint, *EF*, is calculated as

**(3)** $\quad EF = \dfrac{P}{Y_N} \cdot YF \cdot EQF$

where *P* is the amount of a product harvested or $CO_2$ emitted, $Y_N$ is the national average yield for *P* (or carbon sequestration factor), and *YF* and *EQF* are the yield and equivalence factors, respectively.

Yield factors capture the difference between local and world-average productivity for usable products within a given land-use category. They are calculated as the ratio of national-average to world-average yields and vary by country, land use type and year within the National Footprint Accounts.

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 is

**(4)** $\quad YF_L = \dfrac{Y_N}{Y_W}$

In the case of cropland, there are multiple products being produced and the calculation procedure is slightly modified to be

**(5)** $\quad YF_L = \dfrac{\sum\limits_{i \in U} A_{W,i}}{\sum\limits_{i \in U} A_{N,i}}$

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

**(6)** $\quad A_{N,i} = \dfrac{P_i}{Y_N} \quad \text{and} \quad A_{W,i} = \dfrac{P_i}{Y_W}$

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 crop area that produces $i$ within a given country, while $A_{W,i}$ gives the equivalent area of world-average cropland yielding $i$.

Equivalence factors translate the area supplied or demanded of a specific land-use type into units of world average biologically productive area and varies by land-use type and year. They are calculated as the ratio between the average potential ecological productivity of world-average land of a specific land type (e.g. cropland) to the average productivity of all biologically productive lands on Earth. Currently, 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. In the future, more geospecific data sets could be used to assess which land is used for which land type.

### 2.3 Transparency and Standards

The National Footprint Accounts are published on an annual basis by Global Footprint Network and provide national-level results for the biocapacity and Ecological Footprint of nearly 200 nations from 1961 to present (Ewing et al., 2009). The National Footprint Accounts provide a transparent scientific measure that follows an internationally agreed methodology. Three documents describe in detail the methodology, structure, and results of the National Footprint Accounts.[2]

- The *Calculation Methodology for the National Footprint Accounts* describes the methodology for calculating the Ecological Footprint and biocapacity indicators within the National Footprint Accounts (Ewing et al. forthcoming). This document includes the fundamental principles, assumptions, and equations utilized in the National Footprint Accounts.

- The *Guidebook to the National Footprint Accounts* documents the collection of the calculation templates (spreadsheets) that transform data inputs into results perform the calculations in the National Footprint Accounts (Kitzes et al. forthcoming). This document provides detailed information regarding the structure and flow of information—from source datasets to results within the National Footprint Accounts.

- The *Ecological Footprint Atlas* summarizes the results from the National Footprint Accounts and describes the research question, basic concepts, and science underlying the Accounts (Ewing et al. 2009). This document describes recent advances to enhance the consistency, reliability, and resolution of the National Footprint Accounts.

The National Footprint Accounts Review Committee supports continual improvement of the scientific basis of the Accounts. This committee is comprised of 10 researchers and practitioners from throughout the world (GFN 2010a). The Review Committee is elected by the nearly 100 partner organizations affiliated with Global Footprint Network and follows the Global Footprint Network Committee Charter (GFN 2006). This Charter also stipulates the activities of the Ecological Footprint Standards Committee which is comprised of 18 researchers (GFN 2010b), follows the ISEAL Alliance Standard Setting Code (ISEAL 2010), and developed the *Ecological Footprint Standards* (Global Footprint Network 2006, 2009).

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[2] A free Academic Edition of the National Footprint Accounts is available to download at www.footprintnetwork.org.

Independent reviews have been conducted by various governments, universities, and research institutes. A sample list of these reviews include are included in Appendix A.

## 2.4 Source Data

The National Footprint Accounts utilize approximately 50 million data points, primarily based on international datasets published by the United Nations Food and Agriculture Organization (FAOSTAT), United Nations Commodity Trade Statistics Database (UN COMTRADE), International Energy Agency (IEA) and Global Agro-Ecological Zones 2000 (IIASA and FAO, 2000).

Production statistics for agricultural, forestry and fisheries primary and derived products are obtained from the FAO ProdSTAT, FAO ForesSTAT and FAO FishSTAT Statisical Database.  In the National Footprint Accounts, 2009 Edition (NFA 2009), there are production data for 164 crop products, 41 livestock products, 33 forest products and 1439 fish products expressed in tonnes produced or harvested per year.  Production data are presented in the FAO commodity classifications and HS+ commodity classifications where possible. HS+ is an extended version of HS 2002 created by FAO to provide increased resolution and harmonize the FAO and HS commodity classifications.  Production statistics for carbon dioxide emissions are obtained from the International Energy Agency.  In the NFA 2009, there are emission data for 45 products and categories expressed in tonnes of carbon dioxide emissions per year.

Yields are based on regeneration rates for all land use types except cropland; cropland yields are calculated for each crop using the ratio of crops produced and harvest area.  Grazing land yields are the average above-ground net primary production for grassland.  Forest yields are calculated using net annual increment which is the gross annual increment less that of the natural losses to the growing stock due to natural mortality, disease, etc.  Fishing grounds yields are calculated for each species as the product of the inverse primary production rate and available primary productivity (Kitzes et al. 2009).

Equivalence factors are calculated using the suitability index from the Global Agro-Ecological Zones model along with land cover data from CORINE Land Cover (CLC 1990, 2000, 2006), Global Land Cover (GLC 2000), SAGE (Univesity of Wisconsin 1992), GAEZ (FAO and IIASA 2000), and FAO ResourceSTAT (FAOSTAT).

# 3. Harmonizing the National Footprint Accounts with the SEEA

## 3.1 Consistent boundaries

Consumption Footprint focuses on the biocapacity needed to meet the consumption levels of a nation's residents, which implies that EF indicator relies on a pure consumption-based approach. Therefore, demands on biocapacity/demands on the environment are accounted for irrespective of national borders, reflecting thus, in a better way, the environmental pressures of residents' lifestyle. This consumption-based principle leads to the reattribution of embodied biocapacity associated with exports to foreign countries, and domestic biocapacity should thereby be complemented by the biocapacity embodied in imports. As noticed in equation 2, it is not straightforward to link the demands on domestic biocapacity to residents. A portion of domestic demands on biocapacity are for export, while a portion of domestic biocapacity needs are met via imports. Thus, production Footprint needs to adjust to include international trade. SEEA has potential to provide a sound framework for combining the SEEA and production Footprint. Currently, the SEEA accounts for natural resources and residuals, which are inputs for production Footprint.

## 3.2 Consistent classifications

Classification codes vary by accounting frameworks. The NFA product classifications are based mostly on UN Food and Agricultural Organization (FAO), Harmonized Commodity Description and Coding System (HS), International Energy Agency (IEA), and Standard International Trade Classification (SITC). Land cover classifications within the NFA are based on the FAO Land Cover Classification System (LCCS) (FAO 2000). The SEEA classifications for physical and hybrid product and industry flows are based on the Central Production Classification (CPC) and the International Standard Industrial Classification (ISIC). Classifications in physical and monetary supply and use tables for government and household consumption are based on the Classification of the Functions of Government (COFOG) and the Classification of Individual Consumption According to Purpose (COICOP) (SEEA 2003). The environmental assets (EA) of the SEEA are based on the non-financial assets (AN) of the SNA (SNA 2008). Land cover classifications have been proposed for the SEEA 2013 based on the FAO LCCS system. The use of different coding systems thus necessitates the creation of comprehensive bridge tables to harmonize the various products, resources, assets, and activities between accounting systems. The United Nations Statistical Division has published bridge tables between most of these classifications.

Linking the NFA with SEEA requires the creation of bridge tables from the current NFA to SEEA. These bridge tables vary by land-use type, and even within these sub-categories, due to differing product and commodity classifications within both the NFA and SEEA. Overcoming this incongruity requires use of bridge tables provided by the London Group or obtained from the UN Statistics Division and Eurostat.

The NFA 2010 classifications are based on FAO product classifications, SITC rev. 1 commodity classifications, HS 2002 product classifications. FAO classification is utilized for agricultural and forest production data from FAO ProdSTAT, extraction rates for agricultural products from the FAO technical conversion factors, and agricultural trade from the FAO TradeSTAT.

| NFA Land Use Type | Component | NFA Source Data | NFA Classification | SEEA Classification |
|---|---|---|---|---|
| Cropland | Production | FAO ProdSTAT | FAO | CPC v. 2 |
| | Trade | FAO TradeSTAT | FAO | CPC v. 2 |
| | Yield | FAO ProdSTAT | FAO | CPC v. 2 |
| | Biocapacity | CLC, GLC, SAGE, or FAO | CLC or FAO | FAO LCCS |
| Grazing Land | Production | FAO ProdSTAT | FAO | CPC v. 2 |
| | Trade | FAO TradeSTAT | FAO | CPC v. 2 |
| | Yield | GFN Derived | - | - |
| | Biocapacity | CLC, GLC, SAGE, or FAO | CLC or FAO | FAO LCCS |
| Forest Land | Production | FAO ForesSTAT | FAO | CPC v. 2 |
| | Trade | FAO ForesSTAT | FAO | CPC v. 2 |
| | Yield | UN TBFRA & UN GFSM | FAO | CPC v. 2 |
| | Biocapacity | CLC, GLC, SAGE, or FAO | CLC or FAO | FAO LCCS |
| Fishing Grounds | Production | FishSTAT | Species | ? |
| | Trade | FishSTAT | Species | ? |
| | Yield | GFN Derived | Species | ? |
| | Biocapacity | CLC, GLC, SAGE, or FAO | - | FAO LCCS |
| Built-up Land | Production | CLC, GLC, SAGE, or FAO | CLC, GAEZ, GLC, or SAGE | FAO LCCS |
| | Biocapacity | CLC, GLC, SAGE, or FAO | CLC, GAEZ, GLC, or SAGE | FAO LCCS |
| Carbon Footprint | Production | IEA Fossil Fuel Emissions | IEA | ? |
| | Trade | UN Comtrade | SITC rev. 1 | ? |
| | Yield | IPCC | - | ? |

*Table 1: Sample list of correspondence between the National Footprint Accounts and the SEEA*

Harmonizing the biocapacity indicator with SEEA first requires the creation of standard land cover classifications utilized within SEEA. These were discussed at the 14th meeting of the London Group in Canberra. A proposal was then circulated for the 15th meeting of the London Group in Wiesbaden (Weber 2009). It was proposed that these land cover classifications (1) identify 15-20 land cover classes; with further disaggregation possible by using the FAO LCCS and (2) utilize the FAO land-use classifications for agriculture, forests, and fisheries UNECE land-use classification for other land-use types. Fourteen foundational land cover classes were initially proposed (Weber 2009).[3]

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[3] 'Wetlands' are currently excluded due to lack of consistent data sets. 'Bare soil' and 'Permanent snow and ice' are excluded due to lack of significant bioproductivity.

| SEEA Land Cover Propsal | NFA Correspondence |
|---|---|
| Cultivated/managed areas - Rainfed cropland | Cropland |
| Cultivated/managed areas - Irrigated cropland | Cropland |
| Cultivated/managed areas - Complex cropland | Cropland |
| Mosaic of cultivated/managed areas and natural/semi-natural vegetation | Grazing land |
| Forest | Forest land |
| Woody/shrub vegetation | Forest land |
| Grassland/herbaceous vegetation | Grazing land |
| Mosaic of natural and semi-natural vegetation | Grazing land |
| Sparsely vegetated areas | Grazing land |
| Bare soil | Excluded |
| Wetlands | Excluded |
| Water bodies | Inland waters (fishing grounds) |
| Permanent snow and ice | Excluded |
| Artificial surfaces and associated areas | Built-up land |

**Table 2:** *Correspondence between the fourteen proposed SEEA land cover classifications and the National Footprint Accounts land use types*

### 3.3 Extending supply and use tables to production Footprint

The starting point is a supply and use table extended to the environment. This data is typically reported in mass units. It is therefore necessary to convert the tonnes of products and residuals to the units used for the Ecological Footprint and biocapacity—global hectares. To accomplish this we first must align the products and residuals found in the SEEA with the land-use types included in the National Footprint Accounts: cropland, grazing land, forest land, fishing grounds, carbon Footprint (or carbon uptake land on the biocapacity side) and built-up land. They can then be adjusted according to the embodied bioproductivity required to produce or uptake the products and residuals. This follows Equation 3. The SEEA land cover data can be utilized to measure the amount of land inundated with infrastructure or hydropower. This built-up land area can then be converted to the Footprint of production—reported in global hectares—following Equation 1. Furthermore, the fact that the SEEA links with the SNA enables allocation of the Footprint of production to intermediate commodity use, final consumption, exports and imports (see Figure 1).

**Figure 1:** *Hybrid Representation of an Environmentally Extended Input-Output table to materials, emissions, land cover and Ecological Footprint of Production.*

| | | | | Intermediate Demand | | | | | | Final Demand Households (y) | Exports (e) | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (I) | (I) | (III) | (IV) | (V) | (VI) | | | |
| **National Economy** | **Monetary Input-Output Table** | Agriculture | (I) | | | | | | | | | |
| | | Animal production | (I) | | | | | | | | | |
| | | Forestry | (III) | | | Z | | | | y | e | x |
| | | Fishing | (IV) | | | | | | | | | |
| | | Manufacturing | (V) | | | | | | | | | |
| | | Services | (VI) | | | | | | | | | |
| | | Imports | (m) | | | m | | | | $m^{hh}$ | $e^t$ | $m^t$ |
| | | Value Added | (V) | | | v | | | | | | $v^t$ |
| | | Total Output | (X) | | | x | | | | | | $x^t$ |
| **National Environment** | **Natural Resources** | Crops (tonnes) | (CR) | $P^{CR,I}$ | 0 | 0 | 0 | 0 | 0 | $P^{CR,hh}$ | | $P^{CR,t}$ |
| | | Grazing (tonnes) | (GR) | 0 | $P^{CR,I}$ | 0 | 0 | 0 | 0 | $P^{CR,hh}$ | | $P^{CR,t}$ |
| | | Forest (m3) | (FR) | 0 | 0 | $P^{FR,III}$ | 0 | 0 | 0 | $P^{FR,hh}$ | | $P^{FR,t}$ |
| | | Fishing (tonnes) | (FS) | 0 | 0 | 0 | $P^{FS,V}$ | 0 | 0 | $P^{FS,hh}$ | | $P^{FS,t}$ |
| | **Residuals** | CO2 | (CO) | $e^{CO,I}$ | $e^{CO,II}$ | $e^{CO,III}$ | $e^{CO,IV}$ | $e^{CO,V}$ | $e^{CO,VI}$ | $e^{CO,HH}$ | | $e^{CO,t}$ |
| | **Land Cover** | Built-up land | (BL) | $a^{BL,I}$ | $a^{BL,II}$ | $a^{BL,III}$ | $a^{BL,IV}$ | $a^{BL,V}$ | $a^{BL,VI}$ | $a^{BL,HH}$ | | $a^{BL,t}$ |
| | **Production Footprint (EFp)** | Cropland | (CR) | $EFp^{CR,I}$ | 0 | 0 | 0 | 0 | 0 | $EFp^{CR,hh}$ | | $EFp^{CR,t}$ |
| | | Grazing land | (GR) | 0 | $EFp^{GR,IV}$ | 0 | 0 | 0 | 0 | $EFp^{CR,hh}$ | | $EFp^{CR,t}$ |
| | | Forest | (FR) | 0 | 0 | $EFp^{FR,III}$ | 0 | 0 | 0 | $EFp^{FR,hh}$ | | $EFp^{FR,t}$ |
| | | Fishing ground | (FS) | 0 | 0 | 0 | $EFp^{FS,V}$ | 0 | 0 | $EFp^{FS,hh}$ | | $EFp^{FS,t}$ |
| | | Ecological services accounting -CO2. | (ES) | $EFp^{ES,I}$ | $EFp^{ES,II}$ | $EFp^{ES,III}$ | $EFp^{ES,IV}$ | $EFp^{ES,V}$ | $EFp^{ES,VI}$ | $EFp^{CO,HH}$ | | $EFp^{CO,t}$ |
| | | Built-up land | (BL) | $EFp^{BL,I}$ | $EFp^{BL,II}$ | $EFp^{BL,III}$ | $EFp^{BL,IV}$ | $EFp^{BL,V}$ | $EFp^{BL,VI}$ | $EFp^{BL,HH}$ | | $EFp^{BL,t}$ |
| | | Total Production Footprint | (EFp) | $EFp^{.I}$ | $EFp^{.II}$ | $EFp^{.III}$ | $EFp^{.IV}$ | $EFp^{.V}$ | $EFp^{.IV}$ | $EFp^{.hh}$ | | $EFp^{.t}$ |

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## 3.4 Trade

From Equation (2) it is possible to deduce that consumption Footprint differs from the production Footprint due to international trade. If there existed a truly 'closed economy' – where imports and export flows were excluded – then consumption Footprint would equal production Footprint. However, in reality increasing amounts of international flows on a global scale heavily bias indicators that are solely focused on the production side of the equation so international trade therefore must be included in the equation.

International trade issues must be analyzed in order to properly account for resident's biocapacity demands. To account only for natural resources crossing the borders—and its equivalent demand of biocapacity — is insufficient, since this would not reflect the total amount of productive land area required throughout the entire production chain for any given commodity. Moreover, since trade flows are increasingly important in a globalized world, indicators focused solely on domestic production will be heavily biased and inadequate.

Instead, direct and indirect biocapacity embodied in imports and exports are measured to gain accuracy on the total biocapacity embodied in resident consumption. Thus, once that biocapacity available to countries through exports and imports is estimated, the Footprint of production has to be adjusted. Accounting for total biocapacity used by imports and exports through the entire production chain, however, this is not a trivial undertaking and requires some modeling techniques. Appendix C is devoted to develop such modeling framework by using single economy case where all imports are produced with the same technology. Future improvements to this analysis could also include discussion on the use of multi-regional input-output analysis (MIRO) to estimate the biocapacity embodied within imports. However, at this time it is our understanding that when Footprint of production is harmonized with the SEEA and trade is included in the analysis via single economy or multi-regional input-output frameworks, the resulting Footprint of consumption should also be consistent with SEEA. This would allow giving the SEEA framework a consumer-based perspective, which could extend the scope of analysis of the SEEA itself.

# 4. Discussion

## 4.1 Benefits for the National Footprint Accounts

The quality of accounting frameworks and statistics rely on many key characteristics (Statistics Canada 2009):

- Relevance and comprehensiveness
- Accuracy
- Timeliness
- Accessibility
- Interpretability, methodological soundness, and transparency
- Coherence

The National Footprint Accounts provide relevant information in a coherent manner that is accessible for all potential users. However, the timeliness (three-year lag) and accuracy of the National Footprint Accounts could be improved by the harmonization with SEEA. Timeliness could be improved due to the alignment of the National Footprint Accounts with internationally agreed environmental and economic accounts. Consistency with national economic and environmental accountings could be improved by utilizing data sets reported in a more consistent manner. This alignment with internationally agreed accounting practices and alignment with country statistical datasets provide a great deal of benefit to

the National Footprint Accounts and Global Footprint Network. Moreover, alignment with SEEA follows the Stiglitz-Fitoussi-Sen suggestions for more comprehensive economic-environmental accounting within the National Footprint Accounts.

Furthermore, integrating a multi-regional input-output model within the NFA—with a similar framework as the SEEA—would expand the current emphasis on land use classifications to include the supply and use of resource throughput by each country's economy; thus forming a hybrid - physical and monetary - flow account (Hawkins et al. forthcoming; Iha et al. forthcoming). The use of biological natural resources and emissions of carbon dioxide could thereby be separated into intermediate inputs by industry, investment, final consumption by households and government, and imports and exports.

## 4.2 Benefits for the SEEA

Including the National Footprint Accounts in Volume 3 of the 2013 SEEA publication provides a unique opportunity to link pre-existing national environmental accounts—that are produced by an NGO and well perceived from the general public — with the SEEA. The National Footprint Accounts utilize approximately 50 million underlying source data points from approximately 30 data sets. The diversity of these data sets and their applicability to production, consumption, and trade in terms of appropriated biocapacity provides a valuable opportunity to harmonize this information with the inter-disciplinary functionality and compatibility of the SEEA. Linking the National Footprint Accounts with the SEEA as an application of Volume I of the SEEA 2013 is advantageous since the National Footprint Accounts contain physical flow indicators relevant to sustainable production and consumption. The carbon Footprint—in the form included in the National Footprint Accounts—measures the biosphere's uptake of anthropogenic carbon dioxide emissions; providing a key to understanding the driving forces behind ocean acidification and increased atmospheric concentrations of carbon dioxide. The overall Ecological Footprint value, in turn, complements this information by providing a more comprehensive assessment of the full palette of human-induced pressures on the planet.

## 4.3 Policy applications

The Ecological Footprint has its own policy usefulness in the capacity to track the demand countries places on the ecological assets because of the overall structure and functioning of their economies and can address the following main areas (Best et al., 2008):

1. double decoupling[4]
2. sustainable production/consumption
3. land use management
4. energy and climate

To tackle these areas, Ecological Footprint results can be presented through both:

1. Detailed sets of indicators allowing for in-depth reporting of each variable:

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[4] The double decoupling concept aims at both increasing resource efficiency and reducing negative impacts on the environment.

- o Footprint by land category
- o Footprint by households, governments and for investments
- o Footprint by industrial sectors
- o Footprint by consumption activities[5]

2. Final aggregate indicators facilitating communication and reporting to policy makers:
   - o National total Ecological Footprints (in relation to national or global biocapacity)
   - o World-average Ecological Footprint (in relation to global biocapacity)

It should, however, be noted that detailed Ecological Footprint results by "final demand categories" (households, governments and capital investments) and "industrial sectors" can only be obtained by linking classical Ecological Footprint assessments (as reported in the National Footprint Accounts) with standardized accounting framework.

The alignment of the NFA with SEEA strengthens its use by government statistical offices (Kitzes et al., 2009) and explicitly links the NFA to discussions related to decoupling economic activity from environmental degradation (decoupling-decomposition analysis), creation of internationally agreed accounts beyond conventional economic accounts—as identified by the Stiglitz-Fitoussi-Sen Commission and the Beyond GDP initiatives (Stiglitz et al. 2009; EEA 2007), and links directly with policy decisions related to climate change, land use change, etc. Harmonizing the National Footprint Accounts with the SEEA will enable the Ecological Footprint and biocapacity indicators to follow internationally agreed upon agreed practices.

Among others, the use of the Ecological Footprint within an input-output model provides information on the economy-environment interactions that are needed at various stages of the 'policy cycle' from the framing of the most relevant environmental issues, to the development and implementation of environmental policies and the subsequent monitoring of their effectiveness (Iha et al., 2010).

## 4.4 Limitations of the National Footprint Accounts[6]

The National Footprint Accounts are designed to quantify the biosphere's regenerative capacity and the demand for this biocapacity by humanity. The limitations of the Ecological Footprint fall into four broad categories: scope, comprehensiveness, implementation, and extent of implications.

1. Limitations of Scope: The Ecological Footprint is an indicator of human demand for ecological goods and services linked directly to ecological primary production. As such it addresses very specific aspects of the economy– (living) environment relationship, and should not be taken as a stand-alone overall sustainability indicator. Rather, it should be used in the context of a broader set of indicators that provide a more complete picture of sustainability.

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[5] Here the COICOP classification is used.
[6] Limitations section has been adapted for this document from Ewing et al., 2009 and Kitzes et al., 2009.

2. Limitations of Current Methodology and Data: The current National Footprint Accounts have significant potential for improvement as identified in the agenda paper which was also confirmed by the EU review (Gilljum et al 2008). For instance, better assessments of biocapacity required for uptake of carbon dioxide emissions are needed; or bioproduction occupied by hydroelectric reservoirs and other infrastructure would add further resolution; or ecological tradeoffs of land conversion could be further elaborated and analyzed.

3. Potential Errors in Implementation: As with any scientific assessment, Ecological Footprint results need to be evaluated in terms of reliability and validity. This is a complex task given that the National Footprint Accounts draw on a wide range of datasets, many of which have incomplete coverage, and most of which do not specify confidence limits. Considerable care is taken to minimize any data inaccuracies or calculation errors that might distort the National Footprint Accounts, including inviting national governments to collaboratively review the assessment of their country for accuracy, and develop improvements in the method either specific to their country or that generalize to all countries. In addition, efforts are continually made to improve the transparency of the National Footprint Accounts, allowing for more effective internal and external review. Conceptual and methodological errors. These include:
   a. Systematic errors in assessing the overall demand on nature;
   b. Allocation errors;
   c. Data errors in statistical sources for one particular year;
   d. Systematic misrepresentation of reported data in UN statistics; and
   e. Systematic omission of data in UN statistics.

4. Interpreting the Ecological Footprint: The Ecological Footprint functions as an indicator of the drivers of human pressure on ecosystems, rather than measuring these pressures themselves; Overshoot reflects demand rates that exceed supply rates, and thus has physical ramifications: either a drawdown of stocks of natural capital or an accumulation of wastes. However, the National Footprint Accounts do not identify particular outcomes attributable to a specific level of overshoot, regardless of cause. In addition, overshoot in some ecological demand categories may be masked by lower Footprint in others (Ewing et al. 2009).

## 5. Conclusions

Harmonizing the National Footprint Accounts with the SEEA facilitates integrated environmental-economic analysis beyond the scope of currently available international statistical databases. For instance, Global Footprint Network seeks to reduce the temporal delay of providing results and improve the quality of source data by collaborating directly with national statistics offices. In many cases, data is collected within countries using a variety of inconsistent definitions and classifications. Therefore, aligning the National Footprint Accounts with a common framework for environmental accounting is integral to achieving the strategic goals of the National Footprint Accounts: to provide robust and policy relevant accounts on how much biocapacity we have and how much we use.

# APPENDIX A: Sample list of external reviews of the National Footprint Accounts

- Switzerland - http://www.bfs.admin.ch/bfs/portal/en/index/themen/21/03/blank/blank/01.html (both the technical and the descriptive report).
- Germany - http://www.umweltdaten.de/publikationen/fpdf-l/3489.pdf
- France - Stiglitz commission (http://www.stiglitz-sen-fitoussi.fr/documents/Issues_paper.pdf);
- France - SOeS of the French Ministry of Sustainable Development. The study "Une expertise de l'empreinte écologique (May 2009, No 4)" examined the transparency and reproducibility of the National Footprint Accounts and found reproducibility of time trends within 1-3 percent. The initial report is available at http://www.ifen.fr/uploads/media/etudes_documentsN4.pdf or see http://www.ifen.fr/publications/nos-publications/etudes-documents/2009/une-expertise-de-l-empreinte-ecologique-version-provisoire.html
- France - Conseil économique, social et environnemental. «Les indicateurs du développement durable et l'empreinte écologique » - le 11 mai 2009. Projet d'avis présenté au nom de la Commission "ad hoc" par M. Philippe Le Clézio, rapporteur. http://www.conseil-economique-et-social.fr/presidence/publication/PU09-338.pdf
- European Union's Beyond GDP conference (www.beyond-gdp.eu) a strong endorsement arose from the European Economic and Social Committee.
- Ireland – http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=56#files
- Belgium - www.wwf.be/_media/04-lies-janssen-ecologische-voetafdrukrekeningen_236536.pdf
- DG Environment – June 2008: "Potential of the Ecological Footprint for monitoring environmental impact from natural resource use" available at http://ec.europa.eu/environment/natres/studies.htm
- Eurostat – http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-AU-06-001/EN/KS-AU-06-001-EN.PDF
- United Arab Emirates – Al Basama Al Beeiya Initiative http://www.agedi.ae/ecofootprintuae/default.aspx
- Directorate General for Research, Division Industry, Research, Energy, Environment, and Scientific and Technological Options Assessment (STOA), 2001, Ecological Footprinting http://www.europarl.europa.eu/stoa/publications/studies/20000903_en.pdf

# APPENDIX B: Framework linking supporting worksheets to summary results by land use type within the National Footprint Accounts
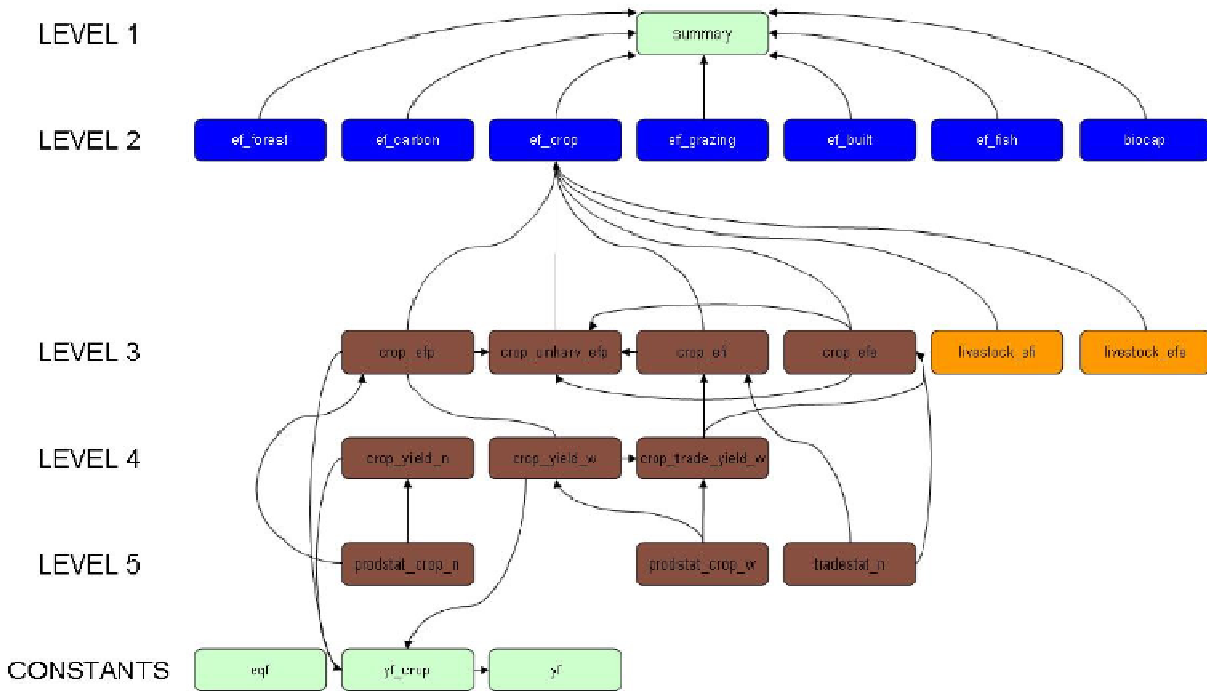


*Figure 3:* *NFA accounting framework: cropland Footprint calculation. Source: Kitzes et al (2008).*
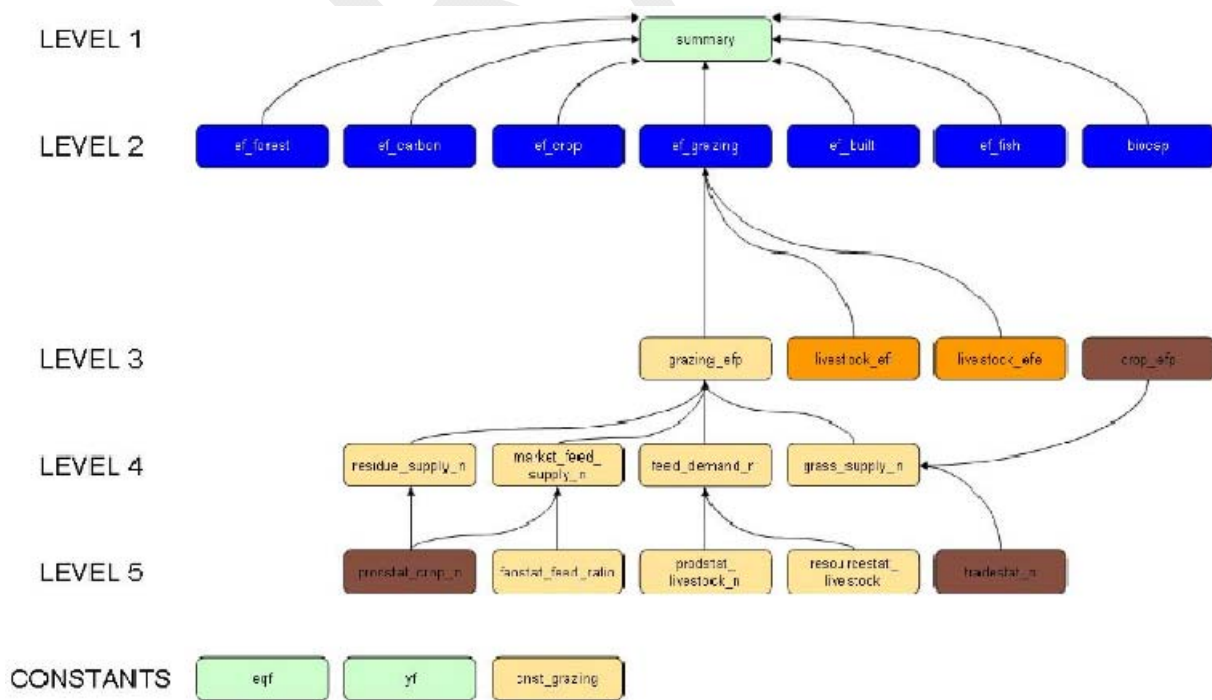
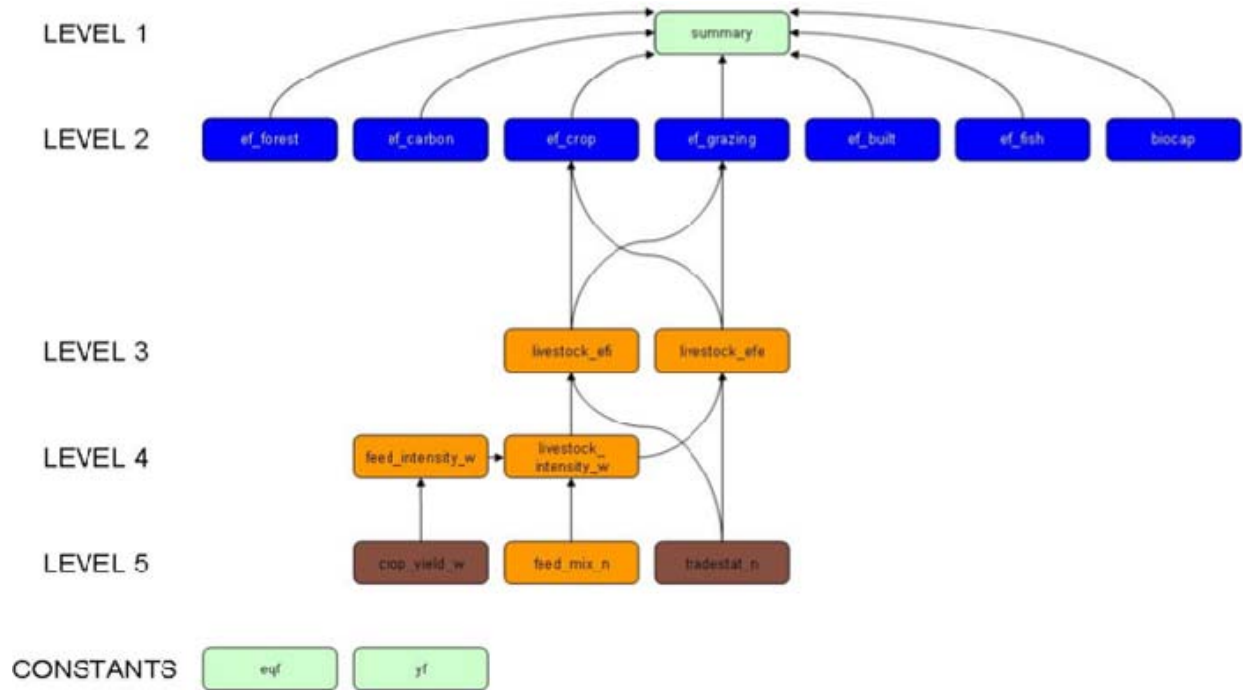*Figure 4: NFA accounting framework: grazing land Footprint calculation. Source: Kitzes et al (2008).*



*Figure 5: NFA accounting framework: livestock trade Footprint calculation. Source: Kitzes et al (2008).*
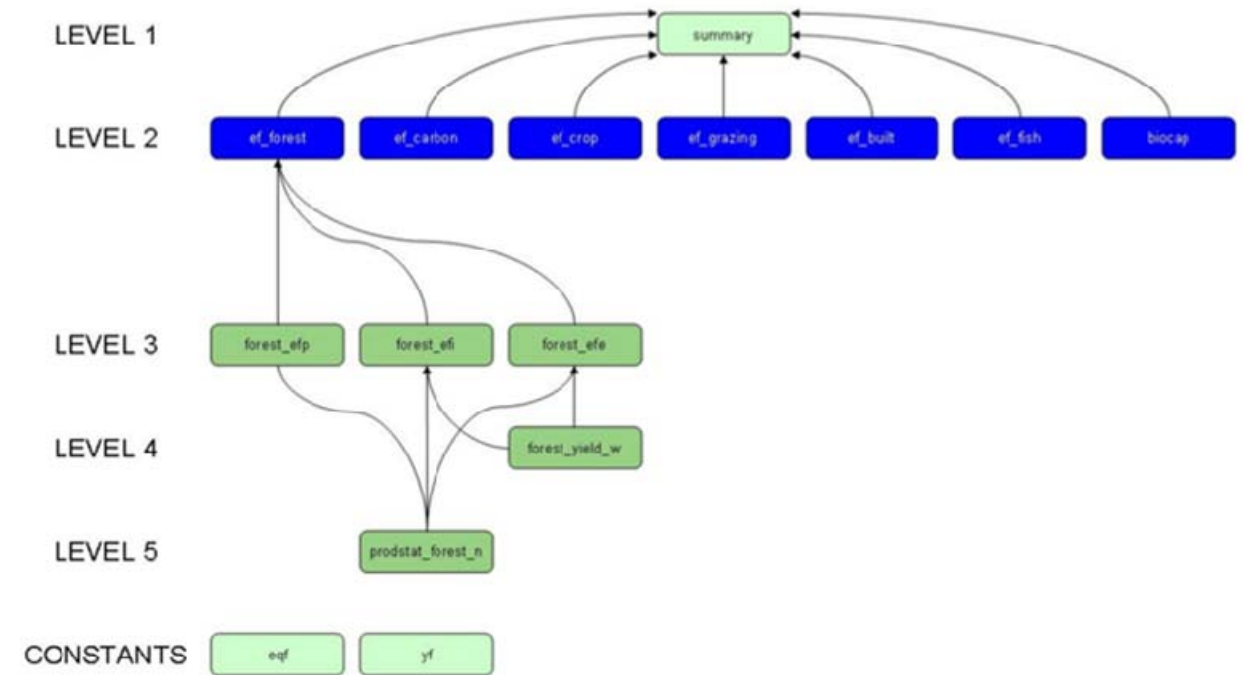


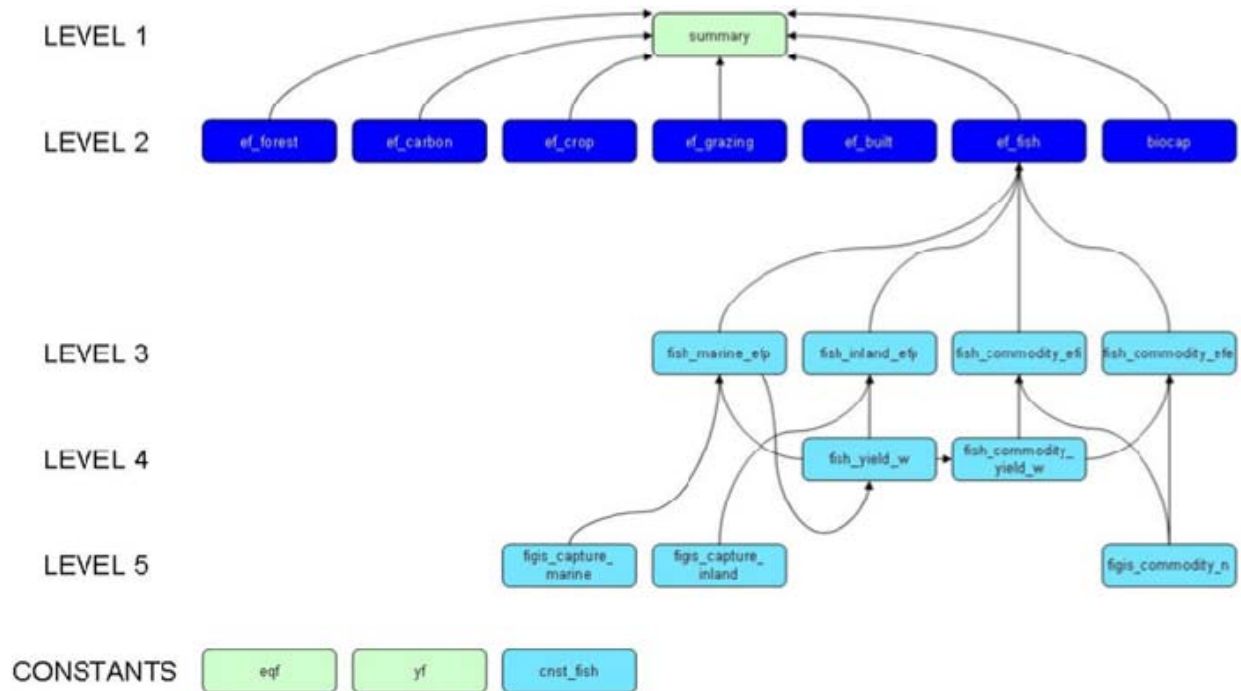*Figure 6: NFA accounting framework: forest Footprint calculation. Source: Kitzes et al (2008).*

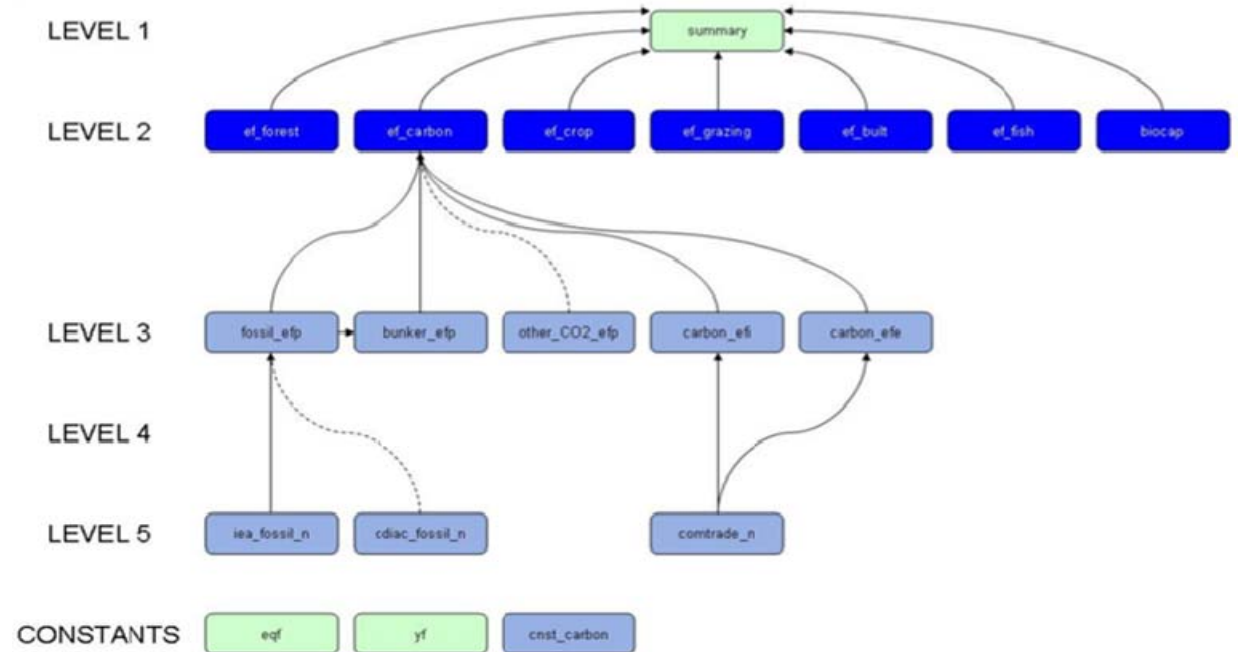*Figure 7: NFA accounting framework: fishing ground Footprint calculation. Source: Kitzes et al (2008).*



*Figure 8: NFA accounting framework: carbon Footprint calculation. Source: Kitzes et al (2008).*
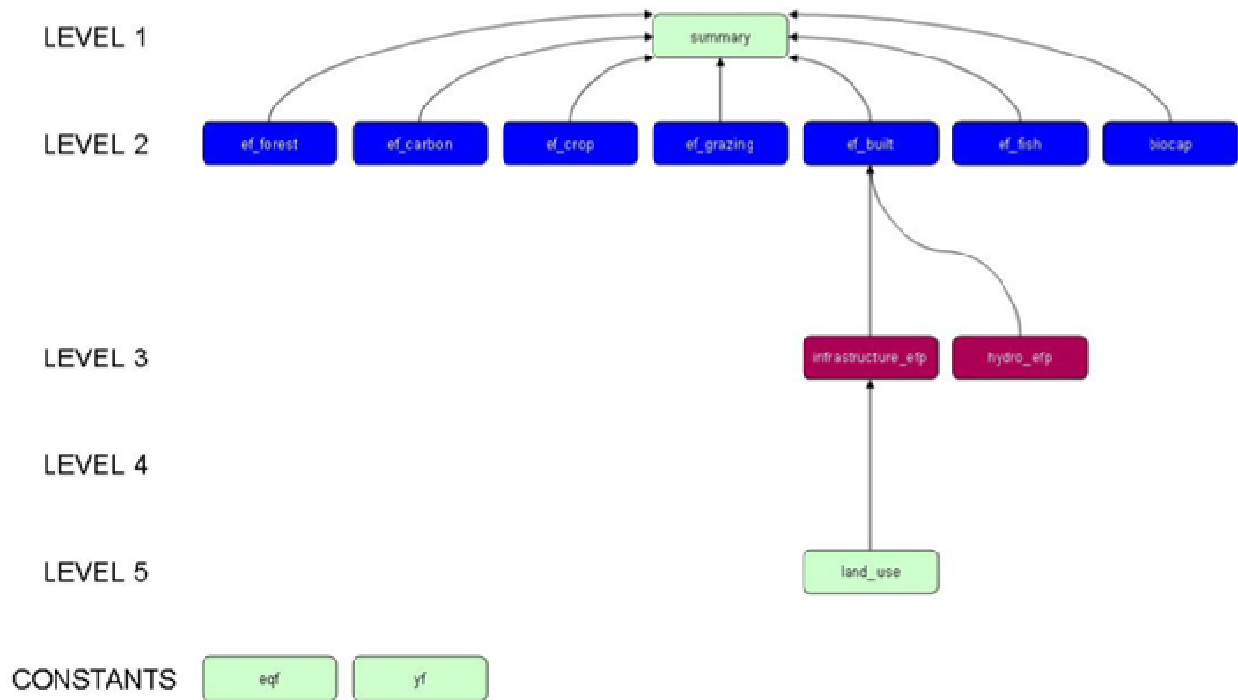
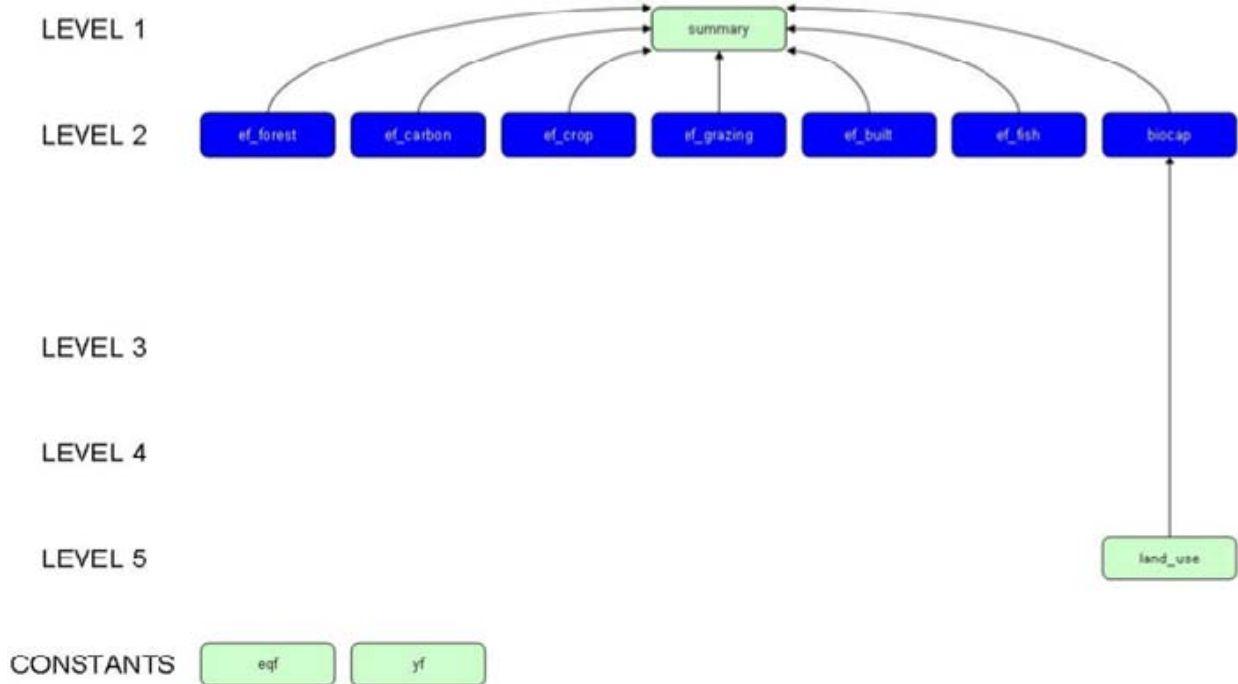*Figure 9:* *NFA accounting framework: built-up Footprint calculation. Source: Kitzes et al (2008).*



*Figure 10:* *NFA accounting framework: biocapacity calculation. Source: Kitzes et al (2008).*

# Appendix C: Modeling biocapacity embodied in imports and exports by using Input-Output Analysis[7]

Input-Output Analysis (IOA) offers a suitable analytical framework for estimating biocapacity embodied in imports and exports, tracing back the biconcavity embodied in traded commodities at the different stages of production and extraction. The analysis begins with a static and open IOA, where the balance between total supply and total commodity use is represented by Equation (7). The supply side is reflected by the total domestic production and total imports, contained in vector xt. The demand side, represented by the right hand side of Equation (7), displays information about commodity use. Matrix Zt denotes the total, imports and domestic production, commodities for intermediate use (IU), i is an auxiliary vector of ones and yt is the vector of total final demand (FD), which also includes exports and domestic final demand.

**(7)** $\qquad x_t = Z_t i + y_t$

Moreover, it is also possible to split up Equation (7) between imported and domestically produced commodities as it is shown in Equations (8) and (9) respectively:

**(8)** $\qquad x_d = Z_d i + y_d$

**(9)** $\qquad m = Z_m i + y_m$

Likewise, variables are defined similar as above but differentiating their origins and use between national production and imports. Thus, xd is the vector of domestic production; Zd is the matrix of domestic IU; vector yd describes the final demand for domestically produced commodities, including household consumption, investment in fixed capital, government expenditure and exports; m is a vector of total imports, i.e. imports for IU and FD; Zm is the matrix of imported commodities for IU, i.e. it reflects the imported commodities that are necessary to produce other commodities within the system; ym is a vector of imported commodities for final demand.

Furthermore, expressing the quantities of commodities Zd and Zm, as a proportion of the domestic output[8], xd, the so-called matrix of technical coefficients, Ai, is obtained:

**(10)** $\qquad A_t \equiv Z_t \hat{x}_t^{-1}; \qquad A_d \equiv Z_d \hat{x}_d^{-1}; \qquad A_m \equiv Z_m \hat{x}_d^{-1}$

---

[7] Current appendix has been taken from Muñoz et al., 2009 and adapted to the Ecological Footprint indicator estimates.
[8] The symbol '^' refers to a vector that has been diagonalized.

From the former Equations it is possible, as it was remarked by Pulido and Fontella (1993, 92-97), to estimate the sectoral production requirements distinguishing between nationally produced commodities and imports needed to satisfy a certain level of final demand. To obtain this, it is necessary to rewrite (8) and (9) in terms of the technical coefficients matrix and break down the final demand for domestically produced commodities, yd, into its exported share, e, and its share for domestic final demand, f, (i.e. yd minus exports). Thus, it is gathered that:

**(10)** $$x_d = A_d.x_d + (h+e) \qquad \Leftrightarrow \qquad x_d = (I-A_d)^{-1}.(h+e)$$

**(11)** $$m = A_m.x_d + y_m \qquad \Leftrightarrow \qquad m = A_m(I-A_d)^{-1}.(h+e) + y_m$$

From Equations (10) and (11) it is feasible to estimate the domestic production requirements for any level of domestic final demand (f) and exports (e), with consistency in IU import requirements (Pulido and Fontella 1993).

*Environmental Extended Input-Output Analysis*

Equation (10) can be extended to biocapacity demand by adding a domestic vector of production footprint intensity (excluding direct household consumption from Figure 1), i.e. production footprint per unit of commodity output. This extension of the model is represented by Equation (12):

**(12)** $$f_{EF}^{he} = \hat{f}_{PF}^{Xd} x_d = f_{PF}^{Xd}(I-A_d)^{-1}(h+e)$$

where, $\hat{f}_{PF}^{Xd}$ is a diagonalized intensity vector of domestic extraction (DE), per unit of domestic commodity output, xd. The term $f_{EF}^{he}$ in Equation (12) gives information about the domestic biocapacity demands reattributed to the domestic final demand as well as the foreign demand. Additionally, it is possible to separate the components of the final demand, obtaining the domestic biocapacity necessary to satisfy domestic final demand by Equation (13):

**(13)** $$f_{EF}^{h} = \hat{f}_{PF}^{Xd}(I-A_d)^{-1}h$$

and the domestic biocapacity necessary to produce exports is given by Equation (14):

**(14)** $$f_{EF}^{e} = \hat{f}_{PF}^{Xd}(I-A_d)^{-1}e$$

The import model presented in Equation (11) accounts for import requirements of an economy. In order to identify the biocapacity embodied in the commodities imported, it is necessary to incorporate the specific technology used for producing them, expressed in the Leontief inverse matrix (I-At)-1, as well as

the linkage between the production output and biocapacity used, $\hat{f}_{PF}^{Xd}$. However, tracing import flows back to their country of origin requires considerable data. It is not only sufficient to know the technology and the biocapacity intensities of the commodities imported from different countries, but also it is necessary to include data of the bilateral trade interrelations among these regions.

In order to keep the calculation method simple, one can introduce the restrictive assumption which states that all imports goods are produced with the same technology and input coefficients. These technology and input coefficients can be represented by either the one from the country under analysis or any other country producing a wide range of commodities in order to properly represent a system of production and its biocapacity demands. This assumption of a similar technology could be interpreted as the materials 'saved' owing to imports. This kind of assumption has been relaxed in recent studies by using multiregional input-output analysis (see Lenzen, 2004 or Munksgaard et al., 2009). However, this approach is out of the scope of this paper. Another aspect not captured by the model is the feedback trade loops that refer to the production dependency between countries. In this model 'autonomous trade flows' are assumed (for details see Lenzen, 2004). Moreover, it should be pointed out that we have used a matrix 'A' in monetary terms; results may change when the coefficient matrix is based on a physical input-output table or on an hybrid table, where primary and manufacturing sectors are expressed in physical units while the service sectors are expressed in monetary units (Weisz, 2007). Further assumptions are intrinsic to the general IO technique (see Miller and Blair, 2009).

Thus, assuming that the technology of production, $(I-A_t)^{-1}$, and the biocapacity intensity, $\hat{f}_{PF}^{Xd}$, are, for example, the same as the economy under analysis, Equation (15) is obtained by pre-multiplying Equation (11) by these terms:

**(15)** $$f_{EF}^m = \underbrace{\hat{f}_{PF}^{Xd}(I-A_t)^{-1}m}_{\text{I}} = \underbrace{\hat{f}_{PF}^{Xd}(I-A_t)^{-1}}_{\text{II}}\underbrace{A_m(I-A_d)^{-1}(h+e)}_{\text{III}}+\underbrace{\hat{f}_{PF}^{Xd}.(I-A_t)^{-1}y_m}_{\text{IV}}$$

where the term I provides general information about the biocapacity needed to meet total imports. Intermediate inputs have not yet been reattributed to final demand in this term. Splitting up I into II, III and IV gives insights of the 'final destinations' of the biocapacity requirements; II provides information about the biocapacity requirements for producing a unit of imports; meanwhile the term III allows estimating the import needs for the intermediate use of domestic production; and IV represents the biocapacity for satisfying the final demand of imported goods.

Therefore, from Equation (15) it is feasible to estimate the biocapacity that is necessary abroad to satisfy the domestic final demand of domestically produced commodities:

**(16)** $$f_{EF}^{mh} = \hat{f}_{PF}^{Xd}(I-A_t)^{-1}A_m(I-A_d)^{-1}h$$

It is also possible to account for imported biocapacity necessary to produce exports, which are kind of 'transit' biocapacity flows in this analytical framework, given by:

**(17)** $$f_{EF}^{me} = \hat{f}_{PF}^{x_d} (I - A_t)^{-1} A_m (I - A_d)^{-1} e$$

Finally, the biocapacity necessary to satisfy the final demand of imports are estimated as follows:

**(18)** $$f_{EF}^{mY_m} = \hat{q}_{DE}^{x_d} (I - A_t)^{-1} y_m$$

*Consumption Footprint*

As previously mentioned in section 3, the Ecological Footprint, (or consumption Footprint) is defined as the production Footprint, including direct household biocapacity demands, plus biocapacity embodied in imports minus biocapacity embodied in exports. From previous methodological analysis, the EF is estimated for each country as follows:

Consumption Footprint = Production Footprint (including direct household biocapacity demands) +
Biocapacity embodied Imports: Equations (16), (17) and (18)        -
Biocapacity embodied Exports: Equations (14) and (17).

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