



GUIDEBOOK TO THE NATIONAL FOOTPRINT ACCOUNTS 2008

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GLOBAL FOOTPRINT NETWORK, RESEARCH AND STANDARDS DEPARTMENT

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2008 Edition**

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Abbreviations

BC	Biocapacity
biocap	Biocapacity
Cnst	Constant Worksheet
EF	Ecological Footprint
efe	Ecological Footprint of Exports
efi	Ecological Footprint of Imports
efp	Ecological Footprint of Production
EQF	Equivalence factor
gha	Global hectares
L1	Level 1 Worksheet
L2	Level 2 Worksheet
L3	Level 3 Worksheet
L4	Level 4 Worksheet
L5	Level 5 Worksheet
m ³	Cubic meters
m ³ rwe	Cubic meters roundwood equivalent
NFA	National Footprint Accounts
nha	National-average hectare (for a given major land use type)
NPP	Net Primary Production
PPR	Primary Production Requirement (for fish species)
t	Metric tonnes
wha	World average hectare (for a given major land use type)
YF	Yield factor

1 Introduction

This guidebook accompanies the National Footprint Accounts 2008 Edition (hereafter *NFA 2008*).

1.1 About the *NFA 2008*

NFA 2008 reflects a major revision to previous editions, 2002 through 2006, of the National Footprint Accounts. The impetus for this revision was threefold:

- A desire to maintain a consistently updated database on a biannual basis, with improvements to methodology and transparency in each subsequent revision.
- A need to update the software system on which the National Footprint Accounts are based in order to:
 - Increase calculation performance,
 - Improve ease of portability to different platforms, and
 - Create a more modular system to aid researchers who wish to adjust or replace specific portions of the calculations.
- A comprehensive revision of the underlying source data for the *NFA 2002-2006*, including a major overhaul of the United Nations Food and Agriculture Organization's FAOSTAT database completed in late 2006 (FAO FAOSTAT Statistical Database).

These three goals have been met through the release of the *NFA 2008*.

The current National Footprint Accounts draw from approximately 5,400 data points in order to calculate the Ecological Footprint and biocapacity a single country in a given year. The National Footprint Accounts can be calculated for 202 countries in the world, for any year between 1961 and 2005. Thus, there are approximately 50 million data points on which the National Footprint Accounts depend.

1.2 About this Guidebook

This guidebook documents the collection of spreadsheets that perform the calculations in the *NFA 2008*. It is intended to be used alongside a copy of the *NFA 2008* workbook. Global Footprint Network provides licensed copies of this workbook in Microsoft Excel format. Free Academic Editions include workbooks for Hungary in 2003 and the World in 2003. Research and project licenses are available for over 150 countries for 1961 to 2006. Detailed information on licensing options, including the link to download a free Academic Edition, is available on Global Footprint Network's website at http://www.footprintnetwork.org/gfn_sub.php?content=nrb or may be obtained by contacting Global Footprint Network directly (data@footprintnetwork.org, or +1.510.839.8879).

This guidebook assumes the reader possesses an intermediate to advanced understanding of Ecological Footprint accounting and methodology. Novice users are advised to first consult the Ecological Footprint Atlas 2008 (<http://www.footprintnetwork.org/atlas>), the *Living Planet Report 2008* (WWF/Global Footprint Network/ZSL 2008) and National Footprint Accounts methodology papers (Ewing et al 2008; Kitzes et al. 2006; Kitzes et al. 2007; Wackernagel et al. 2005) before reading this guidebook.

Global Footprint Network completed this guidebook in 2008 with the generous support of the Skoll Foundation, Pollux-Privatstiftung, Fundação Calouste Gulbenkian, Oak Foundation, The Lewis Foundation, Erlenmeyer Foundation, Roy A. Hunt Foundation, The Winslow Foundation, Flora Family Foundation, TAUPO Fund, Mental Insight Foundation, The Dudley Foundation, Foundation Harafi, The Swiss Agency for Development and Cooperation, the United Arab Emirates (UAE), the Ministry of the Environment of Japan, and the World Wide Fund for Nature (WWF).

2 Structure of the NFA 2008

The workbook *NFA 2008* shows all steps of a national Ecological Footprint calculation, from raw data to the aggregate Footprint. The workbook contains seventy individual worksheets. Throughout this guidebook, worksheet and table names are indicated by *italics* and column names or individual cells are indicated with ‘single quotation marks.’ In the *NFA 2008* workbook, cells containing values and constants obtained from raw data sources or calculations outside the workbook are colored light grey. The individual sources for these data points are described in this guidebook. In all worksheets in *NFA 2008*, blank cells indicate zero values.

2.1 Supporting Workbooks

Some users of the National Footprint Accounts request and receive two additional workbooks in addition to *NFA 2008* that contain supporting raw data and constants used in *NFA 2008*.

NFA Constants 2008 contains results from Global Footprint Network calculations of important factors for Footprint calculations (e.g., the carbon sequestration factor, equivalence factors, Footprint Allocation Factors, etc.). *NFA Data 2008* contains raw data from a variety of sources, usually including time series for all countries. The redistribution of data in these supporting workbook is subject to a series of restrictions according to the data provider, and are thus not generally available for public distribution. Questions about data sources and calculations beyond those included in *NFA 2008* can be directed to Global Footprint Network.

2.2 Worksheets in NFA 2008

The 70 worksheets in NFA 2008 are divided into a hierarchical structure with five levels. Generally, worksheets in Level 1 depend on calculations in Level 2 worksheets, worksheets in Level 2 depend on calculations in Level 3 worksheets, and so on. Level 5 worksheets contain raw data drawn from outside the NFA 2008 workbook. These Level 5 worksheets do not contain any calculations, but rather serve as data sources for calculations in higher level worksheets.

Worksheets are named descriptively according to their function within the Footprint and biocapacity calculation sequence. Full descriptions of each of the worksheets, including a description of their input and output, dependencies, equations, and data sources are included in Chapters 3 - 9. Brief descriptions of the various worksheet levels are included below.

In addition to being divided into levels, worksheets are divided into groups according to the major land use type they represent. The six major land use types are cropland, grazing land, forest land, fishing grounds, carbon uptake land, and built-up land. Each of these six major land use types has a single Level 2 worksheet, and an associated group of Level 3, 4 and 5 worksheets.

The NFA 2008 workbook also contains a seventh Level 2 worksheet which performs the biocapacity calculations for all land types. Figure 3-1 shows an example of this hierarchical structure.

This guidebook uses both worksheet levels and major land use types as organizational frameworks for explaining the Ecological Footprint model. The guidebook begins with the Level 1 and 2 worksheets, providing the broadest overview of the model first. The guidebook then proceeds through each major land use type with a separate chapter for each involved in the calculation, starting with Level 3 worksheets and working down to the details of the lower level worksheets.

There is only one Level 1 worksheet, and this worksheet is explained in full in the section on Level 1 worksheets below. The Level 2 worksheets are also fairly simple and are also briefly introduced below. All level two, three, four and five worksheets are explained in depth within the chapter on each respective major land use type.

Worksheets are color coded to aid in understanding their groupings. This color coding applies to both the actual worksheet tabs in the *NFA 2008* workbook and to the figures throughout this guidebook.

Each chapter in this guidebook contains a graphical flowchart showing the interrelations between the various worksheets in that chapter (e.g., Figure 3-1). Arrows between various worksheets indicate the flow of information, with the worksheet at the head of the arrow drawing data from the worksheet at the tail. Dashed arrows indicate that the destination worksheet only reads from the indicated source in particular circumstances, such as when a different preferred data source is not available. When worksheets are only used in some circumstances, this is also noted in text with brackets ([]) surrounding the name of the worksheet.

Within the text of each chapter, each worksheet is described as shown in Figure 1 below. There is a short one sentence summary of the worksheet, the level of the worksheet is identified, and the layout and supporting data and calculations are described as in detail. Finally, references to other sheets are identified at the bottom.

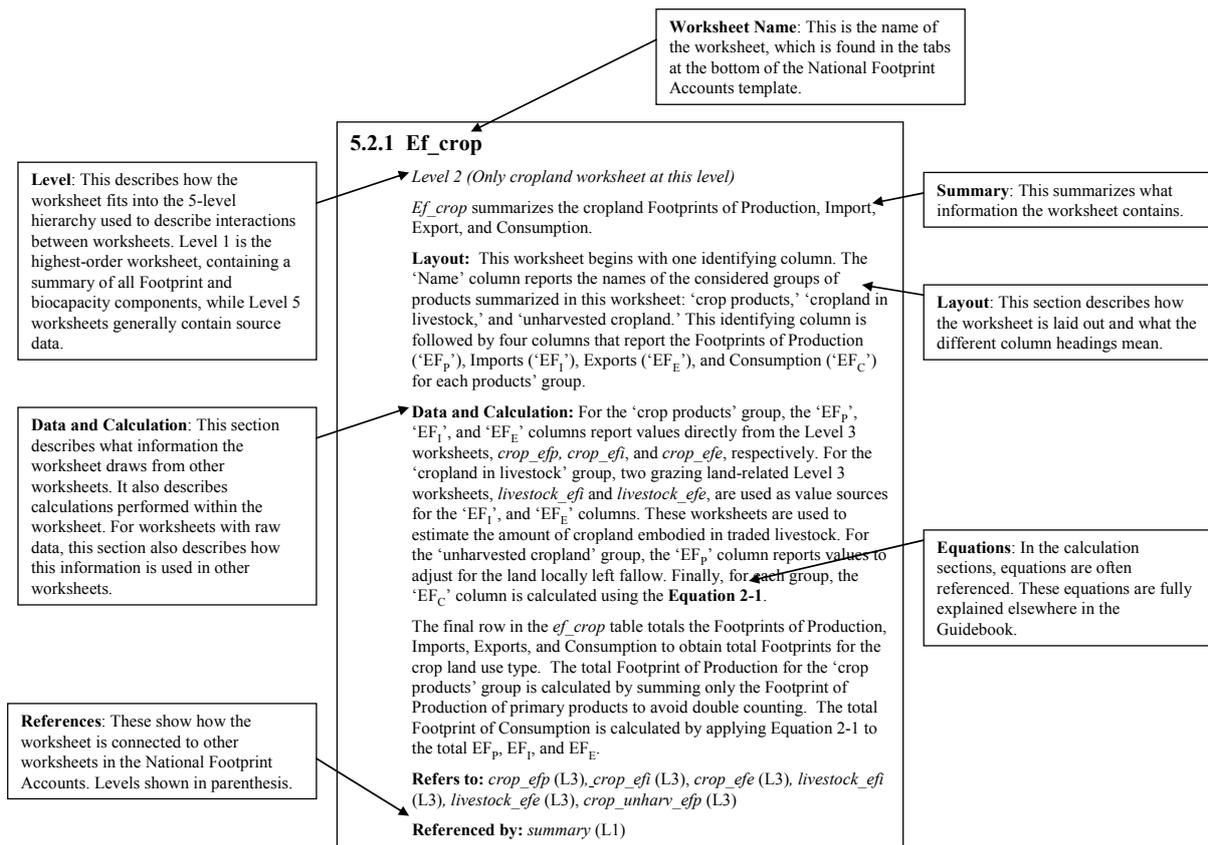


Figure 1: Worksheet description: this shows how worksheets are described in this guidebook.

2.2.1 Level 1 Worksheets

Color: Green

There is only one Level 1 worksheet, called *summary*. It is at the apex of the hierarchical organization of worksheets comprising *NFA 2008* and summarizes the Ecological Footprint and biocapacity calculations for the country and year chosen. Since the *summary* worksheet does not pertain to one particular land use type, it is described in detail here.

summary

Level 1 (Only worksheet at this level)

The *summary* worksheet combines the calculated Ecological Footprint and biocapacity of each major land use type.

Layout: The *summary* worksheet contains three tables. The first two each contain one row corresponding to each major land use type, with columns giving the Ecological Footprints of production, imports, exports and consumption, as well as biocapacity. The last row of each table sums each column and calculates Footprint and biocapacity totals. The first of these tables lists total Footprint and biocapacity for each major land use type, while the second reports a country's Footprint and biocapacity per person.

Below these two tables there is a smaller table which provides a broad overview of the results of the national Ecological Footprint calculation. The row labeled 'Ecological Reserve' lists overall ecological reserve or deficit, for both the specific country and for the world in the year in question. The next row shows the total Footprint embodied in international trade. This applies only to individual countries. The following two rows

report Footprint and biocapacity per person, respectively, for the country being summarized and for the world. Below this is a row calculating the ratio of Footprint to biocapacity. This is labeled the ‘Demand to Supply Ratio.’ The last row shows the number of planets’ worth of biocapacity that would be demanded if the world average Footprint per person were equal to that of the country in question.

To the right of this table is a pie chart showing the relative magnitudes of the Footprints of each major land use type.

Note that this summary worksheet does not contain time series data. Time series of footprint per person may be obtained for any country by contacting Global Footprint Network (data@footprintnetwork.org).

Data and Calculation: The topmost table draws Footprints of domestic production, imports, exports and final consumption from each of the six Level 2 worksheets corresponding to each major land use type. Biocapacity for each major land use type is drawn from the *biocap* worksheet. The last row of the table aggregates these into total national Footprint and biocapacity. Note that the embodied built-up land in traded goods is not calculated, so the imports and exports columns for this land use type will always be blank.

The second table in the summary worksheet draws values from the first, into an identical arrangement of rows and columns. It then divides the values in the first table by national population to determine Footprint and biocapacity per person for each major land use type. Like the preceding table, the last row of this table sums the calculated Footprints and biocapacities of each major land use type to give country totals.

The calculations in the third summary table draw all country specific values from the bottommost rows of the first two tables. The global total values listed in this table are drawn from an external table.

Refers to: *ef_forest* (L2), *ef_carbon* (L2), *ef_crop* (L2), *ef_grazing* (L2), *ef_built* (L2), *ef_fish* (L2), *biocap* (L2), *popstat_n* (L5)

Referenced by: None

2.2.2 Level 2 Worksheets

Color: Blue

The Level 2 worksheets summarize the Footprints of production, imports, exports and consumption. There are seven worksheets in total: one worksheet for each of the six major land use types as well as a single worksheet for biocapacity, which calculates biocapacity for every major land use type except carbon, which is currently assigned a biocapacity of zero (see Chapter 7). The worksheets that report the Footprints for the six major land use types are named with a prefix of *ef_* followed by the name of the major land use type. All level 2 worksheets rely on calculations from associated lower level worksheets.

- *ef_crop* summarizes the Footprint of cropland embodied in both crop and livestock products.
- *ef_grazing* summarizes the Footprint of pasture grass embodied in livestock products.

- *ef_forest* summarizes the forest land Footprint of embodied in primary and processed forest products.
- *ef_fsb* summarizes the Footprint of marine and inland water areas embodied in fish and other aquatic products.
-
- *ef_carbon* summarizes the carbon Footprint of fossil fuel combustion (both domestically emitted and embodied in traded goods) and an additional bunker fuel carbon tax. For the world as a whole, this worksheet also includes an estimate of land use change, unsustainable biofuels, and cement production.
- *ef_built* summarizes the Footprint associated with buildings, infrastructure and hydroelectric reservoir area.
- *biocap* reports a country's actual bioproductive area and biocapacity in each of the six major land use types.

The structure of the six *ef_* worksheets is very similar. Each worksheet reports the Footprint of production, imports, exports, and consumption for the different sub-components (product categories or more specific land use types) that make up each major land use type. The final row in each of these tables sums the Footprints of all sub-components to yield a total Footprint for the major land use type. These totals are used in the *summary* worksheet.

These six *ef_* worksheets apply an identical formula to calculate the Ecological Footprint of consumption from the Footprints of production, imports, and exports. The Footprint of consumption is calculated according to **Equation 2-1**.

<p>Equation 2-1 Calculation of Ecological Footprint of Consumption</p> $EF_C = EF_P + EF_I - EF_E$

Where:

EF_C = Footprint of consumption associated with product or waste

EF_P = Footprint of production associated with product or waste

EF_I = Footprint of imports associated with product or waste

EF_E = Footprint of exports associated with product or waste

The Footprints of consumption of individual products or wastes are summed to obtain an aggregate Footprint of consumption for a given land use category. Adding the Footprints of all of the major land use categories together gives the Footprint of a country or the world.

The single *biocap* worksheet uses data on area, yield factors, and equivalence factors to calculate the biocapacity of each land type. The calculation of biocapacity follows **Equation 2-2**.

Equation 2-2
Calculation of biocapacity for Single Land Type

$$BC = A \cdot YF \cdot EQF$$

Where:

- BC = biocapacity of a given land type, gha
- A = Area of a given land type within a country, nha
- YF = Yield factor of a given land type within a country, wha nha⁻¹
- EQF = equivalence factor for given land type, gha wha⁻¹.

The calculated biocapacities of the major land types are summed to obtain an aggregate biocapacity for a country or the world.

2.2.3 Level 3 Worksheets

Color: According to major land use type

In general, Level 3 worksheets convert tonnes of a product into the number of global hectares necessary to provide that product. Level 3 worksheets are thus those in which Footprint values are actually calculated. Data used by Level 3 worksheets are usually drawn from Level 4 or 5 worksheets. Level 3, 4 and 5 worksheets hold a single table with multiple fields (columns) and records (rows). The first row of each table contains the column headings and is printed in bold type. The second row contains the units of each column, printed in gray, and the remaining rows contain the table's records. Each record is found in a single row, and generally begins with the item name and official code, if applicable, in the first and second column. These codes are drawn from supporting databases and are most commonly linked to the Harmonized Standard 2002 (HS2002) or the SITC Revision 1 classification systems from the United Nations Statistical Division. In most cases, the code classification system is noted in a comment on the column heading.

When necessary, a third column, labeled 'Unit,' may be used to indicate the units of a record, and a fourth column, labeled 'P/S,' may be used to indicate whether the record describes a primary product or a secondary product.

Level 3 worksheets are described in more detail in the chapters associated with their respective major land use types. In general, the data contained in a Level 3 worksheet can be determined by its name. Most Level 3 worksheets begin with the name of the major land use type they pertain to (e.g., forest), followed by the suffixes *_efp* (for the Ecological Footprint of production), *_efi* (for the Ecological Footprint of imports), or *_efe* (for the Ecological Footprint of exports).

Some major land use types, such as carbon, are composed of multiple sub-components or minor land use types. For these, there may be multiple Level 3 worksheets with the same suffix. For example, *fossil_efp*, and *bunker_efp* report the Footprints of production for fossil fuel carbon and bunker fuels, respectively. These two Footprints of production are summed in the Level 2 worksheet *ef_carbon* to obtain the total Footprint of production for the carbon land use type.

In calculating Footprints of production, imports, and exports, Level 3 worksheets rely on the basic Ecological Footprint formula, which can be expressed as follows:

Equation 2-3

Ecological Footprint of Yearly Product Extraction or Waste Generation

$$EF = \frac{P}{Y_N} \cdot YF \cdot EQF$$

Where:

- EF = Ecological Footprint associated with product or waste, gha
- P = amount of product extracted or waste generated, t yr⁻¹
- Y_N = national-average yield for product extraction or waste absorption, t nha⁻¹ yr⁻¹
- YF = Yield factor of a given land type within a country, wha nha⁻¹
- EQF = equivalence factor for given land type, gha wha⁻¹.

Note that in **Equation 2-3**, because the Yield Factor is defined as national divided by world yield, the national-average yields cancel out (see Chapter 10). Thus, the basic Ecological Footprint formula can be expressed more succinctly in the following form:

Equation 2-3b

Ecological Footprint of Yearly Product Extraction or Waste Generation (Simplified)

$$EF = \frac{P}{Y_W} \cdot EQF$$

Where:

- Y_W = world-average yield for product extraction or waste absorption, t wha⁻¹ yr⁻¹

Equation 2-3b reflects the actual implementation of Ecological Footprint calculations in *NFA 2008*. This formula is slightly modified for some calculations, such as the calculation of the Footprint of hydroelectric electricity. Modifications to this standard formula are noted in the chapters on specific land use types below.

2.2.4 Level 4 Worksheets

Color: According to major land use type

Level 4 worksheets contain any intermediate calculations necessary between the raw data and the calculation of the Footprint. Many Level 4 worksheets contain yield calculations, which often involve using extraction rates to convert from daughter to parent product quantities. Common naming conventions for Level 4 worksheets are:

- Name of a major land use type followed by the suffix *yield n* or *yield w*. These worksheets contain the national (_n) or world (_w) yields for the named land use type, respectively. World-average yields are applied to all imports and exports in the National Footprint Accounts, with the exception of certain broad categories of fish products.
- Type of feed followed by the suffix *supply n* or *demand n*. In the grazing land section of *NFA 2008*, there are several worksheets that calculate either the amount of feed (residue, grass, etc) produced in a country (supply_n) or the amount required by livestock in that country (demand_n). e.g. *Feed_demand_n*.

Yields for primary products are calculated based on their respective yearly regeneration rates. For example, the yield for timber reflects the net annual accumulation of merchantable wood on a hectare of forest, not the amount of wood actually harvested from that hectare. Estimates of regeneration rates are used in the yield calculations for pasture land, fishing grounds, forest land, and carbon uptake. Crop yields are calculated as actual production divided by harvested area, as for cropland, harvest yields and regeneration rates are taken to be identical.

A variety of secondary and tertiary products (daughter products) are also included in the Footprint calculations. For any daughter product, yield is calculated by multiplying the yield of the primary parent product (Y^P) by the extraction rate (EXTR) of the daughter product. World average extraction rates are currently used throughout *NFA 2008* to convert secondary products into their parent product equivalents. Extraction rates indicate the amount of the primary product embodied in the daughter product. Yields of daughter products are calculated using **Equation 2-4**.

<p>Equation 2-4 Calculation for Yield of Daughter Products</p> $Y^D = Y^P \bullet EXTR$
--

Where:

$$Y^D = \text{Yield of daughter product, (t daughter) ha}^{-1} \text{ yr}^{-1}$$

$$Y^P = \text{Yield of parent product, (t parent) ha}^{-1} \text{ yr}^{-1}$$

$$EXTR = \text{Extraction rate, (t daughter) (t parent)}^{-1}$$

Country-specific extraction rates would provide a greater level of accuracy in calculations of the Footprints of exports and consumption, but are not currently implemented. The Footprint of production is not affected by extraction rates, since daughter products are not included in the Footprint of production to avoid double counting. The Footprint of imports is always calculated using world average extraction rates, as the *NFA 2008* methodology does not use full bilateral trade data. Thus, only the Footprint of exports would be directly affected by including national extraction rates of secondary products. The use of world average extraction rates will tend to overestimate the Footprint of exports for countries that produce secondary products more efficiently than the world average. This will in turn result in an underestimate of the Footprint of consumption. For countries which produce secondary products less efficiently than the world average, the Footprint of consumption will be overestimated.

Finally, there are few cases where multiple daughter products are created simultaneously from the same parent product. Soybean oil and soybean cake, for example, are extracted simultaneously from the same primary product, in this case soybean. The standard yield calculation procedure cannot be used in the case of these multiple daughter products, as doing so would lead to a double-counting of the total parent product used. As a consequence, every time multiple simultaneous daughter products are considered, the total amount of embedded primary product is split among them through Footprint Allocation Factors (FAFs). These use the relative commercial values of the secondary products to allocate the Footprint of their shared primary product between them.

2.2.5 Level 5 Worksheets

Color: According to major land use type

Level 5 Worksheets contain the raw data that all higher level worksheets use in calculations. These worksheets typically contain data on production, imports, and exports in the units of the product (i.e., tonnes for crop products or heads for animals), sometimes with additional information on the area required to produce those goods. The various products in a table are reported in different units, in which case an additional column specifies the units of each product.

The names of Level 5 worksheets generally begin with the name of a data source, followed by a suffix indicating the major land use type (e.g. *prodstat_forest*). These worksheets contain raw data from the named data source (e.g. ProdSTAT, IEA) that is used in the calculations for the named land use type. A final *_n* suffix on a worksheet name indicates national data, while a *_w* suffix indicates world data (e.g. *prodstat_forest_n* or *prodstat_forest_w*).

2.2.6 Constants Worksheets

Color: According to major land use type

Constants worksheets, worksheets that contain key constants used in calculations, fall outside of the overall worksheet hierarchy. Constants worksheets contain values in a variety of units and contain a column identifying these units.

The names of constants worksheets generally begin with the prefix *cnst_* followed by the name of a major land use type. These worksheets contain constants that are used by Level 3 and 4 worksheets in their calculations. Those constants worksheets which are used exclusively in one section of **NFA 2008** are named with the prefix *cnst_* followed by the corresponding major land use type. Other constants worksheets include data for multiple land use types and are not named according to this convention.

The following is a full list of all constants worksheets with a short description of each. Most constants worksheets are described in more detail in the corresponding chapter (e.g., *Cnst_grazing* is described in Chapter 4, *eqf* is described in Chapter 11 on equivalence factors), but *popstat_n* and *popstat_w* are described below as they are only used by the Level 1 *summary* sheet.

- *eqf* contains a table of equivalence factors for the year of calculation.
- *yf* contains a table of yield factors for a given country and year.
- *yf_crop* contains additional calculations necessary to determine the yield factor for cropland.
- *cnst_grazing* contains information such as the weight of animals and the amount of primary productivity available to animals to eat.
- *cnst_carbon* contains information such as the amount of carbon stored per hectare, the amount of carbon absorbed by the ocean, and the world average carbon intensity of fuels.

- *cnst_fish* contains information such as the amount of primary productivity in the continental shelf, a by-catch discard rate, and transfer efficiency up the food chain.
- *Popstat_n* contains populations for a given country and year.
- *Popstat_w* contains the world population for a given year.

popstat_n and popstat_w

Level 5 (2 worksheets at this level used only by summary)

The sheets *popstat_n* and *popstat_w* provide country and world populations, respectively. Their layouts are identical.

Layout: Each of the two population sheets contains only a single record. The first cell identifies the row as estimated population. The second lists the FAO's code for total population. The third cell gives either country or world population, depending on the worksheet.

Data and Calculation: These worksheets do not perform any calculations. Populations are reported in thousands, and are drawn from the PopSTAT database (FAO PopSTAT Statistical Database).

Refers to: None

Referenced by: *summary* (L1)

3 Cropland Footprint

Color: Brown

3.1 Description

3.1.1 Overview

The cropland Footprint reflects the amount of land necessary to grow all crops consumed by humans and livestock. This includes agricultural products, market animal feed, and grasses cropped and used as livestock feed.

Cropland yields are calculated for each crop type by dividing the amount of crop produced by the amount of area harvested. This differs from other major land use types in that yields for cropland reflect an actual harvest yield, whereas other yields are calculated based on regeneration rates. Harvest yields and regeneration rates for crops are equal by definition, as humans manage all growth on cropland for harvest.

The *NFA 2008* workbook tracks the production of 149 categories of primary agricultural products and 29 secondary and tertiary products created from them. The complete list of products, including both names and codes, has been generated from a complete list of all agricultural goods included in the UN's FAOSTAT ProdSTAT database as of June 2007 (FAO ProdSTAT Statistical Database). A much larger number of traded secondary products are also included in *NFA 2008*.

3.1.2 Data Sources

Data	Used in Worksheet	Data Source
Production (tonnes yr ⁻¹) and area (ha)	<i>prodstat_crop_w</i> , <i>prodstat_crop_n</i>	FAO ProdSTAT Statistical Database. http://faostat.fao.org/site/526/default.aspx (accessed June 2007).
Imports and exports (1000 t yr ⁻¹)	<i>tradstat_n</i>	FAO TradeSTAT Statistical Databases. http://faostat.fao.org/site/406/default.aspx (accessed September 2007).
Technical conversion factors for secondary agricultural products	<i>None (used in extraction rate calculations)</i>	FAO Technical Conversion Factors for Agricultural Commodities (v beta 1.g). http://www.fao.org/es/ess/tcf.asp
Agricultural commodity prices	<i>None (used in extraction rate calculations)</i>	FAO TradeSTAT Statistical Database

3.1.3 Notes

- FAOSTAT codes in the cropland section of *NFA 2008* are based on the HS2002 classification.

- The primary products included in the cropland Footprint calculation include crops used for direct food consumption as well as crops used for animal feed (e.g., alfalfa), fibers (e.g., cotton), and other uses (e.g., tobacco and rubber).
- The *crop_unharv_efp* worksheet provides an adjustment for land not harvested for the crop products being tracked to ensure the Footprint of production is not underestimated.
- The cropland and grazing land Footprints are connected, in that increased crop feed may reduce demands on grazing capacity. The grazing land section of *NFA 2008* includes a subsection on livestock trade, which accounts for both the embodied cropland and grazing land Footprints in traded livestock products.

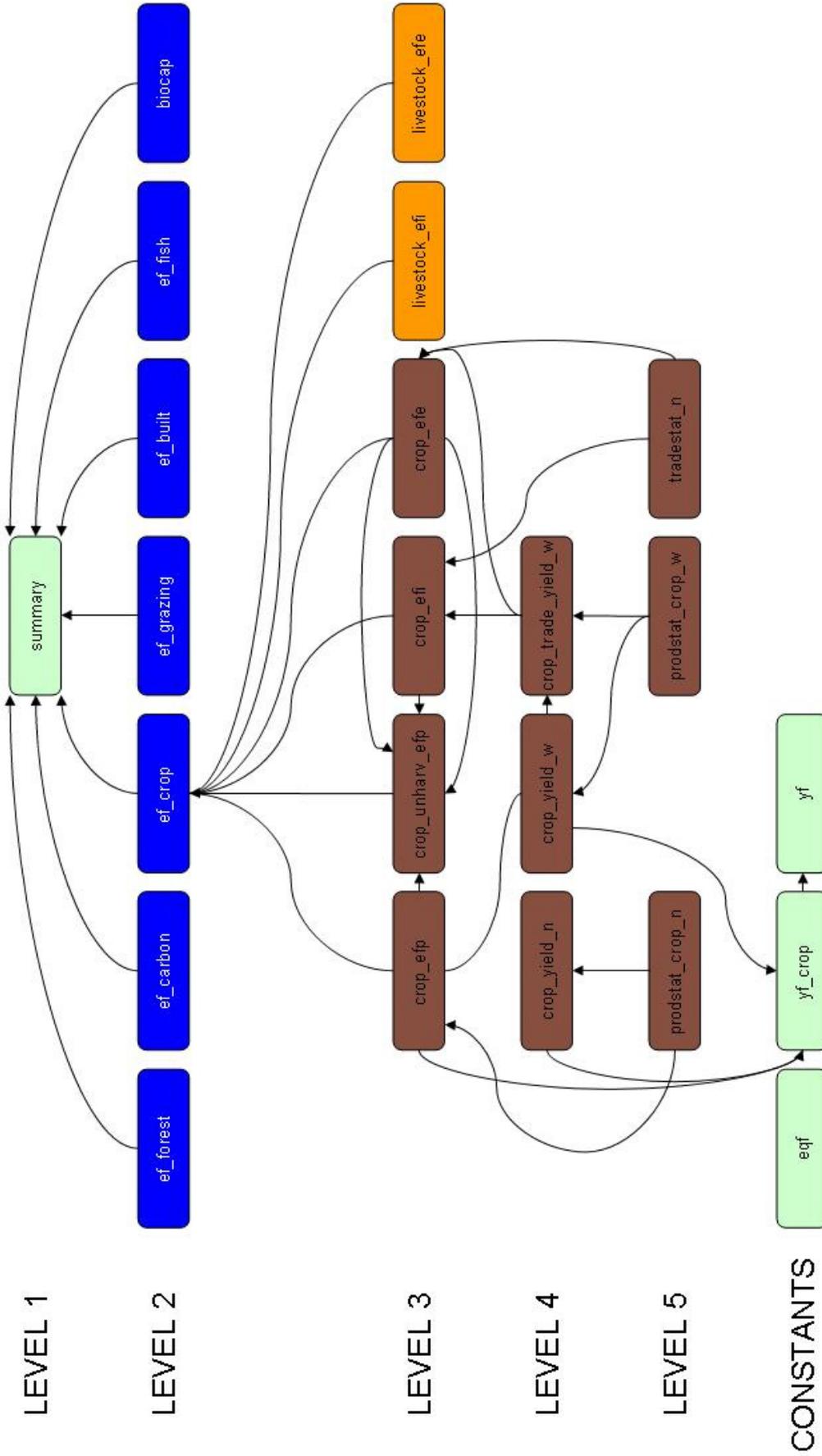


Figure 3-1 Cropland Footprint calculations. Besides the three standard Level 3 worksheets, the cropland section includes a worksheet which calculates a 'tax' intended to account for unharvested cropland. The two Level 3 sheets in the livestock trade section of *NFA 2008* contain calculations of the embodied cropland Footprint in traded livestock and secondary livestock products. Unlike those for the other major land use types, the cropland yield factor depends on calculations in higher level sheets. The yield factor for cropland is calculated in the *yf_crop* worksheet, separate from those for other land use types.

3.2 Worksheets

Figure 3-1 shows all of the worksheets involved in the calculation of the cropland Footprint. The calculation of cropland biocapacity is treated separately in Chapter 9. The cropland Footprint calculation is summarized in the Level 2 worksheet *ef_crop*. The cropland Footprint section of the *NFA 2008* workbook uses six Level 3 worksheets (two of which are in from the grazing land section), three Level 4 and three Level 5 worksheets. The two Level 3 worksheets in the livestock trade section, which include traded crop products embodied in livestock, are colored orange. All other worksheets in the cropland section of the *NFA 2008* workbook are colored brown. The structure and function of each of these worksheets is described below.

3.2.1 ef_crop

Level 2 (1 cropland worksheet at this level)

Ef_crop summarizes the cropland Footprints of production, imports, exports, and consumption.

Layout: This worksheet begins with one identifying column, labeled 'Name,' which identifies the contributions to the cropland Footprint summarized in this worksheet: 'Crop Products,' 'Cropland in Livestock,' and 'Unharvested Cropland.' This column is followed by four columns that report the Footprints of production, imports, exports and consumption for each product group. As in other Level 2 worksheets, these columns are labeled 'EF_p,' 'EF_i,' 'EF_E' and 'EF_C.'

Data and Calculation: For the 'Crop Products' group, the 'EF_p,' 'EF_i,' and 'EF_E' columns report values directly from the Level 3 worksheets *crop_eff*, *crop_efi*, and *crop_efe*, respectively. 'Cropland in Livestock' reports aggregate embodied cropland Footprints calculated in the Level 3 worksheets *livestock_efi* and *livestock_efe*. In the 'Unharvested Cropland' category, the 'EF_p' column reports the Footprint of unharvested crops as estimated in the *crop_unharv_eff* worksheet. For each record the value in the 'EF_C' column is calculated using **Equation 2-1**.

The final row in the *ef_crop* table shows totals for the Footprints of production, imports, exports, and consumption. To avoid double counting, the total Footprint of production for the 'Crop Products' group is calculated by summing only the Footprints of production of primary products. The final cropland Footprint of consumption is calculated by applying **Equation 2-1** to the column totals.

Refers to: *crop_eff* (L3), *crop_efi* (L3), *crop_efe* (L3), *livestock_efi* (L3),
livestock_efe (L3), *crop_unharv_eff* (L3)

Referenced by: *summary* (L1)

3.2.2 crop_eff

Level 3 (4 cropland worksheets at this level)

Crop_eff calculates the Footprint of production of 178 agricultural products.

Layout: *Crop_eff* begins with three identifying columns, 'Name,' 'Code' and 'P/S.' These report the name, the FAOSTAT official code and whether the record is a primary or secondary product, respectively. The next two columns, labeled 'Production' and 'Yield,' show the production quantities and yields for domestically produced goods. The 'EQF'

column provides the equivalence factor for cropland. Finally, the column labeled 'EF_p' calculates the cropland Footprint of production for each crop included in this worksheet.

Data and Calculation: 'Production' is drawn from *prodstat_crop_n*. 'Yield' is drawn either from *crop_yield_w*. 'EQF' is drawn from the *eqf* worksheet. The 'EF_p' column is calculated according to **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *prodstat_crop_n* (L5), *crop_yield_w* (L4), [*crop_yield_n* (L4)]

Referenced by: *ef_crop* (L2), *crop_unharv_efp* (L3)

3.2.3 crop_efi

Level 3 (4 cropland worksheets at this level)

Crop_efi calculates the Footprint of imports for 546 agricultural products.

Layout: *Crop_efi* begins with three identifying columns showing product names, identifying codes and specifying the product's level on the production chain. The next two columns, 'Import' and 'Yield,' show import quantities and world-average yields for imported products. The 'EQF' column gives the equivalence factor for cropland. The final column, labeled 'EF_i' uses the values in the preceding three columns to calculate the Footprint of imports for each product. Note that the list in this worksheet contains a large number of secondary agricultural goods, and is not identical to that in the *crop_effp* worksheet.

Data and Calculation: 'Import' is drawn from the *tradedstat_n* worksheet. 'Yield' is drawn from *crop_trade_yield_w* as world-average yields are used for all imports and exports in the cropland section of **NFA 2008**. 'EQF' is drawn from the *eqf* worksheet. The 'EF_i' column is calculated by applying **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *tradedstat_n* (L4), *crop_trade_yield_w* (L4), *eqf* (Cnst)

Referenced by: *ef_crop* (L2), *crop_unharv_efp* (L3)

3.2.4 crop_efe

Level 3 (4 cropland worksheets at this level)

Crop_efe calculates the Footprint of exports of 546 agricultural products.

Layout: *Crop_efe* has a layout which mirrors that of the *crop_efi* worksheet. The three identifying columns are followed by two columns, 'Export' and 'Yield,' which show export quantities and world-average yields for exported products. The 'EQF' column gives the equivalence factor for cropland. The final column, labeled 'EF_e' uses the values in the preceding three columns to calculate the Footprint of exports for each product. The list of products used in this worksheet is identical to that in *crop_efi*.

Data and Calculation: 'Export' is drawn from the *tradedstat_n* worksheet. 'Yield' is drawn from *crop_trade_yield_w* as world-average yields are used for all imports and exports in the cropland section of **NFA 2008**. 'EQF' is drawn from the *eqf* worksheet. The 'EF_e' column is calculated by applying **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *tradedstat_n* (L4), *crop_trade_yield_w* (L4), *eqf* (Cnst)

Referenced by: *ef_crop* (L2), *crop_unharv_efp* (L3)

3.2.5 *crop_unharv_efp*

Level 3 (4 cropland worksheets at this level)

Crop_unharv_efp calculates the Footprint of unharvested cropland.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Unit,' followed by a 'Value' column.

Data and Calculation: *Crop_unharv_efp* uses a national 'unharvested tax %' to account for the amount of cropland nationally left unharvested. This percentage is based on the percentage of total cropland area that is not accounted for in the list of harvested products reported by FAOSTAT, and is included to ensure that all land managed by humans as cropland, even that which is fallow in a given year, is reported as occupied and assigned a Footprint (FAO ProdSTAT Statistical Database).

Refers to: *crop_efp* (L3), *crop_efe* (L3), *crop_efi* (L3)

Referenced by: *ef_crop* (L2)

3.2.6 *livestock_efi*

Level 3 (2 livestock trade worksheets at this level in the cropland section)

Livestock_efi calculates the cropland Footprint embodied in imported livestock products.

Relevance: Together with *livestock_efe*, this worksheet is one of the two worksheets from the grazing land section of *NFA 2008* that are used in calculating the cropland Footprint. It provides a cropland Footprint of imports for 59 categories of livestock and secondary livestock products.

Refers to: *livestock_intensity_w* (L4), *tradedstat_n* (L5)

Referenced by: *ef_crop* (L2), *ef_grazing* (L2)

See section 4.3.1 for full worksheet description.

3.2.7 *livestock_efe*

Level 3 (2 livestock trade worksheets at this level in the cropland section)

Livestock_efe calculates the cropland Footprint embodied in exported livestock products.

Relevance: Together with *livestock_efi*, this worksheet is one of the two worksheets from the grazing land section of *NFA 2008* that are used in calculating the cropland Footprint. It provides a cropland Footprint of exports for 59 categories of livestock and secondary livestock products.

Refers to: *livestock_intensity_w* (L4), *tradedstat_n* (L5)

Referenced by: *ef_crop* (L2), *ef_grazing* (L2)

See section 4.3.2 for a full worksheet description.

3.2.8 *crop_yield_n*

Level 4 (3 cropland worksheets at this level)

Crop_yield_n calculates the national-average yield of the 178 agricultural products that are considered in the calculation of a country's cropland Footprint of production. This worksheet is used in calculating the yield factor for crops.

Layout: The columns in this worksheet are identical to those in the *crop_yield_w* worksheet, except that this worksheet does not contain an 'Indicator Crop' column. It begins with five identifying columns, the first three of which are identical to the first three in the *crop_eff* worksheet. The fourth and fifth columns, 'Parent Name' and 'Parent Code', show the names and FAOSTAT codes of parent products. These columns are blank for primary products. The next column is labeled 'Extr' and lists the extraction rates for secondary products. The next two columns, 'Production' and 'Area,' show world production for all 178 agricultural products and the total area devoted to cultivating each, respectively. The final column, 'Yield,' calculates the world-average yield for each product.

Data and Calculation: Values in the 'Production' and 'Area' columns are drawn from the *prodstat_crop_w* worksheet. The 'Area' column is blank for secondary and tertiary products, since yields for these are calculated by applying extraction rates to the yields of their parent products. These extraction rates are calculated using world average values from the FAO (FAO 2000). An adjustment factor to ensure that simultaneous secondary products are not double counted is also considered in the calculation (see section 2.2.4, on Level 4 worksheets, where extraction rates are discussed in detail).

Values in the 'Yield' column are calculated differently for primary and secondary products. For primary products, yield is equal to the world annual production divided by the harvested area. For daughter products, yield is calculated by multiplying the yield of the appropriate parent product (calculated as explained above) by the daughter product's extraction rate.

Refers to: *prodstat_crop_n* (L5)

Referenced by: *yf_crop* (Cnst)

3.2.9 *crop_yield_w*

Level 4 (3 cropland worksheets at this level)

Crop_yield_w calculates the world-average yields of the 178 agricultural products that are considered in the calculation of a country's cropland Footprint of production.

Layout: This worksheet begins with five identifying columns, the first three of which are identical to the first three in the *crop_eff* worksheet. The fourth and fifth columns, 'Parent Name' and 'Parent Code', show the names and FAOSTAT codes of parent products. These columns are blank for primary products. The next column is labeled 'Extr' and lists the extraction rates for secondary products. The next two columns, 'Production' and 'Area,' show world production for all 178 agricultural products and the total area devoted to cultivating each, respectively. The next column, 'Yield,' calculates the world-average yield for each product. The final column is labeled 'Indicator Crop,' and specifies which of the crops listed are used in calculating a country's yield factor for cropland.

Data and Calculation: Values in the 'Production' and 'Area' columns are drawn from the *prodstat_crop_w* worksheet. The 'Area' column is blank for secondary and tertiary products, since yields for these are calculated by applying extraction rates to the yields of their parent products. These extraction rates are calculated using world average values

from the FAO. An adjustment factor to ensure that simultaneous secondary products are not double counted is also considered in the calculation (see section 2.2.4, on Level 4 worksheets, where extraction rates are discussed in detail).

Values in the 'Yield' column are calculated differently for primary and secondary products. For primary products, yield is equal to the world annual production divided by the harvested area. For daughter products, yield is calculated by multiplying the yield of the appropriate parent product (calculated as explained above) by the daughter product's extraction rate.

Refers to: *prodstat_crop_w* (L5)

Referenced by: *crop_efp* (L3)

3.2.10 *crop_trade_yield_w*

Level 4 (3 cropland worksheets at this level).

Crop_trade_yield_w calculates world-average yields for the 546 agricultural products tracked in the trade Footprint calculations.

Layout: The columns in this worksheet are identical to those in *crop_yield_n*. The first five identify traded goods, as well as any corresponding parent products. The next column, 'Extr,' lists extraction rates for daughter products. The 'Production' column shows global production totals. 'Area' gives the global area devoted to cultivating each primary product. Finally, 'Yield' calculates the world-average yield per hectare for each agricultural commodity listed.

Data and Calculation: This worksheet uses total production and area harvested in addition to extraction rates to calculate the yield for all agricultural products. The worksheet presents all yields in units of world average cropland.

For primary products, 'Yield' is equal to the world annual production divided by the world harvested area. For daughter products, 'Yield' is calculated by multiplying the yield of the appropriate parent product by the daughter product's extraction rate. The extraction rates used here are the same world averages used in the *crop_yield_w* and *crop_yield_n* worksheets.

Refers to: *prodstat_crop_w* (L5), *crop_yield_w* (L4)

Referenced by: *crop_efe* (L3), *crop_eft* (L3)

3.2.11 *prodstat_crop_n*

Level 5 (3 cropland worksheets at this level)

Prodstat_crop_n reports the total amount of crops produced domestically and the amount of area harvested to produce these crops.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code.' These are the same as the first two columns in the *crop_efp* worksheet, except that their lists contain a few additional aggregate categories, designated by a plus ("+") symbol after the identifier in the 'Name' column. These aggregated categories are not included in any calculations so as to avoid double counting. The next columns, 'Area' and 'Production' report the domestic area cultivated and the national harvest, respectively, for each agricultural product.

Data and Calculation: *Prodstat_crop_n* does not contain any calculations and only reports raw data drawn directly from ProdSTAT (FAO ProdSTAT Statistical Database). *Prodstat_crop* is used by the worksheet *crop_yield_n* to calculate a country's yield for all primary crop products. 'Production Quantity' values reported in *prodstat_crop_n* are also used in the *crop_eff* worksheet to calculate a country's Footprint of production for all 178 crops products.

The production quantities from this worksheet are also used in two worksheets in the grazing land section of **NFA 2008**. The *market_feed_supply_n* worksheet uses them to calculate the amount of crop-derived livestock feed available domestically. The *residue_supply_n* worksheet uses them to calculate the amount of crop residues available as livestock feed.

Refers to: None

Referenced by: *crop_yield_n* (L4), *crop_eff* (L3), *market_feed_supply_n* (L4), *residue_supply_n* (L4)

3.2.12 prodstat_crop_w

Level 5 (3 cropland worksheets at this level)

Prodstat_crop_w reports the total amount of crops produced worldwide and the amount of area harvested to produce these crops.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' identical to those in the *prodstat_n* worksheet. The next columns, 'Area' and 'Production,' report the global area cultivated and world total harvest, respectively, for each agricultural product or category.

Data and Calculation: *Prodstat_crop_w* does not contain any calculations and only reports raw data drawn directly from ProdSTAT (FAO ProdSTAT Statistical Database). *Prodstat_crop_w* is used by the *crop_yield_w* and *crop_trade_yield_w* worksheets to calculate world-average yields for various agricultural goods.

Refers to: None

Referenced by: *crop_yield_w* (L4), *crop_trade_yield_w* (L4)

3.2.13 tradestat_n

Level 5 (3 cropland worksheets at this level)

The *tradestat_n* worksheet reports the imports and exports of all agricultural products traded by countries. It is nominally assigned to the cropland component but is used in both the grazing land and livestock trade sections.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' identical to those in the *crop_efi* and *crop_efe* worksheets. These identifying columns are followed by two columns, 'Import + Food Aid' and 'Export + Food Aid,' showing the imported and exported quantities for each of the traded products, respectively.

Data and Calculation: The *tradestat_n* worksheet does not contain any calculations and only reports raw data drawn directly from TradeSTAT (FAO TradeSTAT Statistical Database). In the cropland section of **NFA 2008**, *tradestat_n* is used by the *crop_efi* and *crop_efe* worksheets to calculate a country's Footprint embodied Footprint of trade. The

trdestat_n worksheet is also used in calculating the embodied grazing land Footprint in livestock products, as explained in section 4.2.12.

Refers to: None

Referenced by: *crop_efi* (L3), *crop_efe* (L3), *grass_supply_n* (L4), *livestock_intensity_w* (L4), *livestock_efi* (L3), *livestock_efe* (L3)

4 Grazing Land Footprint

Color: Light Orange

4.1 Description

4.1.1 Overview

The grazing land Footprint assesses demand for grazing land to feed livestock, as well as the embodied grazing land in traded goods. This is the most logically complex section of *NFA 2008*. The calculation estimates the total feed requirements of all livestock produced and the percentage of livestock energy requirements derived from concentrate feeds, forage crops, and crop residues. The difference between total feed requirement and total cropped feed supply is taken to equal the demand for grazing land.

The grazing land section of *NFA 2008* relies heavily on the methodology and data proposed by Haberl et al (2008) for calculating human appropriation of net primary production. The calculation starts with the number of livestock in a country and their feed requirements. These feed requirements are filled through market feed (crops grown specifically to be fed to animals), residues (crop scraps that can be fed to livestock but not to humans), and cropped grasses (grasses that are grown on cropland and cut specifically to be fed to livestock). Once the feed demand satisfied by the above sources has been accounted for, the remaining amount of feed required is assumed to be provided by grazing land. The amount of grazing land required is based on dividing the grass feed required by the average grass yield of rangeland.

This chapter on grazing land is divided into two sections: Grazing Land (section 4.2) and Livestock Trade (section 4.3). The first of these describes all worksheets containing calculations or data pertaining solely to the grazing land Footprint. The second includes worksheets which track trade in livestock and livestock derived products. These livestock trade worksheets calculate both embodied grazing land and cropland Footprints, since both land use types contribute to livestock feed. Thus, the livestock trade section affects both the cropland and grazing land Footprints of consumption.

4.1.2 Data Sources

Data	Worksheet Referenced	Data Source
Production quantities of livestock products, and livestock populations (tonnes year ⁻¹ or heads or 1000 heads)	<i>prodstat_livestock_n</i> , and <i>prodstat_livestock_w</i> use this for the production data. <i>Resourcestat_n</i> uses this to assess stocks of livestock that are supported by not harvested yearly.	FAO ProdSTAT Statistical Database. http://faostat.fao.org/site/452/default.aspx (accessed January 2007).
Imports and exports of livestock (1000)	<i>tradestat_n</i>	FAO TradeSTAT Statistical Databases. http://faostat.fao.org/site/406/default.aspx (accessed September 2007).

tonnes year ⁻¹)		
Feed efficiency (kg dry matter head ⁻¹ day ⁻¹) and feed intake (tonnes dry matter year ⁻¹)	<i>feed_demand_n</i>	Haberl, H., K.H. Erb, F. Krausmann, V. Gaube, A. Bondeau, C. Plutzer, S. Gingrich, W. Lucht and M. Fischer-Kowalski. 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. <i>PNAS</i> 104: 12942-12947.
Dry matter percent (tonnes dry matter crop (tonne crop) ⁻¹)	<i>residue_supply_n</i>	Haberl, H., K.H. Erb, F. Krausmann, V. Gaube, A. Bondeau, C. Plutzer, S. Gingrich, W. Lucht and M. Fischer-Kowalski. 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. <i>PNAS</i> 104: 12942-12947.
Market feed percent (tonnes feed (tonne market product) ⁻¹)	<i>faostat_feed_ratio</i>	FAO Supply Utilization Accounts Statistical Database. 2003. (Archived from prior FAOSTAT release, no longer available online).
Animal weights (tonnes head ⁻¹)	<i>cnst_grazing</i>	Vaclav Smil. 2000. <i>Feeding the World: A Challenge for the Twenty-First Century</i> . Cambridge: MIT Press.
Above-ground NPP %, edible % of above-ground NPP	<i>cnst_grazing</i>	Chad Monfreda (personal communication). 2008. SAGE, University of Wisconsin, Madison.
Number of Animals in stock (heads or 1000 heads)	<i>resourcesat_livestock</i>	FAO ResourceSTAT Statistical Database. http://faostat.fao.org/site/348/default.aspx (accessed August 2007).

4.1.3 Notes

- Because grazing land biocapacity represents the total amount of above ground net primary production available annually, overshoot from year to year is not physically possible. To reflect this, the grazing land Footprint of production is not allowed to exceed available biocapacity.
- Depending on the livestock species in question, feed requirement may be calculated based on standing stocks or annual meat production.

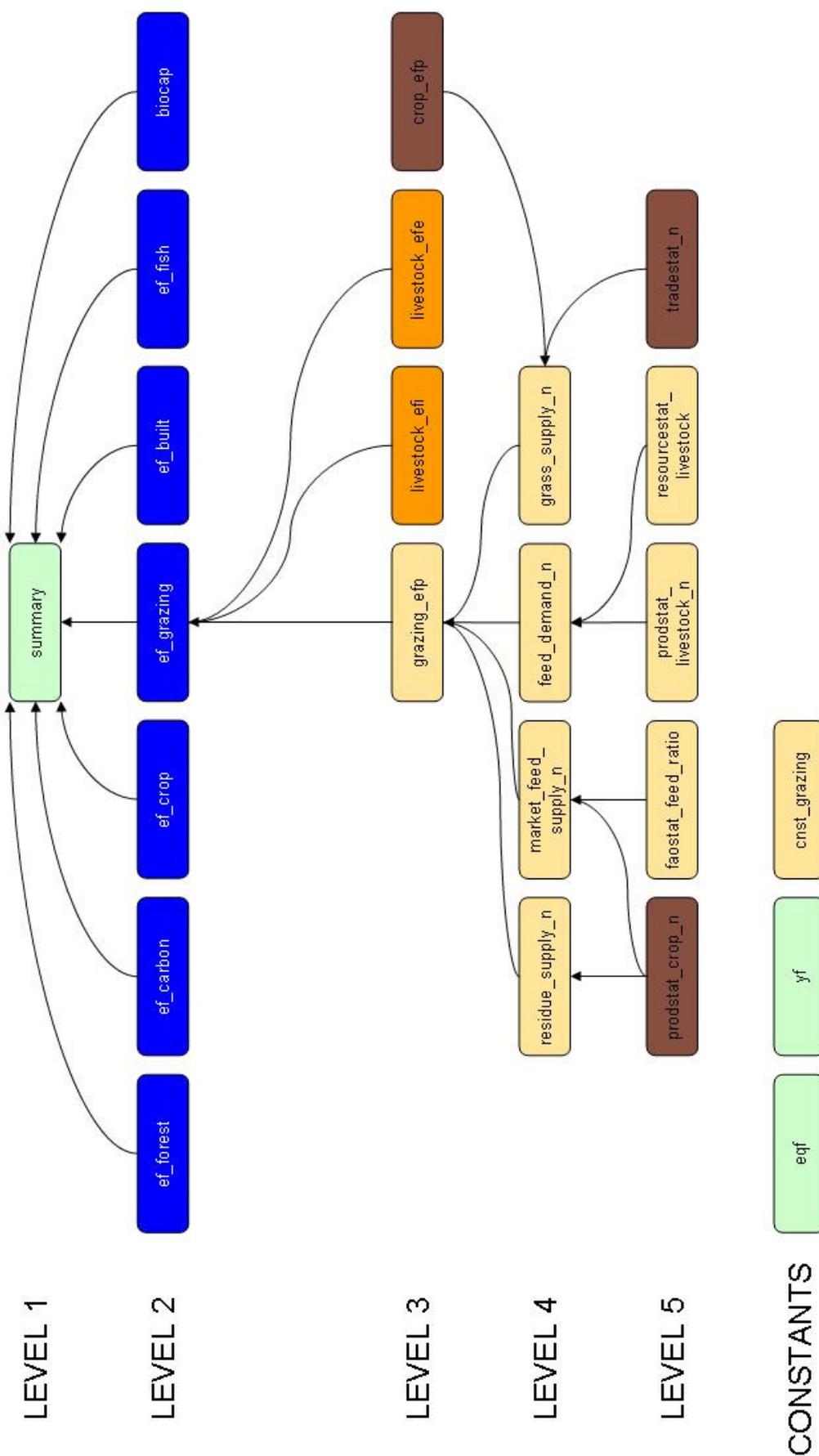


Figure 4-1

Grazing land Footprint calculations. The Grazing Land section itself contains only one Level 3 worksheet, calculating domestic grazing land demand. The Grazing Footprint embodied in traded goods is calculated entirely in the livestock trade section. Several cropland footprint worksheets supply data for the grazing land Footprint calculation, in order to account for the portion of the total livestock feed requirement being met by crops and crop residues.

4.2 Worksheets

Figure 4-1 shows all of the worksheets involved in the calculation of the grazing land Footprint. The calculation of grazing land biocapacity is treated separately in Chapter 9.

The grazing land section of the *NFA 2008* workbook contains one Level 2 worksheet, *ef_grazing*, one Level 3 worksheet, four Level 4 worksheets, and three Level 5 worksheets. In addition, the grazing land Footprint calculation draws data from three sheets in the cropland section of *NFA 2008*, one at Level 3 and two at Level 5. The grazing land worksheets are colored light orange in the *NFA 2008* workbook and in this guidebook. The structure and function of each of these worksheets is described below.

4.2.1 ef_grazing

Level 2 (Only grazing land worksheet at this level)

Ef_grazing summarizes the grazing land Footprints of production, imports, exports, and consumption.

Layout: This worksheet begins with one identifying column. The 'Name' column reports the names of the considered groups of products: 'Domestic Grazing Land', which contains the Footprint of production, and 'Grazing Land in Livestock', which reports the Footprint of imports and exports. This identifying column is followed by four columns that report the grazing land required, or Footprints of production, imports, exports, and consumption for each main group. As in other Level 2 worksheets, these columns are labeled 'EF_p', 'EF_i', 'EF_E' and 'EF_C'.

Data and Calculation: The 'EF_p', 'EF_i' and 'EF_E' columns report values directly from the Level 3 worksheets *grazing_efp* into 'Domestic Grazing Land' and *livestock_efi*, and *livestock_efe*, into 'Grazing Land in Livestock.' The 'EF_C' column is calculated using **Equation 2-1**.

The final row in the *ef_grazing* table totals the Footprints of production, imports, exports, and consumption to obtain total Footprints for the grazing land use type. The total Footprint of production is determined by domestic use of grazing land, while the total Footprints of imports and exports represent the grazing land embodied in the traded livestock. The total Footprint of consumption is calculated by applying **Equation 2-1** to the column totals.

Refers to: *grazing_efp* (L3), *livestock_efi* (L3), and *livestock_efe* (L3)

Referenced by: *summary* (L1)

4.2.2 grazing_efp

Level 3 (Only grazing land worksheet at this level)

Grazing_efp calculates the total Pasture Grass Demand needed to feed livestock nationally.

Layout: *Grazing_efp* begins with one identifying column, 'Name,' which identifies categories of feed supply and demand. The next two columns are labeled 'Feed Supply' and 'Feed Demand.' In each row in the table, only one of these columns holds a value, depending on whether the row represents a feed supply or demand category.

The remaining four columns pertain only to the last row: 'Pasture Grass Demand.' The 'Yield' and 'EQF' columns report national average grazing land yield, and the equivalence factor for grazing land, respectively. The next column, 'Est EF_p,' calculates the grazing land Footprint of production. The last column is labeled 'EF_p,' and adjusts the estimate in the previous column to account for domestic grazing land availability.

'Market Feed' contains data on the amount of crop feed grown for livestock. 'Residue Feed' contains data on the amount of residue crops fed to livestock. 'Cropped Grass Feed' contains data on the amount of grasses grown for livestock. 'Total Feed Demand' estimates the tonnes of feed required to feed livestock. 'Pasture Grass Demand' is used to calculate the remaining feed demand supplied by grazing land.

Data and Calculation: The calculation assumes that livestock are fed with available crop derived feeds and then, if necessary, with grass from grazing lands. The first three rows report the feed quantities supplied in each crop feed category, calculated in lower level sheets. The fourth row reports total livestock feed demand, and the final row calculates the demand for pasture grass by subtracting the amounts of crop derived feed from this total demand.

The estimated Footprint of production is calculated by converting the demand for pasture grass into the number of global hectares needed, using **Equation 2-3b**. This calculation takes place in the 'Est EF_p' column.

If this estimated Footprint of production is less than available biocapacity, it is reported in the 'EF_p' column as the final grazing land Footprint of production. Otherwise, 'EF_p' is capped at the calculated domestic grazing land biocapacity.

Refers to: *cnst_grazing* (Cnst), *feed_demand_n* (LA), *residue_supply_n* (LA), *grass_supply_n* (LA), *market_feed_supply_n* (LA)

Referenced by: *ef_grazing* (L2)

4.2.3 crop_efp

Level 3 (1 cropland worksheets at this level in the grazing land section)

Crop_efp calculates the Footprint of production of 178 primary agricultural products. This worksheet is from the cropland section of **NFA 2008** but is used here to determine cropped feed supplies for livestock.

Relevance: Production quantities drawn from *crop_efp* are used in the grazing land Footprint calculation to account for the amount of cropped grass feed available for livestock. This calculation is explained in more detail in the description of the *grass_supply_n* worksheet (see section 4.2.5).

See section 3.2.2 for full worksheet description.

4.2.4 feed_demand_n

Level 4 (4 grazing land worksheets at this level)

Feed_demand_n calculates the total amount of feed needed to produce the stock of livestock of a country.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' reporting the names and ProdSTAT codes for each of the animals and products listed.

The next two columns, labeled 'Production' and 'Heads,' show the number of livestock, or the quantity of animal products produced. The 'Feed Efficiency' column shows the ratio of feed to meat for those livestock. The next column, 'Feed Intake,' gives the daily feed demand per head for those animals for which total stocks are reported. The last column, 'Feed Demand,' calculates the total annual feed demand for each animal or product.

Data and Calculation: 'Production' is drawn from *prodstat_livestock_n* while values in 'Heads' are drawn from *resourcestat_livestock*. Each record in the table will contain a value in only one of these fields, as each record is reported either as a producing stock or as a production quantity. Products are listed in the 'Production' column when production is reported in tonnes while they are listed in the 'Heads' column when available data specify only the producing stock of animals. Depending on whether stock or production quantity is reported, each record will have a value in either the 'Feed Efficiency' or the 'Feed Intake' column.

The last column, 'Feed Demand,' calculates the total demand for feed of each considered livestock group or animal product. For products measured in tonnes, 'Feed Demand' is calculated by multiplying 'Production' by 'Feed Efficiency.' For products measured in number of heads, 'Feed Demand' is calculated by multiplying 'Heads' by 'Feed Intake,' then for consistency converting this daily feed demand in kilograms into an annual demand in tonnes. Total 'Feed Demand' is then obtained by summing the contributions of all animals and products. This total is reported in the last row of the 'Feed Demand' column.

Refers to: *prodstat_livestock_n* (L5), *resourcestat_livestock* (L5)

Referenced by: *grazing_eff* (L3)

4.2.5 *grass_supply_n*

Level 4 (4 *grazing land worksheets at this level*)

The *grass_supply_n* worksheet shows the amount of cropped feed grass available nationally.

Layout: *Grass_supply_n* begins with two identifying columns, 'Name' and 'Code.' These report the ProdSTAT names and codes for each type of grass used for feed. The third column, 'Production,' shows the harvested quantities of each of the grass crops, in tonnes of dry matter. The two following columns, 'Import' and 'Export,' show the traded quantities of these grass products. The last column, labeled 'Available,' shows the total amount of cropped grass fed to livestock.

Data and Calculation: *Grass_supply_n* only accounts for grass specifically produced for the purpose of being fed to livestock. This worksheet is used by the *grazing_eff* worksheet to determine the amount livestock feed demand that is met with cropped grass.

Domestic cropped grass production is calculated by multiplying production values (in wet weight) drawn from the 'Production' column of the *crop_eff* worksheet by the dry weight fraction value, drawn from *cnst_grazing*. Due to the lack of better data, this value is assumed to be equal for all grass products. Data on imports and exports is drawn from the *tradedstat_n* worksheet. The available quantity is calculated for each grass type as production plus imports minus exports, in a manner analogous to **Equation 2-1**.

Refers to: *crop_eff* (L3), *tradedstat_n* (L5), *cnst_grazing* (Cnst)

Referenced by: *grazing_eff* (L3)

4.2.6 market_feed_supply_n

Level 4 (4 *grazing land worksheets at this level*)

Market_feed_supply_n calculates the amounts of various domestic crop harvests used as animal feed.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' reporting the ProdSTAT names and codes for each crop product potentially used for feed. The list of products reported in 'Name' excludes products already counted in the *grass_supply_n* worksheet. A third identifying column, 'Feed Name,' is drawn from the previous revision of the FAOSTAT Supply Utilization Accounts (FAO Supply Utilization Accounts Statistical Database). This is necessary because the product names in the Supply Utilization Accounts, which *faostat_feed_ratio* uses, are not necessarily the same as those used in ProdSTAT. The fourth column, 'Production,' shows the national production of each crop used as animal feed. This is followed by a 'Market Feed Percent' column, which reports the country specific percentages of the various crops used for feed. The last column, 'Market Feed,' calculates the market feed supply within a country.

Data and Calculation: 'Production' is drawn from the *prodstat_crop_n* worksheet. The following column, 'Market Feed Percent,' is drawn from the *faostat_feed_ratio* worksheet (see Section 4.2.8) and shows the percentage of market crop harvest that is used as feed. 'Market Feed' is calculated by multiplying 'Production' by 'Market Feed Percent.' The sum of the values in this column is used in the *grazing_eff* worksheet.

Refers to: *prodstat_crop_n* (L5), *faostat_feed_ratio* (L5)

Referenced by: *grazing_eff* (L3)

4.2.7 residue_supply_n

Level 4 (4 *grazing land worksheets at this level*)

Residue_supply_n worksheet shows the national supply of crop residues used as livestock feed.

Layout: This worksheet begins with two identifying columns, 'Crop Name' and 'Code,' reporting the ProdSTAT names and codes of each crop producing residues potentially used as feed.

The third column, 'Production,' shows the amounts of various crops grown within a country. The next column, 'Dry Matter %,' shows the percentage of dry matter in each product. The following column, 'Residue Feed Ratio,' shows the amount of crop residues used as feed, as a percentage of the dry mass of usable crop material harvested. The last column, 'Residue Feed,' calculates the amount of feed derived from each type of crop residue produced within a country.

Data and Calculation: Production is drawn from the *prodstat_crop_n* worksheet. 'Dry Matter %' and 'Residue Feed Ratio' are drawn from Haberl et al. (Haberl et al. 2007). The 'Residue Feed' value shown in the final column is calculated for each row by multiplying 'Production,' 'Dry Matter %' and 'Residue Feed Ratio.'

Refers to: *prodstat_crop_n* (L5)

Referenced by: *grazing_eff* (L3)

4.2.8 faostat_feed_ratio

Level 5 (4 grazing land worksheets at this level)

Faostat_feed_ratio worksheet shows the percentages of various harvested crops used as animal feed.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' reporting the names and codes from the older FAOSTAT Supply Utilization Accounts for each feed type (FAO Supply Utilization Accounts Statistical Database). The third column, 'Market Feed Percent,' shows the percentage of the crop harvest used as feed.

Data and Calculation: The market feed percent values are drawn from the previous revision of the FAOSTAT Supply Utilization Accounts (FAO Supply Utilization Accounts Statistical Database). This is used to calculate the total amount of market feed available within a country.

Refers to: None

Referenced by: *market_feed_supply_n* (L4)

4.2.9 prodstat_livestock_n

Level 5 (4 grazing land worksheets at this level)

Prodstat_livestock_n worksheet reports national data on primary livestock products, drawn directly from ProdSTAT (FAO ProdSTAT Statistical Database).

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' reporting the names and ProdSTAT codes for each livestock product. These columns are followed by three columns labeled 'Production,' 'Heads' and 'Yield.' These give the production quantity for each animal product, the number of producing animals and the yield per producing animal, respectively.

Data and Calculation: All values in this worksheet are from ProdSTAT (FAO ProdSTAT Statistical Database). Together with the *resourcestat_livestock* worksheet, *prodstat_livestock_n* is used by the *feed_demand_n* worksheet to calculate the total amount of feed needed to maintain the stock of livestock within a country.

Refers to: None

Referenced by: *feed_demand_n* (L4)

4.2.10 prodstat_livestock_w

Level 5 (4 grazing land worksheets at this level)

Prodstat_livestock_w worksheet reports global stock and production data for livestock, from ProdSTAT (FAO ProdSTAT Statistical Database). **This worksheet is not used in NFA 2008; it is only provided for reference. It is not shown in Figure 6-1.**

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' reporting the names and ProdSTAT codes for each livestock product. These columns are followed by three columns labeled 'Production,' 'Heads' and 'Yield.' These give the production quantity for each animal product, the number of producing animals and the yield per producing animal, respectively.

Data and Calculation: All values in this worksheet are from ProdSTAT (FAO ProdSTAT Statistical Database). This worksheet is provided so as to provide a comparison with *prodstat_livestock_n* such that users can compare national and world livestock production.

Refers to: None

Referenced by: None

4.2.11 resourcestat_livestock

Level 5 (4 grazing land worksheets at this level)

The *resourcestat_livestock* worksheet reports stocks of live animals, obtained from ResourceSTAT (FAO ResourceSTAT Statistical Database).

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' reporting the ProdSTAT names and codes for each stock of live animals. These columns are followed by one column, 'Stocks,' showing the number of animals in a country.

Data and Calculation: All data on animal stocks reference ResourceSTAT (FAO ResourceSTAT Statistical Database). Together with the *prodstat_livestock_n* worksheet, *resourcestat_livestock* is used by the *feed_demand_n* worksheet to calculate the total amount of feed needed to maintain the stock of livestock of a country.

Refers to: None

Referenced by: *feed_demand_n* (L4)

4.2.12 tradestat_n

Level 5 (1 cropland worksheets at this level in the grazing land section)

The *tradestat_n* worksheet reports data on traded livestock and crop products, drawn directly from TradeSTAT (FAO TradeSTAT Statistical Database). It is nominally assigned to the cropland component but is used in both the grazing land and livestock trade sections.

Relevance: In the grazing land section of *NFA 2008*, the *tradestat_n* worksheet is used by the *grass_supply_n* worksheet in calculating the net amount of cropped grass available.

Refers to: None

Referenced by: *grass_supply_n* (L4), *livestock_efi* (L3), *livestock_efe* (L3), *crop_efi* (L3), *crop_efe* (L3)

See section 3.2.13 for full worksheet description.

4.2.13 prodstat_crop_n

Level 5 (3 cropland worksheets at this level)

Prodstat_crop_n reports the total amount of crops produced in a country and the amount of area harvested to produce these crops. This worksheet is part of the cropland section of *NFA 2008*, but is also used here to determine cropped feed supplies for livestock.

Relevance: This worksheet is used in the grazing land section of *NFA 2008* to provide the *residue_supply_n* and *market_feed_supply_n* worksheets with total crop production data.

Refers to: None

Referenced by: *residue_supply_n* (L4), *market_feed_supply_n* (L4)

See section 3.2.11 for full worksheet description.

4.2.14 **cnst_grazing**

Constant (*only constant grazing land worksheet*)

Cnst_grazing reports several constants for the grazing section including the percentage of above-ground NPP and edible above-ground NPP in world average grazing land as well as the weight of several animals.

Layout: This worksheet begins with one column 'Name,' which describes the constant listed. The following two columns define the value, with the 'Unit' noted as well as the 'Value.' If applicable, notes are listed in the final column.

Data and Calculation: *cnst_grazing* is used by both *grazing_efb* and *feed_intensity_w* worksheets to estimate the grass yield of world average grazing lands. This worksheet also reports animal weights (Smil 2000), used in *livestock_efi* and *livestock_efe* to determine imported and exported amounts, respectively (see sections 4.3.1 and 4.3.2).

Refers to: FAO ProdSTAT Statistical Database

Referenced by: *grazing_efb* (L3), *feed_intensity_w* (L5), *livestock_efi* (L3), *livestock_efe* (L3)

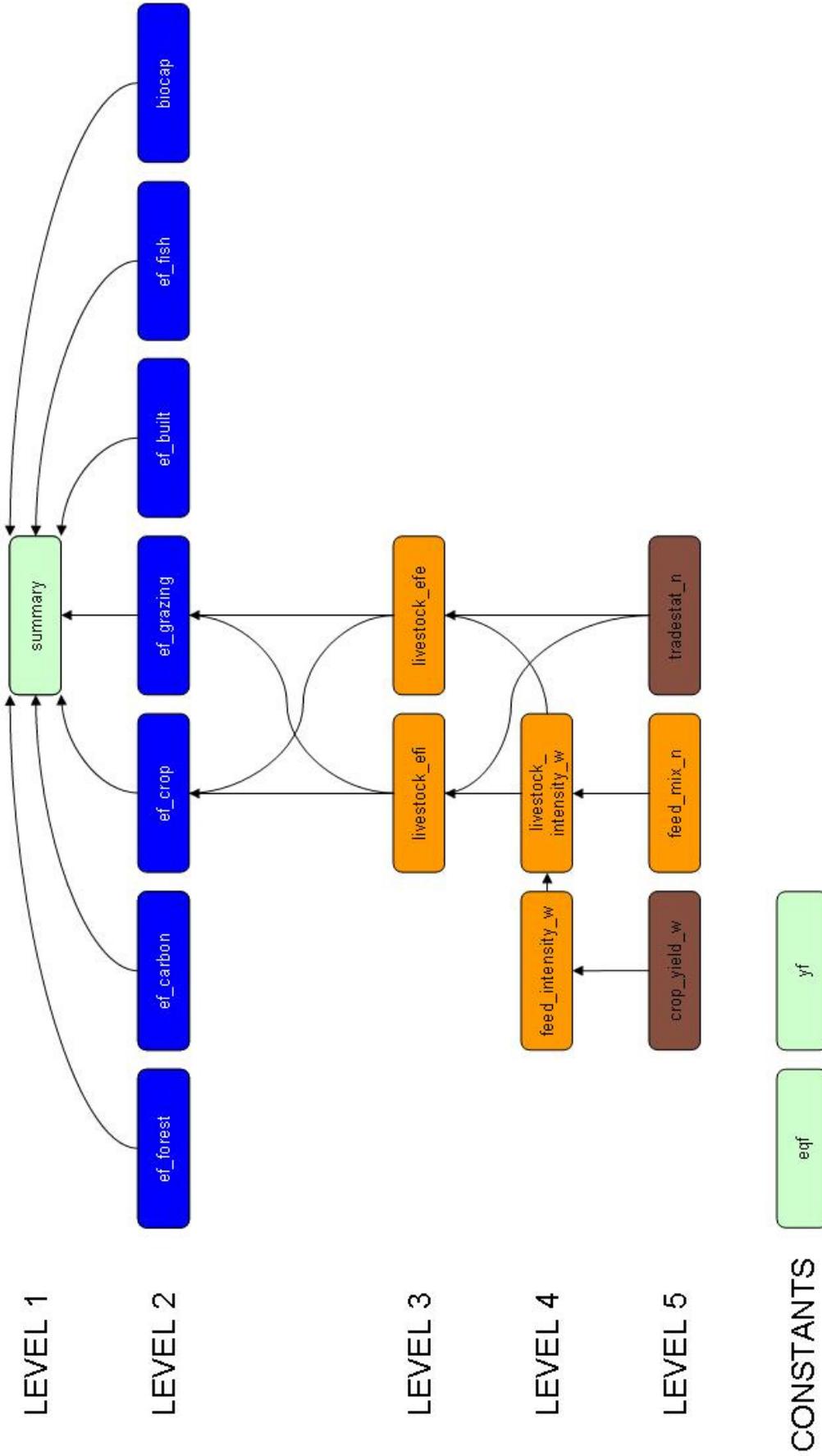


Figure 6-2
Livestock Trade Footprint calculations. The livestock trade section calculates the embodied Footprints of both grazing land and cropland in traded livestock and secondary livestock products. Thus, the Level 3 sheets in this section contribute to both the cropland and grazing land sections of *NFA 2008*.

4.3 Worksheets: Livestock Trade

Color: Dark Orange

The livestock trade section of **NFA 2008** acts as a bridge between the grazing land and the cropland Footprint sections, as livestock are fed from both grazing land and cropland (see section 4.1 for a detailed explanation). The livestock trade section does not calculate a footprint of production. It only accounts for the cropland and grazing land Footprints embodied in traded livestock products. It contains of two Level 3 worksheets, two Level 4 worksheets and one Level 5 worksheet.

Figure 6-2 shows all of the worksheets involved in the calculation of the livestock trade section. Two worksheets from the cropland section of **NFA 2008** (*crop_yield_w* and *tradedstat_n*) are used in the livestock trade section. Like all cropland worksheets, these are colored brown. All livestock trade worksheets are colored dark orange in the **NFA 2008** workbook and this guidebook. The structure and function of each of these worksheets is described below.

Data	Worksheet Referenced	Data Source
Extraction rates	<i>livestock_intensit_y_w</i> , <i>feed_intensivity_w</i>	FAO. 2000. <i>Technical Conversion Factors for Agricultural Commodities</i> .
Feed requirements for livestock	<i>feed_mix_n</i>	Vaclav Smil. 2000. <i>Feeding the World: A Challenge for the Twenty-First Century</i> . Cambridge: MIT Press.

4.3.1 livestock_efi

Level 3 (2 livestock trade worksheets at this level)

Livestock_efi calculates the Footprints of imports of 59 livestock and animal products.

Layout: This worksheet begins with two identifying columns. The ‘Product Name’ and ‘Code’ columns report the TradeSTAT names and codes for each of the 59 products. The third column, ‘Import,’ shows the imported amount of each of the 59 products. This column is followed by a summary column, labeled ‘Total.’ Subsequent columns calculate the Footprint of various feed types contributing to the imported animal products.

Data and Calculation: Raw data on meat imports are drawn from the *tradedstat_n* worksheet. For a few products, *tradedstat_n* worksheet provides data in units of heads rather than tonnes. In this case, animal weights drawn from the *cnst_grazing* worksheet are used to convert to tonnes.

Footprints reported by feed type are calculated by multiplying the total imported quantity (shown in the ‘Import’ column) by the corresponding Footprint intensity value drawn from the *livestock_intensivity_w* worksheet (see section 4.3.3). ‘Total’ is calculated by summing the Footprints of the various feed sources into one embodied Footprint value.

Of these column values, the embodied Footprint of grass production is applied to the total grazing land Footprint. All other embodied Footprint values are cropland Footprints, since this is the origin of the various feeds listed. The ‘Fish Meal’ and ‘Other Concentrate Feed’ columns are not implemented in **NFA 2008**, and contain zeroes for all records.

Refers to: *tradedstat_n* (L5), *livestock_intensity_w* (L4), *cnst_grazing* (Cnst),
Referenced by: *ef_crop* (L2), *ef_grazing* (L2)

4.3.2 *livestock_efe*

Level 3 (2 *livestock trade worksheets at this level*)

livestock_efe calculates the Footprint of exports of 59 livestock and animal products.

Layout: The layout of *livestock_efe* is identical to that of *livestock_efi*. This worksheet begins with two identifying columns. The ‘Product Name’ and ‘Code’ columns report the TradeSTAT names and codes for each of the 59 products. The third column, ‘Export,’ shows the exported amount of each of the 59 products. This column is followed by a summary column, labeled ‘Total.’ Subsequent columns calculate the Footprint of various feed types contributing to the exported animal products.

Data and Calculation: Export quantities are drawn from the *tradedstat_n* worksheet. For a few products, *tradedstat_n* worksheet provides data in units of heads rather than tonnes. In this case, animal weights drawn from the *cnst_grazing* worksheet are used to convert to tonnes.

Footprints reported by feed type are calculated by multiplying the total exported quantity (shown in the ‘Export’ column) by the corresponding Footprint intensity value drawn from the *livestock_intensity_w* worksheet (see section 4.3.3). ‘Total’ is calculated by summing the Footprints of the various feed sources into one embodied Footprint value.

Of these column values, the embodied Footprint of grass production is applied to the total grazing land Footprint. All other embodied Footprint values are cropland Footprints, since this is the origin of the various feeds listed. The ‘Fish Meal’ and ‘Other Concentrate Feed’ columns are not implemented in *NFA 2008*, and contain zeroes for all records.

Refers to: *tradedstat_n* (L5), *livestock_intensity_w* (L4), *cnst_grazing* (Cnst)
Referenced by: *ef_crop* (L2), *ef_grazing* (L2)

4.3.3 *livestock_intensity_w*

Level 4 (1 *livestock trade worksheet at this level*)

The *livestock_intensity_w* worksheet provides the world average embodied Footprint of each feed type for the goods tracked in the livestock trade section of *NFA 2008*.

Layout: This worksheet begins with five identifying columns. The ‘Product Name’ and ‘Code’ columns report the ProdSTAT names and codes for each animal product and ‘P/S’ indicates whether a record refers to a primary or secondary product. The fourth and fifth columns, ‘Parent Product’ and ‘Parent Code,’ show the ProdSTAT name and code of the corresponding product’s parent product. These five identifying columns are followed by a column labeled ‘Extr,’ which shows the extraction rate for each daughter product. As elsewhere in *NFA 2008*, extraction rates convert secondary products into their primary product equivalents. The next column, ‘Intensity,’ calculates the total Footprint embodied in a tonne of each livestock product, by summing the contributions of all feed types. This column is followed by numerous columns (‘Maize,’ ‘Soybeans,’ etc.) showing the Footprint intensities of each feed type.

Data and Calculation: Extraction rates are calculated internally by Global Footprint Network. The amounts of various crop feeds allocated to each type of livestock product are calculated by multiplying feed intensity values drawn from the *feed_intensity_w* worksheet (see section 4.3.4) with the feed mix values drawn from the *feed_mix_n* worksheet (see section 4.3.5).

Livestock_intensity_w is used by the *livestock_efi* and *livestock_efe* worksheets to calculate the Footprint of traded livestock and animal products (see sections 4.3.1 and 4.3.2). The feed products embodied in livestock trade are treated as trade in embodied cropland and thus reported in the *ef_crop* worksheet, while the grass embodied in livestock trade (in the last column) is treated as trade in embodied grazing land and reported in the *ef_grazing* worksheet.

Refers to: *feed_intensity_w* (L4), *feed_mix_n* (L4)

Referenced by: *livestock_efi* (L3), *livestock_efe* (L3), *ef_crop* (L2)

4.3.4 *feed_intensity_w*

Level 5 (2 livestock trade worksheets at this level)

The *feed_intensity_w* worksheet calculates the embodied Footprint of a tonne of feed, for each category of feed (fish meal and other concentrate feed are listed, but are not included in *NFA 2008*).

Layout: This worksheet begins with five identifying columns. The 'Name' and 'Code' columns report the ProdSTAT names and codes for each category of feed and 'P/S' indicates whether a record refers to a primary or secondary product. The fourth and fifth columns, 'Parent Name' and 'Parent Code' show the name and the ProdSTAT code of the corresponding product's parent product. These columns are blank for primary products. The five identifying columns are followed by a column labeled 'Extr,' which lists the extraction rates for daughter products. The next column, 'Yield,' shows the world-average yield for agricultural and grass products used as feed. The following column, 'EQF' gives the equivalence factor the corresponding land use type, either cropland or grazing land. The last column, 'Intensity,' calculates the Footprint intensity of each type of feed.

Data and Calculation: Extraction rates are calculated internally by Global Footprint Network. Yields for primary products are drawn from the *crop_yield_w* worksheet, while yields for secondary products are calculated by multiplying values drawn from the *crop_yield_w* worksheet by 'Extr.' Equivalence factors are drawn from the *eqf* worksheet. The Footprint intensity, or number of global hectares required to produce each tonne of feed, is calculated by dividing 'EQF' by 'Yield.' The *feed_intensity_w* worksheet is used by the *livestock_intensity_w* worksheet to calculate the embodied Footprint in a tonne of each of the 59 livestock products.

Refers to: *crop_yield_w* (L4), *feed_intensity_w* (L4) *eqf* (Cnst)

Referenced by: *livestock_intensity_w* (L4)

4.3.5 *feed_mix_n*

Level 5 (2 livestock trade worksheets at this level)

Feed_mix_n worksheet estimates the amount of feed needed to produce a tonne of each livestock product.

Layout: This worksheet begins with three identifying columns. The ‘Name’ and ‘Code’ columns report the names and ProdSTAT codes for each of the animal products and ‘P/S’ indicates whether a record refers to a primary or secondary product. The fourth column (‘TFR’) reports the total feed requirement for each animal product, in tonnes of feed per tonne of final product. This column is followed by several columns reporting the amounts of various feed types required to produce a tonne of each livestock product.

Data and Calculation: This data is drawn from *Feeding the World* (Smil 2000). *Feed_mix_n* worksheet is used by the *livestock_intensity_w* worksheet to calculate the area of each feed-related land use type needed to produce a tonne of each livestock product.

Refers to: None

Referenced by: *livestock_intensity_w* (L4)

4.3.6 tradestat_n

Level 5 (2 cropland worksheets at this level in the livestock trade section)

The *tradestat_n* worksheet reports traded quantities of livestock and crops, drawn directly from TradeSTAT (FAO TradeSTAT Statistical Database). It is nominally assigned to the cropland component but is used in both the grazing land and livestock trade sections.

Relevance: In the livestock trade section, *tradestat_n* is used by the *livestock_efi* and *livestock_efe* worksheets to calculate the Footprints of imports and exports for the 59 livestock and animal products.

Refers to: None

Referenced by: *livestock_efi* (L3), *livestock_efe* (L3)

See section 3.2.13 for full worksheet description.

4.3.7 crop_yield_w

Level 5 (2 cropland worksheets at this level in the livestock trade section)

Crop_yield_w calculates the world-average yields of the 178 crop products that are considered in the calculation of a country’s cropland Footprint of production.

Relevance: In the livestock trade section, *crop_yield_w* is used by the *feed_intensity_w* worksheet to calculate the intensity of each feed category.

Refers to: None

Referenced by: *feed_intensity_w*

See section 3.2.9 for full worksheet description.

5 Forest Footprint

Color: Green

5.1 Description

5.1.1 Overview

The forest land Footprint assesses human demand for the regenerative capacity of the world's forests. The forest land Footprint of production is comprised of two broad types of primary product: wood used for fuel, and timber used as a raw material to produce secondary timber products.

The forest land Footprint represents the area of world average forest land needed to supply wood for construction, fuel and paper. To calculate Footprint of forest products, timber harvests are compared against the net annual growth rates of the world's forests. Global and country specific forest yields (i.e. net annual increments) are drawn from a combination of sources, including the FAO Temperate and Boreal Forest Resource Assessment, FAO's Global Fibre Supply Model, and Global Footprint Network calculations based on an IPCC accounting methodology (IPCC 2006). Although the carbon Footprint has an indirect relation to forest yield, the carbon and forest Footprints are treated entirely separately in the ***NFA 2008*** workbook. The calculation of the carbon Footprint is described in Chapter 6.

The ***NFA 2008*** workbook tracks the production of 16 categories of primary forest products and 17 secondary products created from them. Of the primary products counted in ***NFA 2008***, there are 13 categories of raw timber and 3 categories of fuelwood. The complete list of products has been generated from a list of all forest products included in the UN's FAOSTAT ForesSTAT database as of December 2007 (FAO ForesSTAT Statistical Database). The product names and codes correspond to those used in this database.

5.1.2 Data Sources

Data	Worksheet Referenced	Data Source
Production, imports, exports (tonnes, m ³ or m ³ roundwood equivalent)	<i>prodstat_forest_n</i> , <i>prodstat_forest_w</i>	FAO ForesSTAT Statistical Database. http://faostat.fao.org/site/626/default.aspx#ancor (accessed December 2007).
Secondary product extraction rates (unit primary product / unit secondary product)	<i>forest_yield_w</i>	UNECE and FAO. 2005. <i>European Forest Sector Outlook Study</i> . http://www.unece.org/timber/docs/sp/sp-20.pdf (accessed October 2008)
Net annual increment (m ³ ha ⁻¹ yr ⁻¹)	<i>forest_yield_n</i> , <i>forest_yield_w</i>	UNECE and FAO. 2000. <i>Temperate and Boreal Forest Resource Assessment</i> . Geneva: UNECE, FAO. FAO. 1998. <i>Global Fiber Supply Model</i> . ftp://ftp.fao.org/docrep/fao/006/X0105E/X0105E.pdf (accessed October 2008). IPCC. 2006. <i>2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture Forestry and Other Land Use</i> . http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html (accessed September 2008).

5.1.3 Notes

- Although the Ecological Footprints of timber and wood fuel have been treated separately in previous NFA editions, they are reported together in **NFA 2008** in one combined forest Footprint. The *ef_forest* worksheet does, however, show the two forest subcategories used in earlier editions ('Timber Products' and 'Wood Fuel') with a separate Footprint calculation for each.
- All primary forest products are reported in units of m³ roundwood equivalent (rwe), since these are cut or otherwise processed from raw harvested wood.
- Paper products might be considered tertiary products as they are made from pulp, a secondary product. However, the **NFA 2008** workbook treats paper as a secondary product. The extraction rates used for paper products convert tonnes of paper directly into a roundwood equivalent.
- The 3 categories of fuel wood are listed as secondary products, as they are assigned an extraction rate greater than 1 to convert yield values for merchantable timber into equivalent fuelwood yields. Fuel wood has no parent product counted in another category, however. Thus including fuel wood in the final EF_p does not lead to double counting.

- Various secondary forest products are reported either in units of cubic meters (m³) or in metric tonnes (t). For this reason, each worksheet listing forest products includes a unit column.
- Non-timber forest products, such as tree nuts, herbs, and barks, are not currently included in the *NFA 2008* due to a shortage of data on total national extraction of these products and the small scale of their current extraction relative to timber products. These non-timber products do fall within the bounds of Ecological Footprint accounting, and should eventually be included.

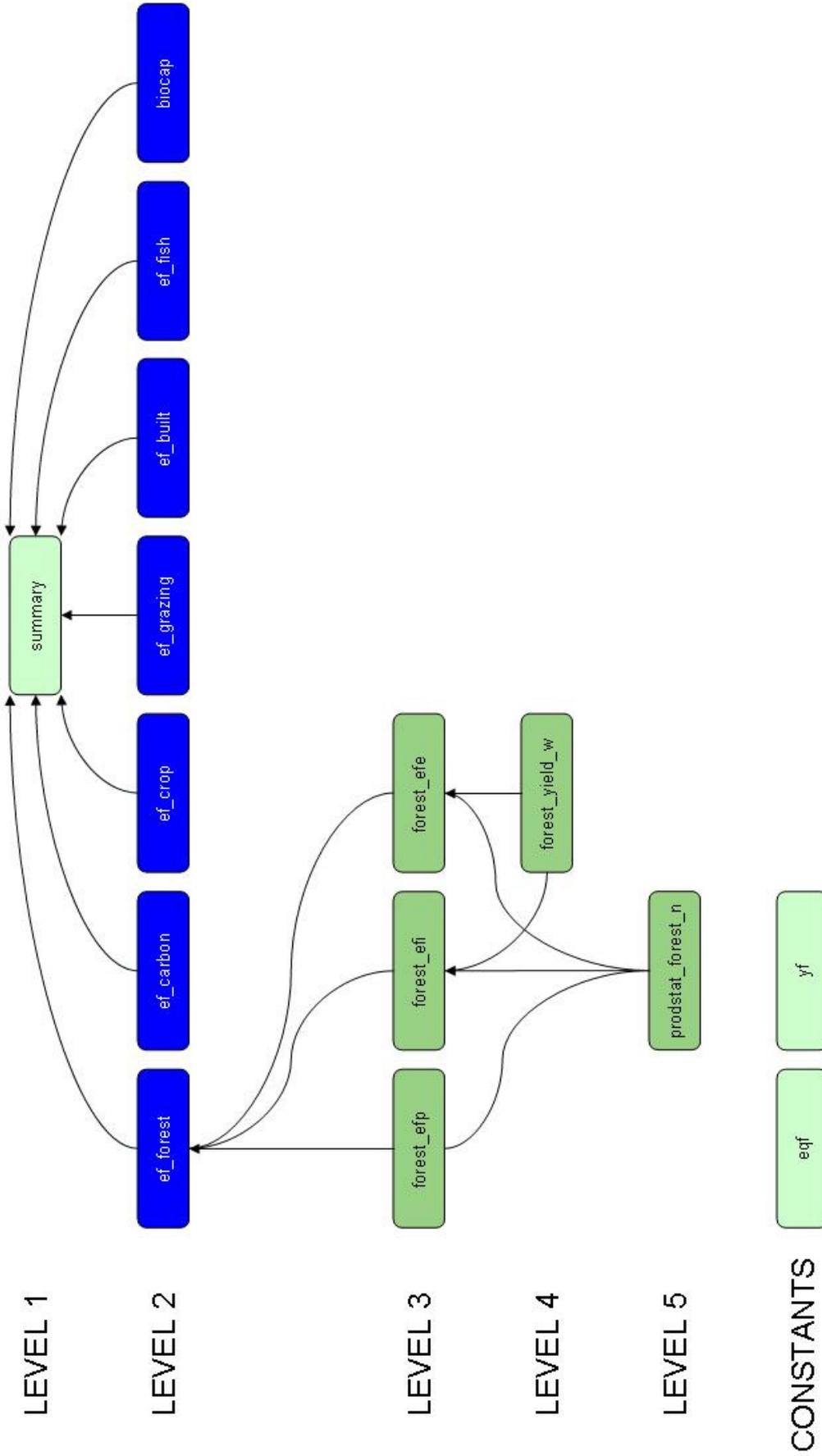


Figure 3-1
Forest Footprint. This flow diagram illustrates the calculation of the Forest land Footprint in *NFA 2008*. The forest section contains the standard Level 3 worksheets, calculating Footprints of production, imports and exports. Lower level sheets provide production and trade quantities, and calculate yields for primary forest products.

5.2 Worksheets

Figure 3-1 shows all of the worksheets involved in the calculation of the forest land Footprint. The calculation of forest biocapacity is treated separately in Chapter 9.

The forest land section of *NFA 2008* contains three Level 3 worksheets, two Level 4 worksheets, and one Level 5 worksheet. All lower level sheets in the forest land section are colored green. The structure and function of the forest worksheets is described below.

5.2.1 ef_forest

Level 2 (*Only forest worksheet at this level*)

The *ef_forest* worksheet summarizes the Footprints of production, imports, exports, and consumption both for timber and for fuelwood products.

Layout: This worksheet begins with an identifying column, labeled ‘Name,’ which identifies the broadest categories of timber products. This is followed by four columns labeled ‘EF_p,’ ‘EF_i,’ ‘EF_E’ and ‘EF_C.’ These report the Footprints of production, imports, exports and consumption, respectively, for each category.

There are two categories of forest product in this worksheet: ‘Timber Products’ and ‘Wood Fuel.’ These correspond to what in previous versions of the National Footprint Accounts were treated as two separate land use types, but now comprise the forest Footprint.

Data and Calculation: The ‘EF_p,’ ‘EF_i,’ and ‘EF_E’ columns report values directly from the Level 3 worksheets *forest_efp*, *forest_efi*, and *forest_efe*, respectively. The ‘EF_C’ column is calculated using **Equation 2-1**.

The ‘Wood Fuel’ category aggregates the first 3 products in the lists in *forest_efp*, *forest_efi*, and *forest_efe*. All other products in the lists are summed under ‘Timber Products,’ though secondary products contribute only to the embodied Footprint of trade flows.

The final row in *ef_forest* totals the Footprints of production, imports, exports, and consumption for the two forest use categories to obtain total Footprints for the forest land use type. The total Footprint of consumption is calculated by applying **Equation 2-1** to the column totals.

Refers to: *forest_efp* (L2), *forest_efi* (L2), *forest_efe* (L2)

Referenced by: *summary* (L1)

5.2.2 forest_efp

Level 3 (*3 forest worksheets at this level*)

The *forest_efp* worksheet calculates the Footprint of production for all primary forest products harvested in a country.

Layout: *Forest_efp* worksheet contains the entire list of 33 forest products, and calculates a Footprint of production for each of them. *Forest_efp* begins with four identifying columns: ‘Name’ identifies categories of forest product, ‘Code’ gives the code used in ForesSTAT to identify the product category, ‘Unit’ indicates the unit of each product (m³

rwe, m³, or t) and 'P/S' contains either a "p" to indicate a primary product or an "s" to indicate a secondary product.

The next column is labeled 'Production' and shows production quantities for the various products. This is followed by 'Yield,' which gives product yields in tonnes per hectare, incorporating extraction rates for secondary products. The next column, 'EQF,' provides the equivalence factor for forest land. This is followed by a column labeled 'EF_p,' which calculates the forest land Footprint of production for each of the 33 listed products.

Data and Calculation: 'Production' is drawn from the *prodstat_forest_n* worksheet. 'Yield' is drawn from *forest_yield_w* or *forest_yield_n* worksheet. 'EQF' is drawn from the *eqf* worksheet.

The 'EF_p' column is calculated according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values. Note that only the Footprints of production for fuelwood and for timber products marked as primary ("p") are included in a country's total forest Footprint of production.

Refers to: *prodstat_forest_n*(L5), *forest_yield_w*(L4), *eqf* (Cnst), [*forest_yield_n*(L4)]

Referenced by: *ef_forest*(L2)

5.2.3 forest_efi

Level 3 (3 forest worksheets at this level)

The *forest_efi* worksheet calculates the forest Footprint of a country's imports.

Layout: The *forest_efi* worksheet calculates the Footprint of imports of 33 forest products. *Forest_efi* begins with four identifying columns, identical to those in the *forest_efp* worksheet.

The next column, 'Import,' shows the imported product quantities. This is followed by 'Yield' and 'EQF' columns which report yields for imported products, and the equivalence factor for forest land, respectively. The last column, labeled 'EF_i,' calculates the Footprint of imports for each of the 33 products tracked in the forest land section of **NFA 2008**.

Data and Calculation: 'Imports' is directly drawn from *prodstat_forest_n* worksheet. Because the **NFA 2008** workbook lacks information about bilateral trade between countries, the yield applied to imports is assumed to be equal to world-average yield. Thus, 'Yield' is drawn from *forest_yield_w* worksheet. 'EQF' is drawn from *eqf* worksheet.

The 'EF_i' column is calculated according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *prodstat_forest_n* (L5), *forest_yield_w*(L4), *eqf* (Cnst)

Referenced by: *ef_forest* (L2)

5.2.4 forest_efe

Level 3 (3 forest worksheets at this level)

The *forest_efe* worksheet calculates the embodied forest Footprint of a country's exports.

Layout: The *forest_efe* worksheet calculates the embodied Footprint of exports for 33 forest products. *Forest_efe* begins with four identifying columns, identical to those in the *forest_efp* and *forest_efi* worksheets.

The next column, 'Export,' shows the imported product quantities. This is followed by 'Yield' and 'EQF' columns which report yields for imported products, and the equivalence factor for forest land, respectively. The last column, labeled 'EF_E,' calculates the Footprint of exports for each of the 33 products tracked in the forest land section of *NFA 2008*.

Data and Calculation: 'Exports' is directly drawn from *prodstat_forest_n* worksheet. 'Yield' is drawn from *forest_yield_w*, as world average extraction rates are assumed for secondary forest products. 'EQF' is drawn from *eqf* worksheet.

The 'EF_E' column is calculated according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *prodstat_forest_n* (L5), *forest_yield_w* (L4), *eqf* (Cnst)

Referenced by: *ef_forest* (L2)

5.2.5 forest_yield_n

Level 4 (2 Forest worksheets at this level)

The *forest_yield_n* worksheet calculates a country's domestic yield for two categories of primary forest products. This worksheet is used in calculating a country's forest biocapacity.

Layout: This worksheet begins with four identifying columns identical to those in the Level 3 worksheets. The next two columns, 'Parent Name' and 'Parent Code,' show the name and the code of any parent product, as listed elsewhere in the table. For primary products, these columns are blank. The next column is labeled 'Extr' and gives the extraction rates for secondary products. The final column, labeled 'Yield,' calculates the world-average yield for each product.

The *forest_yield_n* worksheet contains only yields for 'Sawlogs + Veneer Logs' and 'Pulpwood, Round & Split,' as these are used as the parent product categories for all secondary forest products. Since only primary products are listed, the columns 'Parent Name' and 'Parent Code' are blank in this table.

Data and Calculation: As both categories in the *forest_yield_n* worksheet are primary forest products, their extraction rates are 1. For both categories, 'Yield' is the national average net annual increment for all forests.

Refers to: None

Referenced by: *yf* (Cnst), [*forest_efp*(L3)]

5.2.6 forest_yield_w

Level 4 (2 forest worksheets at this level)

The *forest_yield_w* worksheet calculates the world-average yields of the 33 products accounted for in the forest Footprint section of *NFA 2008*.

Layout: The columns of this worksheet are identical to those of *forest_yield_n* worksheet. It calculates the yield of 33 forest products as the secondary product yields are used to calculate the Footprints of production, import and export.

Data and Calculation: For primary products, either world average forest growth rates are used. For secondary products 'Yield' is calculated by applying extraction rates to convert quantities to primary product equivalents, following **Equation 2-4**.

In **NFA 2008**, secondary processed wood products are assigned to the parent product 'Sawnlogs+Veneer Logs (C).' Secondary pulp and paper products are assigned to the parent product 'Pulpwood, Round&Split(C).' Because all primary products in **NFA 2008** are assigned the same yield, the choice of which of these to associate with each secondary product has no impact on that secondary product's calculated yield.

Extraction rates are determined based on weighted averages of extraction rates for European countries as reported in the *European Forest Sector Outlook Survey* (UNECE and FAO 2005). Extraction rates ('Extr') for primary products are set equal to 1.

Refers to: None

Referenced by: *forest_efi* (L3), *forest_efe* (L3)

5.2.7 prodstat_forest_n

Level 5 (2 Forest worksheets at this level)

The *prodstat_forest_n* worksheet reports total national production, import and export quantities for each of the 33 forest products accounted for in the forest land section of **NFA 2008**.

Layout: The *prodstat_forest_n* worksheet begins with two identifying columns, 'Name' and 'Code,' which report the names and ForesSTAT codes for each forest product.

The next columns report production quantities, imports, and exports for each forest product. These are labeled 'Production,' 'Imports' and 'Exports,' and their values are used in the *forest_efp*, *forest_efi* and *forest_efe* worksheets, respectively. The units of these columns may be either cubic meters or metric tonnes, depending on the product described. A complete list of the units associated with each product is available from ForesSTAT (FAO ForesSTAT Statistical Database). Units are also reported in all the Level 3 worksheets involved in calculating the forest Footprint.

Data and Calculation: The *prodstat_forest_n* worksheet reports a country's production, import and export quantities for the products in the forest land section of **NFA 2008**. These data are drawn from ForesSTAT (FAO ForesSTAT Statistical Database).

Refers to: None

Referenced by: *forest_efp*(L3), *forest_efi*(L3), *forest_efe*(L3)

5.2.8 prodstat_forest_w

Level 5 (2 Forest worksheets at this level)

The *prodstat_forest_w* worksheet lists production quantities and total international trade flows for each of the 33 products accounted for in calculating the forest land Footprint.

This worksheet is not used for any calculations in NFA 2008; it is provided only for reference. It is not shown in Figure 3-1.

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' reporting the names and ForesSTAT codes for each of the 33 forest products.

The next column, 'Production,' reports global total production quantities, imports and exports for each forest product. These are labeled 'Production,' 'Imports' and 'Exports.' The units of these columns may be either cubic meters or metric tonnes depending on the product. A complete list of the units associated with each product is available from ForesSTAT (FAO ForesSTAT Statistical Database) and is reported in all the Level 3 worksheets involved in the forest Footprint calculation.

Data and Calculation: The *prodstat_forest_w* worksheet reports data drawn directly from FAOSTAT (FAO ForesSTAT Statistical Database). The *prodstat_forest_w* worksheet is not used by any other worksheets in **NFA 2008** workbook, and is provided solely for user reference and comparison to *prodstat_forest_n* worksheet.

The total traded quantities in the 'Import' and 'Export' columns are not exactly equal due to discrepancies in various countries' individually reported imports and exports.

Refers to: None

Referenced by: None

6 Fishing Grounds Footprint

Color: Cyan

6.1 Description

6.1.1 Overview

The fishing grounds Footprint represents fisheries' demands on aquatic ecosystems as the equivalent surface area required to sustainably support a country's catch.

The fishing grounds Footprint is calculated by dividing the amount of primary production consumed by an aquatic species over its lifetime by an estimate of the harvestable primary production per hectare of marine area. This harvestable primary production is based on a global estimate of the sustainable catch of several aquatic species (FAO, 1971). These sustainable catch figures are converted into primary production equivalents, and divided by the total area of continental shelf. This same calculation is currently used for inland fish as well. Fish yields are calculated outside of the *yf* worksheet based on the average trophic level of each species. A higher trophic level fish requires more space on the continental shelf than one at a lower trophic level.

The *NFA 2008* workbook tracks the production of 1,538 marine and freshwater species, including fish, invertebrates, mammals, and aquatic plants. The fishing grounds Footprint includes all wild caught fish but currently does not account for production through aquaculture. The complete list of species corresponds to all species tracked in FishSTAT (FAO FishSTAT Fisheries Statistical Database).

6.1.2 Data Sources

Data	Worksheet Referenced	Data Source
Production, imports, exports (tons)	<i>figis_capture_marine, figis_capture_inland</i>	FAO FishSTAT Fisheries Statistical Database. http://www.fao.org/fishery/figis (accessed March 2008).
Trophic levels	<i>fish_yield_w</i>	Fishbase Database. Froese, R. and D. Pauly (Eds.) 2008. http://www.fishbase.org (accessed June 2008).
Area of EEZ	<i>None (used in calculation of available NPP)</i>	Sea Around Us Project. Fisheries Centre, Pew Charitable Trusts and the University of British Columbia. 2008. http://www.searoundus.org/project.htm (accessed October 2008).
Discard factor, transfer efficiency, carbon content of fish per tonne wet weight	<i>cnst_fish</i>	Pauly D. and V. Christensen. 1995. Primary production required to sustain global fisheries. <i>Nature</i> . 374: 255-257.
Sustainable catch	<i>None (used in calculation of available NPP)</i>	Gulland, J.A. 1971. <i>The Fish Resources of the Ocean</i> . West Byfleet, Surrey, England: Fishing News.

6.1.3 Notes

- Calculations of the yield for fish are extremely sensitive to the estimated trophic level of the species. These estimates are drawn from average values from Fishbase, many of which have large standard errors (Fishbase Database). The uncertainty in the fisheries yields for individual species is thus large compared to other products in the *NFA 2008*.
- The yields for fish catches are calculated by estimating the amount of primary production that can be harvested sustainably. This calculation considers only the raw primary production available to feed marine consumers, and not the dynamics of individual marine species stocks. To the extent that stocks are degrading or eroding over time, this analysis may significantly overestimate the available biocapacity of fisheries each year
- A discard rate is used to scale the yield of each species downward to reflect the discarded primary production related to their harvest. This discard rate is currently assumed to be constant across all species. This will tend to underestimate the yields for species that do not have high discard rates associated with their fisheries, and overestimate the yield for species that have higher discard rates in their fisheries (e.g. prawns).
- The Footprint of production of wild fish species tracks the total catch landed within a country, rather than of the fish caught within the waters of that country. This differs from the definition of Footprint of production for the other major land use types, where the Footprint of production refers to all products extracted from land physically located within the country. The Footprint of production calculated for fishing grounds thus cannot be compared to the biocapacity of fishing grounds for a specific country to determine whether that country's own waters are, according to world average PPR, over-fished.

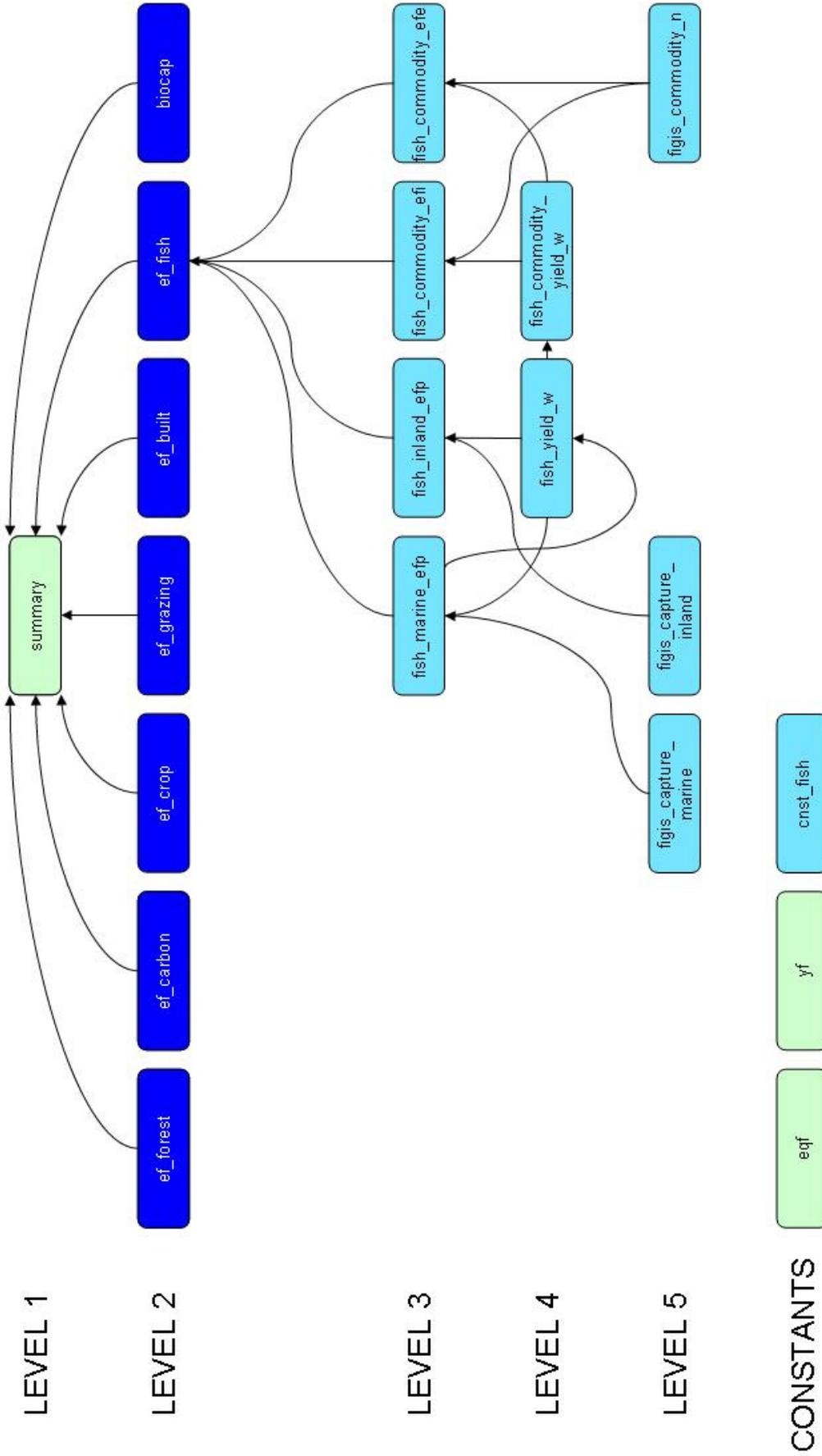


Figure 8-1
Fishing grounds Footprint calculations. The Fishing Grounds section of the *NFA 2008* contains four Level 3 worksheets, since Footprints of Production are calculated separately for marine and inland fisheries. Footprints embodied in trade are calculated for fish products, rather than the primary catch species used to calculate Footprints of production.

6.2 Worksheets

Figure 8-1 shows all of the worksheets involved in the calculation of the fishing grounds Footprint. The calculation of fishing grounds biocapacity is treated separately in Chapter 9.

The fishing grounds Footprint section of *NFA 2008* consists of four Level 3 worksheets, two Level 4 worksheets, three Level 5 worksheets and one Constants worksheet. All of the fishing grounds worksheets are colored cyan in *NFA 2008* and in this guidebook. The structure and function of each of these worksheets is described below.

6.2.1 ef_fish

Level 2 (*Only fishing grounds worksheet at this level*)

Ef_fish summarizes the Fishing grounds Footprints of production, imports, exports, and consumption.

Layout: This worksheet begins with an identifying column labeled ‘Name.’ This identifying column is followed by four columns that report the Footprints of production, imports, exports, and consumption for each product. These columns are labeled ‘EF_p,’ ‘EF_i,’ ‘EF_E’ and ‘EF_C,’ respectively. Each row in the *ef_fish* table corresponds to one of the broadest categories of fish catch or trade. The last row totals the Footprints of production, imports and exports and uses these column totals to calculate the fishing grounds Footprint of production.

There are three categories totaled in this worksheet: ‘Marine capture,’ ‘Inland capture’ and ‘Commodities.’ FishSTAT reports both ‘capture’ groups in terms of the species landed, while ‘Commodities’ encompasses trade in many secondary fish products. Thus, production data are split between the inland and marine catch categories while the ‘Commodities’ row reports all trade.

Data and Calculation: The ‘EF_p,’ ‘EF_i,’ and ‘EF_E’ columns report values directly from the Level 3 worksheets. ‘Marine capture’ sums the Footprints of all 1,325 species listed in *fish_marine_efp*, while ‘Inland capture’ does the same for the 233 freshwater species in *fish_inland_efp*. Since traded quantities are not available by species, these rows provide only a Footprint of production equal to the Footprint consumption.

Imports and exports are drawn from *fish_commodity_efi*, and *fish_commodity_efe*, respectively. The total Footprint of production is calculated by summing only the Footprint of production of primary products only to avoid double counting. The total Footprint of consumption is calculated by applying **Equation 2-1** to the total EF_p, EF_i, and EF_E.

Refers to: *fish_marine_efp* (L3), *fish_inland_efp* (L3), *fish_commodity_efi* (L3), *fish_commodity_efe* (L3)

Referenced by: *summary* (L1)

6.2.2 fish_marine_efp

Level 3 (*4 fishing grounds worksheets at this level*)

The *fish_marine_efp* worksheet calculates the Footprint of production of 1,325 fish species that are landed in the country. Catch data does not include information on the origins of landed fish, so fish caught outside the country’s Exclusive Economic Zone still contribute to that country’s Footprint of production.

Layout: *Fish_marine_efp* begins with three identifying columns, ‘Common Name,’ ‘Scientific Name,’ and ‘ISSCAAP Group Code,’ which report the names and codes for each of the 1,325 marine species. The next column lists the trophic level of each species. A ‘Production’ column giving landed catch in tonnes follows this. The next three columns list estimated sustainable yield, the equivalence factor for marine fishing grounds, and the footprint of production for each of the 1,325 species. Following the convention used throughout *NFA 2008*, these are labeled ‘Yield,’ ‘EQF’ and ‘EF_p,’ respectively.

The list of species is split into two groups, separated by a blank line (nr. 1174). The species below this split are reported as trade categories in *fish_commodity_efi* and *fish_commodity_efe*. Those above the split are not, and are therefore assumed to comprise the broader categories of secondary fish products. This is done so that *fish_commodity_yield_w* sheet can average all non-commodity-tracked categories and apply this yield to commodity yields lacking a value (ie. Fish fillets, frozen).

Data and Calculation When available, individual species’ average trophic levels are obtained from Fishbase (Fishbase Database). If a trophic level estimate is not available, average values for the species’ ISSCAAP groups are used. The trophic levels listed here are used only in *fish_yield_w*, to calculate the weighted average trophic level of a country’s catch. ‘Production’ is drawn from *figis_capture_marine*. ‘Yield’ is drawn from *fish_yield_w*. ‘EQF’ is drawn from *eqf*. The ‘EF_p’ column calculates the Footprint of production according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *figis_capture_marine* (L4), *fish_yield_w* (L4), *eqf* (Cnst)

Referenced by: *ef_fish* (L2), *fish_yield_w* (L4)

6.2.3 fish_inland_efp

Level 3 (4 fishing grounds worksheets at this level)

Fish_inland_efp calculates the Footprint of production of 233 fish species caught in inland waters and landed within the country of interest.

Layout: *Fish_inland_efp* contains columns identical to those in *fish_marine_efp*. It begins with three identifying columns, ‘Common Name,’ ‘Scientific Name,’ and ‘ISSCAAP Group Code,’ which report the names and codes for each of the 1,326 marine species. The next column lists the trophic level of each species. A ‘Production’ column giving landed catch in tonnes follows this. The next three columns list estimated sustainable yield, the equivalence factor for marine fishing grounds, and the footprint of production for each of the 233 species. Following the convention used throughout *NFA 2008*, these are labeled ‘Yield,’ ‘EQF’ and ‘EF_p,’ respectively.

The list of species is split into two groups, separated by a blank line (nr. 214). The species below this split are reported as trade categories in *fish_commodity_efi* and *fish_commodity_efe*. Those above the split are not, and are therefore assumed to comprise the broader categories of secondary fish products. This is done so that *fish_commodity_yield_w* sheet can average all non-commodity-tracked categories and apply this yield to commodity yields lacking a value (ie. Fish fillets, frozen).

Data and Calculation When available, individual species' average trophic levels are obtained from Fishbase (Fishbase Database). If a trophic level estimate is not available, average values for the species' ISSCAAP groups are used. The trophic levels listed here are used only in *fish_yield_w*, to calculate the weighted average trophic level of a country's catch. 'Production' is drawn from *figis_capture_marine*. 'Yield' is drawn from *fish_yield_w*. 'EQF' is drawn from *eqf*. The 'EF_P' column calculates the Footprint of production according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *figis_capture_inland* (L4), *fish_yield_w* (L4), *eqf* (Cnst)

Referenced by: *ef_fish* (L2)

6.2.4 fish_commodity_efi

Level 3 (4 fishing grounds worksheets at this level)

Fish_commodity_efi calculates the Footprint of imported fish for each of the 117 fish commodities reported.

Layout: *Fish_commodity_efi* begins with one identifying column, 'Commodity,' which reports a slight FAO modification of the 2002 Harmonized Standard name of the traded products. The next column, 'Import,' shows the tonnes of each product imported. This is followed by columns listing the world-average yield for each traded product, the equivalence factor for fishing grounds, and the Footprint of imports for each product. These last three rows are labeled 'Yield,' 'EQF' and 'EF_P.'

Data and Calculation: 'Import' is drawn from *figis_commodity_n*, which reports raw trade data. 'Yield' is drawn from *fish_commodity_yield_w*, applying worldwide average yields to all imported products. 'EQF' is drawn from the *eqf* worksheet. The 'EF_P' column calculates the Footprint of production according to **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *figis_commodity_n* (L5), *fish_commodity_yield_w* (L4), *eqf* (Cnst)

Referenced by: *ef_fish* (L2)

6.2.5 fish_commodity_efe

Level 3 (4 fishing grounds worksheets at this level)

Fish_commodity_efe calculates the Footprint of exported fish for each of the 117 fish commodities reported.

Layout: *Fish_commodity_efe* begins with one identifying column, 'Commodity,' which reports a slight FAO modification of the 2002 Harmonized Standard name of the traded products. The next column, 'Export,' shows the tonnes of each product imported. This is followed by columns listing the world-average yield for each traded product, the equivalence factor for fishing grounds, and the Footprint of exports for each product. These last three rows are labeled 'Yield,' 'EQF' and 'EF_E.'

Data and Calculation: 'Export' is drawn from *figis_commodity_n*, which reports raw trade data. 'Yield' is drawn from *fish_commodity_yield_w*. The embodied Footprints of most exported goods are calculated assuming world-average yields. However, there are a few very broad categories of fish products that are not derived from any one species. The yields for these products depend on the composition of a country's catch (See section 6.2.6). 'EQF' is drawn from the *eqf* worksheet. The 'EF_E' column calculates the Footprint

of production according to **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values.

Refers to: *figis_commodity_n* (L4), *figis_commodity_yield_w* (L4), *eqf* (Cnst)

Referenced by: *ef_fish* (L2)

6.2.6 fish_commodity_yield_w

Level 4 (2 fishing grounds worksheets at this level)

Fish_commodity_yield_w calculates the yield for each of the 117 fish commodities. These yields serve as the basis for calculating the embodied fishing grounds Footprint in trade.

Layout: *Fish_commodity_yield_w* begins with two identifying columns, 'Commodity,' which reports a slight FAO modification of the 2002 Harmonized Standard names of the traded products. For all secondary products, the parent species is listed in the 'Parent' column. The next column, 'Extr,' reports the extraction rates for all secondary products and is blank for all primary products. The final two columns, 'Import Yield' and 'Export Yield,' report the yields applied to imports and exports of each commodity.

Data and Calculation: Import and export yields are calculated according to **Equation 2-4**, applying extraction rates to primary product yields to find the yield of the secondary product. Import and export yields are equal except where there is not a specific parent species for the product. For these, imports are assigned world-average yields, while the yield for exports is based on the weighted average trophic level of all catch species not specifically listed elsewhere in *fish_commodity_yield_w*, as defined by the split in the fish species list in *fish_marine_efp* and *fish_inland_efp*. The export yields calculated in this manner are highlighted in yellow.

Refers to: *fish_yield_w* (L4)

Referenced by: *fish_commodity_efi* (L3), *fish_commodity_efe* (L3)

6.2.7 fish_yield_w

Level 4 (2 fishing grounds worksheets at this level)

Fish_yield_w calculates the world-average yields of 1,462 marine and freshwater species.

Layout: *Fish_yield_w* begins with three identifying columns, 'Common Name,' 'Scientific Name,' and 'ISSCAAP Group Code,' which correspond to the first three columns in *fish_marine_efp* and *fish_inland_efp*. The next column, 'Trophic Level,' presents the fractional average trophic level for each species. The following column, labeled 'PPR,' calculates the primary production required to support a tonne of each species. The effective yield per hectare is calculated in the final column, labeled 'Yield.'

Data and Calculation: The 'PPR' column calculates the primary production requirement: the ratio of the mass of primary producers required to support a fish to the mass of said fish. This calculation is based on the trophic level of the fish species in question. This column is calculated according to **Equation 6-1** (Pauly and Christensen 1995).

Equation 6-1

PPR for Yield of Aquatic Species

$$\text{PPR} = \text{CC} * \text{DR} * \left(\frac{1}{\text{TE}} \right)^{(\text{TL}-1)}$$

Where:

- PPR = Primary production required, t C (t product)⁻¹
TE = Transfer efficiency of aquatic ecosystems, t feed (t product)⁻¹
= 10% (Pauly and Christensen 1995).
TL = Average fractional trophic level for given species
DR = Discard rate of bycatch
= 1.27, currently applied to all fish species (Pauly and Christensen 1995).
CC = Carbon content of fish biomass, per unit wet weight
= 1/9 (Pauly and Christensen 1995).

By this equation, embodied primary production increases exponentially with trophic level, assuming a transfer efficiency of 10% between trophic levels all the way up the food chain. With poor information on the bycatch discard rates associated with different fisheries, we apply an average discard rate of 1.27 to all catch. We further assume that the bycatch is at the same trophic level as the primary catch. These are assumptions we hope to avoid in the next edition of the *NFA 2008* as bycatch data becomes more available. *NFA 2008* uses primary production figures in tonnes of carbon per hectare. Both discard rate and transfer efficiency are stored in *cnst_fish*.

The final column shows yield ('Yield') which is calculated using the PPR in the previous column to find the tonnes of fish product produced per hectare of continental shelf per year. Yield is calculated according to **Equation 6-2**.

Equation 6-2

Yield for Aquatic Species

$$\text{Yield} = \frac{1}{\text{PPR}} * \text{APP}$$

Where:

- PPR = Primary Productivity Requirement, as calculated in **Equation 6-1**.
APP = Available Primary Productivity, the amount of primary productivity that can be sustainably harvested from each hectare of continental shelf area. This is calculated from an estimate of sustainable harvest (Gulland 1971), multiplied by the PPR for world average harvested fish and divided by the area of the continental shelf (World Resources Institute Global Land Cover Classification Database).

Calculated yield, and hence Footprint, for a given fish species are very sensitive to the assumed trophic level for that species. Information about the derivation of these trophic levels as well as their standard errors are available from the Fishbase database (Froese and Pauly 2008).

Refers to: *cnst_fish* (L4)

Referenced by: *fish_commodity_yield_w* (L4), *fish_inland_efp* (L3), *fish_marine_efp* (L3)

6.2.8 *figis_capture_marine*

Level 5 (3 fishing grounds worksheets at this level)

Figis_capture_marine reports the tonnes of marine fish landed within the country for each of the 1,332 species reported.

Layout: *Figis_capture_marine* begins with two identifying columns, ‘Common Name,’ ‘Scientific Name,’ report the FAO names for each of the 1,332 marine species. The final column shows the tonnes of production (‘Production’).

Data and Calculation: There are no calculations in this worksheet as this reports only raw data from the FishSTAT (FAO FishSTAT Statistical Database). This worksheet is used by *fish_marine_efp* to calculate the Footprint of production for marine fish.

Refers to: None

Referenced by: *fish_marine_efp* (L3)

6.2.9 *figis_capture_inland*

Level 4 (8 fishing grounds worksheets at this level)

Figis_capture_inland reports the tonnes of inland fish landed within the country for each of the 236 inland fish species reported.

Layout: *Figis_capture_inland* begins with two identifying columns, ‘Common Name,’ ‘Scientific Name,’ report the FAO names for each of the 236 inland species. The final column shows the tonnes of production (‘Production’).

Data and Calculation: There are no calculations in this worksheet as this reports only raw data from FishSTAT (FAO FishSTAT Statistical Database). This worksheet is used by *fish_inland_efp* to calculate the Footprint of production for inland fish.

Refers to: None

Referenced by: *fish_inland_efp* (L3)

6.2.10 *figis_commodity_n*

Level 4 (8 fishing grounds worksheets at this level)

Figis_commodity_n reports the imports and exports for each of the 117 fish commodities reported from the FishSTAT (FAO FishSTAT Statistical Database).

Layout: *Figis_commodity_n* begins with one identifying column: ‘Name,’ which reports a slight FAO modification of the 2002 Harmonized Standard name of the traded products. The final two columns report the import (‘Import’) and export (‘Export’) quantities for each commodity.

Refers to: None

Referenced by: *fish_commodity_efe* (L3), *fish_commodity_efi* (L3)

6.2.11 *figis_aquaculture_inland*

Level 4 (8 fishing grounds worksheets at this level)

Figis_aquaculture_inland reports the tonnes of production from inland aquaculture. **This worksheet is not used for any calculations in NFA 2008; it is provided only for reference. It is not shown in Figure 8-1.**

Layout: *Figis_aquaculture_inland* begins with two identifying columns, ‘Common Name’ and ‘Scientific Name,’ which report the FAO names for 230 inland species. The final column, ‘Production,’ shows the tonnes of production.

Refers to: None

Referenced by: None

6.2.12 *figis_aquaculture_marine*

Level 4 (8 fishing grounds worksheets at this level)

Figis_aquaculture_marine reports the tonnes of production from inland aquaculture. **This worksheet is not used for any calculations in NFA 2008; it is provided only for reference. It is not shown in Figure 8-1.**

Layout: *Figis_aquaculture_marine* begins with two identifying columns, ‘Common Name’ and ‘Scientific Name,’ which report the FAO names for 284 marine species. The final column, ‘Production,’ shows the tonnes of aquaculture production.

Refers to: None

Referenced by: None

6.2.13 *cnst_fish*

Constants (1 fishing grounds worksheet at this level)

Cnst_fish provides three constant values which are used in fish yield calculations: Available Primary Productivity, Discard Factor, and Transfer Efficiency.

Layout: The first column here names the constant of interest (‘Name’). The unit and value for each constant is provided in the next two subsequent columns, ‘Unit’ and ‘Value.’

Data and Calculation: This worksheet does not contain any calculations. ‘Available PP’ provides an estimate of the amount of primary production sustainably harvestable per hectare each year. This value is derived by calculating the primary production equivalent of an FAO estimate of globally sustainable fish catch (Gulland 1971) for several species. This total primary production quantity is then divided by the total global area of continental shelf. This is used as the estimate of total sustainably harvestable primary production per hectare.

‘Discard Factor’ indicates the percentage of total catch that is discarded (Pauly and Christensen 1995). This factor is used to reduce the yield of each species to reflect the primary production embodied in discarded bycatch.

‘Transfer Efficiency’ represents the efficiency of energy transfer between adjacent trophic levels in aquatic ecosystems. This value is estimated at 10% (Pauly and Christensen 1995), meaning that PPR increases tenfold for every trophic level.

Refers to: None

Referenced by: *fish_yield_w* (L4)

7 Carbon Footprint

Color: Blue

7.1 Description

7.1.1 Overview

The carbon Footprint is represents the area of forest land required to take up anthropogenic carbon dioxide emissions. The **NFA 2008** workbook accounts for the Footprint of carbon dioxide emissions from several sources: domestic fossil fuel combustion, embodied carbon in traded items, a country's share of global international transport emissions, and non fossil-fuel sources.

The total amount of carbon dioxide allocated to each country is converted into global hectares by using the net annual growth of forests as the yield for carbon uptake. The carbon uptake rate used to convert tonnes of carbon dioxide to global hectares is derived from data on the net annual growth of forests drawn from the IPCC (2006). The uptake rate is calculated assuming that carbon comprises half of that net increase in biomass. This 'yield' for carbon uptake, combined with the forest equivalence factor, converts tonnes of carbon dioxide into a Footprint in global hectares. The methodology of this approach continues to be discussed, and any changes could have a significant impact on the carbon Footprint calculations.

The International Energy Agency (IEA) tracks various countries' carbon dioxide emissions from fossil fuel combustion across 33 different economic sectors. These data are used in **NFA 2008** to calculate the carbon Footprint of production. If IEA data are not available for the country and year in question, an estimate from the Carbon Dioxide Information Analysis Center (Marland et al. 2007) is used instead. The IEA also publishes the total world emissions in international transport as "bunker fuel." These emissions are allocated to countries according to their domestic fossil fuel combustion. Emissions other than those from fossil fuels are only included in the world total carbon Footprint.

7.1.2 Data Sources

Data	Worksheet Referenced	Data Source
Emissions from fossil fuels, by country and economic sector	<i>iea_fossil_n</i>	IEA CO ₂ Emissions from Fuel Combustion Database. 2007. http://wds.iea.org/wds/ (accessed October 2008).
Emissions from fossil fuels, by country	<i>cdiac_fossil_n</i>	Marland, G., T.A. Boden, and R. J. Andres. 2007. Global, Regional, and National Fossil Fuel CO ₂ Emissions. In <i>Trends: A Compendium of Data on Global Change</i> . Oak Ridge, TN: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory and U.S. Department of Energy.
International trade quantities by commodity	<i>comtrade_n</i>	UN Commodity Trade Statistics Database. http://comtrade.un.org/ (accessed June 2008).
Embodied energy of traded commodities	<i>fossil_efi, fossil_efe</i>	Global Footprint Network internal database, available upon request.
Carbon sequestration factor	<i>cnst_carbon</i>	IPCC. 2006. <i>2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture Forestry and Other Land Use</i> . http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html (accessed September 2008).
Ocean sequestration	<i>cnst_carbon</i>	IPCC. 2001. <i>Climate Change 2001: The Scientific Basis</i> . Cambridge, UK: Cambridge University Press, 2001.
World heat and electricity carbon intensity	<i>cnst_carbon</i>	IEA CO ₂ Emissions from Fuel Combustion Database. 2007. http://wds.iea.org/wds/ (accessed October 2008).

7.1.3 Notes

- Unlike elsewhere in *NFA 2008*, the carbon Footprint section lists traded commodities by their SITC revision 1 codes. This is because the longest historical time series are only available in this classification system.
- Embodied carbon emissions in traded goods are calculated by multiplying estimated embodied emissions by the world average carbon intensity of electricity and heat production.
- The embodied energy figure for each product category represents the sum of all energy use for production of a good up to the point at which it is traded. Like the carbon intensity of energy use, the embodied emissions figures used in *NFA 2008* are world averages.
- The carbon emissions embodied in traded fossil fuels are distinct from the physical carbon content of those fuels. Take for example a barrel of oil exported by the United Arab Emirates and sent to the United States. The carbon emissions associated with extracting the barrel of oil and bringing it to market will be applied to the United States, as emissions embodied in imports. When that oil is subsequently burned, its physical

carbon content will be included in the domestic fossil fuel combustion component of the United States' carbon Footprint.

- **NFA 2008** includes a category of carbon dioxide emissions from sources other than fossil fuels. It aggregates emissions due to anthropogenic forest fires, cement production, and unsustainable biofuel production, which the IPCC estimates to be 10% of biofuel combustion. These carbon emissions are not allocated to individual countries due to a current lack of data and methodology for estimating their global trade (e.g. which country receives the Footprint of the carbon released when Amazonian forest is cleared).

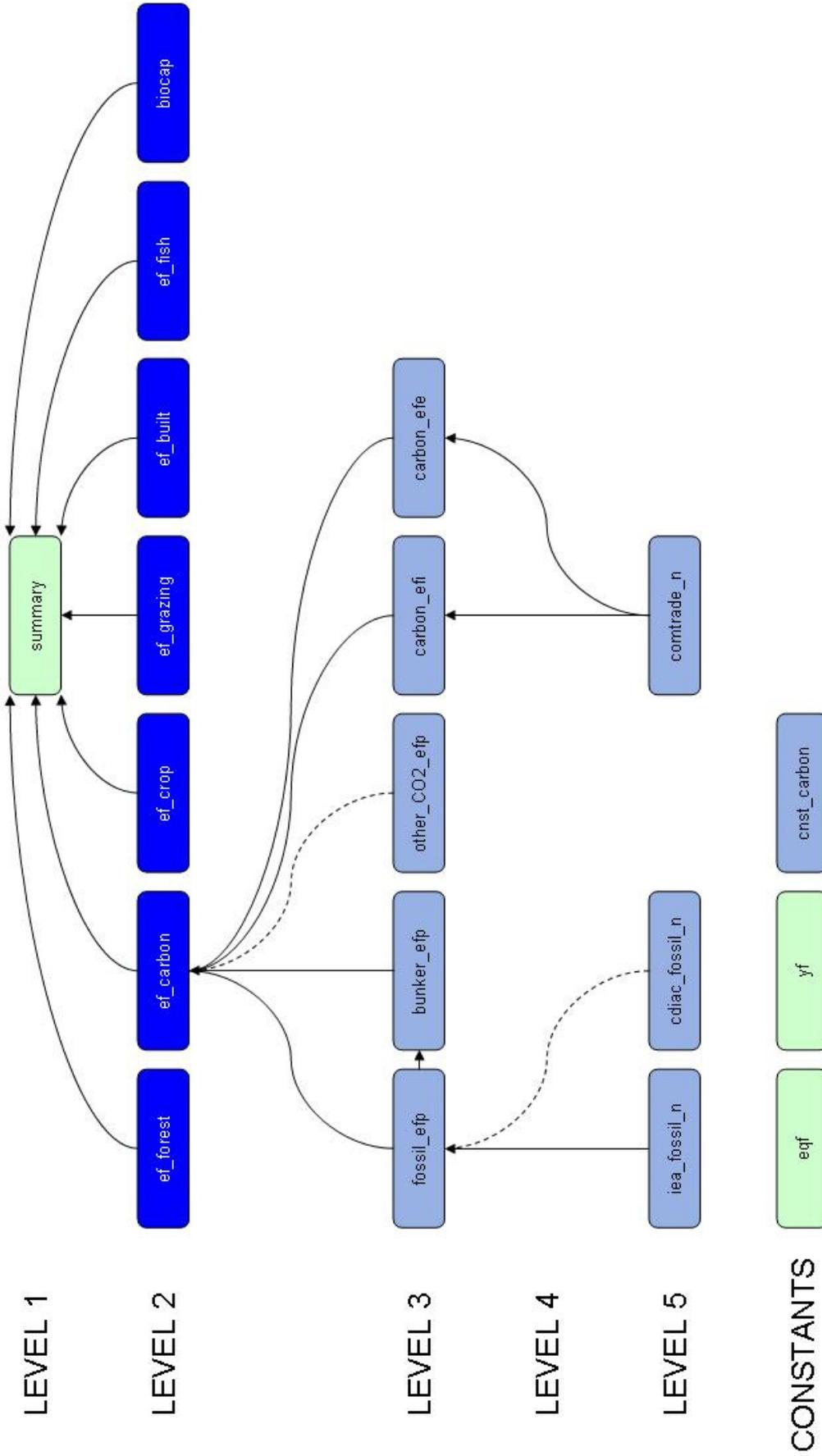


Figure 4-1
Carbon Footprint calculations. In addition to the standard Level 3 sheets calculating the Footprints of production, imports and exports, the carbon Footprint section includes worksheets to track emissions from international transport fuels and from non fossil fuel sources. All other sheets in the carbon Footprint section contain either raw emissions data or constants.

7.2 Worksheets

Figure 4-1 shows the relations between the worksheets in the carbon Footprint section of *NFA 2008*.

The carbon Footprint section of *NFA 2008* is summarized in the Level 2 worksheet *ef_carbon*. All lower level carbon worksheets are colored blue. The carbon section of *NFA 2008* contains five Level 3 worksheets, three Level 5 worksheets and one Constants worksheet. The structure and function of each of these worksheets is described below.

7.2.1 *ef_carbon*

Level 2 (Only carbon worksheet at this level)

Ef_carbon summarizes the carbon Footprints of production, imports, and exports for anthropogenic carbon emissions.

Format: This worksheet begins with one identifying column. The ‘Name’ column reports the names of the emissions sources summarized in this worksheet: ‘Fossil Fuel Emissions,’ ‘Non Fossil Fuel Carbon Emissions’ and ‘Bunker Fuel.’ This identifying column is followed by four columns that report the Footprints of production, imports, exports and consumption for each emissions category. Following the convention used throughout *NFA 2008*, these are labeled (EF_p), (EF_I), (EF_E) and (EF_C), respectively.

Note that only the embodied emissions stemming directly from fossil fuel combustion are included in trade flows. Thus, only the ‘Fossil Fuel Emissions’ category, capturing all fossil fuels burned within a country, will contain values in the EF_I and EF_E columns. ‘Non Fossil Fuel Carbon Emissions’ accounts for the Footprints of land use change, an unsustainable fraction of biofuel use, and cement production. This is only included in the global total carbon Footprint. ‘Bunker Fuel’ lists the Footprint of a country’s share of international travel and shipping.

Data and Calculation: For the ‘Fossil fuel Emissions’ category, the EF_p , EF_I , and EF_E columns report values aggregated from the Level 3 worksheets *fossil_eff*, *carbon_efi*, and *carbon_efe*, respectively. The EF_C column for this category is calculated according to **Equation 2-1**. The two other emissions categories do not involve traded commodities, and so EF_C is equal to EF_p for each.

When calculating the global total carbon Footprint, the ‘Non Fossil Fuel Carbon Emissions’ category draws its EF_p value from the Level 3 worksheet *other_CO2_eff*. For individual countries, the Footprint of production for this category is set to zero. While ideally non fossil fuel emissions would be assigned to the final consumption activities they serve, there is insufficient data on which to base this allocation. Setting non fossil fuel emissions to zero for national calculations ensures a conservative bias in the final estimate of each country’s carbon Footprint.

The ‘Bunker Fuel’ category draws its EF_p value from the Level 3 worksheet *bunker_eff*, accounting for international transportation of goods.

The final row in the *ef_carbon* table sums the Footprints of production, imports, exports and consumption for all categories. The total carbon Footprint is then calculated by applying **Equation 2-1** to the column totals.

Refers to: *fossil_efp* (L3), *bunker_efp* (L3), *carbon_efi* (L3), *carbon_efe* (L3), [*other_CO2_efp* (L3)]

Referenced by: *summary* (L1)

7.2.2 fossil_efp

Level 3 (5 carbon worksheets at this level)

Fossil_efp calculates the carbon Footprint of all emissions from fossil fuel combustion within a country.

Layout: The *fossil_efp* worksheet calculates the carbon Footprint of production of 33 economic sectors. These, as well as several sector aggregates (e.g. ‘Manufacturing Industries and Construction’ or ‘Transport’), are identified in the first column, ‘Name.’ Since some of the categories in the list are subtotals, the whole column cannot be summed to calculate the Footprint of production for fossil fuel combustion. Rather, total emissions are reported in the first record of this table.

The two columns immediately following the list of sector names are labeled ‘Production’ and ‘Yield’ for consistency with other level 3 sheets in *NFA 2008*. However, in the carbon Footprint section these show emissions and world average carbon uptake per hectare, respectively. The next column is labeled ‘EQF’ and contains the equivalence factor for forest land. Finally, the column labeled ‘EF_p’ calculates the carbon Footprint of emissions from each of the 45 sectors and sector summaries.

Data and Calculation: ‘Production’ for the ‘CO₂ Sectoral Approach’ is drawn from *cdiac_fossil_n* or *iea_fossil_n*, depending on data availability for the country (IEA CO₂ Emissions from Fuel Combustion Database; Marland et al. 2007). If data from the IEA are not available then all records other than the first will be blank, as CDIAC reports only total carbon dioxide emissions. ‘Yield’ is drawn from *cnst_carbon*, and returns the carbon sequestration factor divided by the ratio of carbon to carbon dioxide. Yield here represents the annual carbon uptake of a hectare of world average forest. ‘EQF’ is the equivalence factor for forest land, drawn from *eqf*. The ‘EF_p’ column is calculated according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values.

The total Footprint of production is reported in the first record, named ‘CO₂ Sectoral Approach.’ The total emissions from this record are used to calculate the fossil fuel Footprint of production, which is then used in *ef_carbon*.

Refers to: *iea_fossil_n* (L5), *cnst_carbon* (Cnst), *eqf* (Cnst), [*cdiac_fossil_n* (L5)]

Referenced by: *ef_carbon* (L2), *bunker_efp* (L3)

7.2.3 bunker_efp

Level 3 (5 carbon worksheets at this level)

This worksheet calculates a country’s share of the carbon Footprint of emissions from bunker fuels, the fuels used for international transport.

Layout: This worksheet consists of three columns: ‘Name’ identifies each step in the calculation. The next column, ‘Unit,’ gives units and the final column, ‘Value,’ holds results of each calculation step.

Data and Calculation: Worldwide airplane and ship bunker fuels are added as a “tax” on all countries relative to their total fossil fuel combustion Footprint. This tax, known as the bunker fuel Footprint of production, is calculated in the last row of the table, named ‘Bunker Tax.’

The bunker fuels “tax” is calculated by multiplying the fossil fuel Footprint of production, drawn from *fossil_efp*, by a value representing the percent of world fossil fuel emissions stemming from international transport. This percentage has historically been near 3-4% of total global carbon dioxide emissions.

Refers to: *fossil_efp* (L3)

Referenced by: *ef_carbon* (L2)

7.2.4 other_CO2_efp

Level 3 (5 carbon worksheets at this level)

The *other_CO2_efp* worksheet calculates the Footprint of carbon dioxide emissions from sources other than fossil fuels. This worksheet is only used for the calculation of the world as there is currently no good principle for allocating these emissions to individual countries.

Layout: This worksheet contains three columns. The first, ‘Name,’ provides a description of each step in the calculation. The following two, ‘Units’ and ‘Value,’ show the units and the calculated values for each calculation step.

Data and Calculation: The first record in the *other_CO2_efp* worksheet, non fossil fuel emissions, draws its value from the IEA (IEA CO₂ Emissions from Fuel Combustion Database 2007). This value is a combination of carbon dioxide emissions from industrial processes (mainly concrete manufacture), forest land clearing, flaring associated with oil and natural gas extraction, and 10% of biofuels emissions (assumed to be the fraction produced unsustainably, according to IPCC Sink/Source Category 5). The lack of a good way of allocating these emissions to final consumption activities precludes using them in calculations for individual countries. Thus the carbon Footprint calculated in this worksheet is only included in the global total Ecological Footprint.

Refers to: None

Referenced by: [*ef_carbon* (L2)]

7.2.5 carbon_efi

Level 3 (5 carbon worksheets at this level)

The *carbon_efi* worksheet calculates the embodied Footprint of imports of 625 traded goods.

Layout: The *carbon_efi* worksheet begins with two identifying columns: ‘Name’ and ‘Code,’ which provide a descriptive name and the SITC rev.1 code, respectively, for each product category.

The third column, 'ImportT,' gives the total imported quantity for each product category. This is followed by a column labeled 'EmbEn,' which lists the average embodied energy per tonne of each product group. The 'ImportE' column calculates the total embodied energy in the imported goods. The next column, 'ImportCO2,' then converts this energy amount into equivalent carbon dioxide emissions. The final column is labeled 'ImportGHA,' and calculates the embodied Footprint of imports for each of the 625 categories of traded goods.

Data and Calculation: 'ImportsT' is drawn directly from *comtrade_n*. The values in 'EmbEn' are drawn from a supporting Global Footprint Network database including information collected from a variety of sources. 'ImportE' is calculated by multiplying 'ImportT' by 'EmbEn' for each traded good.

The carbon emissions associated with internationally traded items are calculated based on the global average carbon intensity of fuels used for heating and electricity production. 'Import CO2' is calculated by multiplying 'ImportE' by two constants drawn from *cnst_carbon*: 'Gigajoules per Terawatt hour' and 'World Electricity and Heat Carbon Intensity.' 'ImportGHA' is then calculated by multiplying 'ImportCO2' by the Footprint intensity of carbon, drawn from *cnst_carbon*.

The last row in *carbon_efi* sums 'ImportGHA' values for all imported goods. This sum total is used as the Footprint of imports in *ef_carbon*.

Refers to: *comtrade_n* (L5), *cnst_carbon* (Cnst)

Referenced by: *ef_carbon* (L2)

7.2.6 carbon_efe

Level 3 (5 carbon worksheets at this level)

Carbon_efe calculates the embodied Footprint of exports of 625 categories of traded goods. Its structure and function parallel those of *carbon_efi*.

Layout: The *carbon_efe* worksheet begins with two identifying columns: 'Name' and 'Code,' which provide a descriptive name and the SITC rev.1 code, respectively, for each product category.

The third column, 'ExportT,' gives the total imported quantity for each product category. This is followed by a column labeled 'EmbEn,' which lists the average embodied energy per tonne of each product group. These embodied energy figures are the same ones used in *carbon_efi*. The 'ExportE' column calculates the total embodied energy in the imported goods. The next column, 'ExportCO2,' then converts this energy amount into equivalent carbon dioxide emissions. The final column is labeled 'ExportGHA,' and calculates the embodied Footprint of imports for each of the 625 categories of traded goods.

Data and Calculation: 'ExportsT' is drawn directly from *comtrade_n*. The values in 'EmbEn' are drawn from a supporting Global Footprint Network database including information collected from a variety of sources. 'ExportE' is calculated by multiplying 'ExportT' by 'EmbEn' for each traded good.

The carbon emissions associated with internationally traded items are calculated based on the global average carbon intensity of fuels used for heating and electricity production. 'Export CO2' is calculated by multiplying 'ExportE' by two constants drawn from

cnst_carbon: ‘Gigajoules per Terawatt hour’ and ‘World Electricity and Heat Carbon Intensity.’ ‘ExportGHA’ is then calculated by multiplying ‘ExportCO2’ by the Footprint intensity of carbon, drawn from *cnst_carbon*.

The last row in *carbon_efe* sums ‘ExportGHA’ values for all exported goods. This sum total is used as the Footprint of exports in *ef_carbon*.

Refers to: *comtrade_n* (L5), *cnst_carbon* (Cnst)

Referenced by: *ef_carbon* (L2)

7.2.7 *cnst_carbon*

Constant (*1 carbon constants worksheet*)

This worksheet contains constants specific to the carbon Footprint calculation, such as the Footprint intensity of carbon and the world average carbon intensity of energy use.

Layout: The *cnst_carbon* worksheet provides seven constant values that are used throughout the Level 3 carbon worksheets. The first column, ‘Name,’ gives a description of each constant. The units and values of each constant are provided in the two subsequent columns, ‘Unit’ and ‘Value.’

Data and Calculation: This worksheet provides constants for use in the rest of the carbon Footprint calculations. The only calculation performed in this worksheet is the Footprint intensity of carbon dioxide emissions.

The first two records, ‘C to CO2 Ratio’ and ‘Gigajoule to Terrawatt hour,’ contain simple unit conversions.

‘Carbon Sequestration Factor’ estimates the annual carbon uptake of a hectare of world average forest land. This factor is based on the average sequestration potential of world forests, and is calculated using IPCC data (IPCC 2006). The calculations are contained in a supporting Global Footprint Network workbook, and are available upon request.

‘Ocean Sequestration Percentage’ reflects the percentage of global fossil fuel carbon emissions that are sequestered by oceans. This percentage is calculated for each year as the ratio of the estimated annual oceanic carbon sink (IPCC 2001) to total global emissions from fossil fuel combustion in that year.

‘World Electricity and Heat Carbon Intensity’ is taken directly from International Energy Agency (IEA CO₂ Emissions from Fuel Combustion Database 2007).

‘Footprint Intensity of Carbon’ gives the Footprint per ton of carbon dioxide emitted. It is calculated by multiplying the reciprocal of the ‘Carbon Sequestration Factor’ by the equivalence factor for forest land (drawn from *eqf*), which yields the number of tonnes of carbon sequestered per global hectare each year. This is then multiplied by the percentage of carbon not sequestered by oceans and the mass ratio of carbon to carbon dioxide, yielding a final result in global hectares per tonne of carbon dioxide per year.

Refers to: None

Referenced by: *fossil_efp* (L3), *other_CO2_efp* (L3), *carbon_efi* (L3), *carbon_efe* (L3)

7.2.8 comtrade_n

Level 5 (3 carbon worksheets at this level)

Comtrade_n reports data on imports and exports of traded items drawn from the United Nations COMTRADE database (UN Commodity Trade Statistics Database).

Layout: This worksheet begins with two identifying columns, 'Name' and 'Code,' which give a descriptive name and the SITC rev. 1 code, respectively, for each product category. The following two columns, 'Import' and 'Export,' report tonnes of imports and exports for each trade category.

Data and Calculation: All data in this worksheet come from the UN's COMTRADE database (UN Commodity Trade Statistics Database). Like most Level 5 worksheets, *comtrade_n* contains no calculations.

Refers to: None

Referenced by: *carbon_efi* (L3), *carbon_efe* (L3)

7.2.9 iea_fossil_n

Level 5 (3 carbon worksheets at this level)

The *iea_fossil_n* worksheet contains carbon dioxide emissions data as reported by the IEA (IEA CO₂ Emissions from Fossil Fuel Combustion Database).

Layout: This worksheet consists of two columns, labeled 'Name' and 'Production-CO₂.' These correspond to the first two columns in *fossil_efp*.

Data and Calculation: 'Name' lists various sectors and sector summaries as reported by the IEA. 'Production-CO₂' gives the CO₂ emissions for each listed sector, drawn directly from the IEA (IEA CO₂ Emissions from Fossil Fuel Combustion Database). Like most Level 5 worksheets, *iea_fossil_n* contains no calculations.

Refers to: None

Referenced by: *fossil_efp* (L2)

7.2.10 cdiac_fossil_n

Level 5 (3 carbon worksheets at this level)

This worksheet provides data on total domestic emissions from fossil fuel combustion as reported by the Carbon Dioxide Analysis Center (Marland et al. 2007). This worksheet is only used in the absence of IEA data on domestic emissions.

Layout: The *cdiac_fossil_n* worksheet begins with an identifying column, 'Name.' This is followed by columns showing the production of carbon, 'Production-C,' and the production of carbon dioxide, 'Production-CO₂.'

Data and Calculation: 'Production-C' is drawn from a Carbon Dioxide Information Analysis Center study (Marland et al. 2007). 'Production-CO₂' is calculated by dividing 'Production-C' by the constant ratio of carbon to carbon dioxide (drawn from *cnst_carbon*) and converting units from tonnes to mega-tonnes. This is one of the few Level 5 worksheets containing any calculations.

Refers to: *cnst_carbon* (Cnst)

Referenced by: *fossil_eff* (L3)

8 Built-up Land Footprint

Color: Maroon

8.1 Description

8.1.1 Overview

The built-up land Footprint represents bioproductive land which has been physically occupied by human activities.

The *NFA 2008* workbook tracks two types of built-up area: infrastructure areas required for housing, transportation and industrial production, and hydroelectric areas which represent the areas flooded by dams. The calculations assume that infrastructure area covers former cropland, and apply the yield and equivalence factors for cropland to the calculation of the Footprint. Hydroelectric reservoirs are assumed to occupy world average bioproductive land.

Data from 20 dams, for which both hydroelectric output and inundated area were calculated, are used to estimate the area intensity of hydroelectric generation.

8.1.2 Data Sources

Data	Worksheet Referenced	Data Source
Infrastructure area (ha)	<i>Infrastructure_efp</i>	World Resources Institute Global Land Cover Classification Database. http://earthtrends.wri.org (accessed March 2008).
Hydroelectricity Production (MWh)	<i>Hydro_efp</i>	British Petroleum. 2007. Statistical Review of World Energy. http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622 (accessed October 2008).
Yield for Hydroelectricity (MWh/ha)	<i>Hydro_efp</i>	Goodland. 1997. Environmental Sustainability in the Hydro Industry. Large Dams: Learning from the Past, Looking at the Future. Washington DC: Workshop Proceedings, IUCN, Gland, Switzerland and Cambridge, UK and the World Bank Group.

8.1.3 Notes

- Infrastructure areas are assumed to occupy former cropland and yield and equivalence factors for cropland are thus used in the Footprint calculation. This assumption will overestimate both the Footprint and biocapacity of infrastructure areas located on areas of formerly low productivity. However, since the Footprint and biocapacity of built-up land are equal, any inaccuracies in this assumption will equally affect both. Arid countries in particular may be subject to a systematic overestimate of their infrastructure Footprint and biocapacity.
- Hydroelectric areas are assumed to occupy world average land. Data from 32 dams for which both hydroelectric output and inundated area were collected, are used to estimate the area used based on electricity produced. This assumption will overestimate the Footprint of hydroelectricity in countries where unproductive land (e.g. barren rock) has

been flooded, and underestimate it in countries where very productive land (e.g. cropland) has been flooded.

- The *NFA 2008* workbook does not track imports and exports of built-up land, although built-up land is embodied in goods which are traded internationally (e.g. the physical area of a factory producing a given product for export) and thus should be counted as an export of Footprint embodied in that product. This omission likely causes an overestimate of the built-up Footprint of exporting countries, and an underestimate of the built-up Footprint of importing countries.
- Electricity data used to calculate the Footprint of production for hydroelectricity report the total amount of electricity consumed within a country, not the amount produced. The *NFA 2008* assumes there is no trade in hydroelectricity. Because the *NFA 2008* shows no Footprint of imports or exports for hydroelectricity, the Footprint of production and consumption are equal.
- Since low-resolution satellite images are not able to capture dispersed infrastructure such as roads and houses, estimates of infrastructure areas have high levels of uncertainty. The numbers reported in the *NFA 2008* workbook likely underestimate the actual extent of impermeable surfaces overlaying productive land.

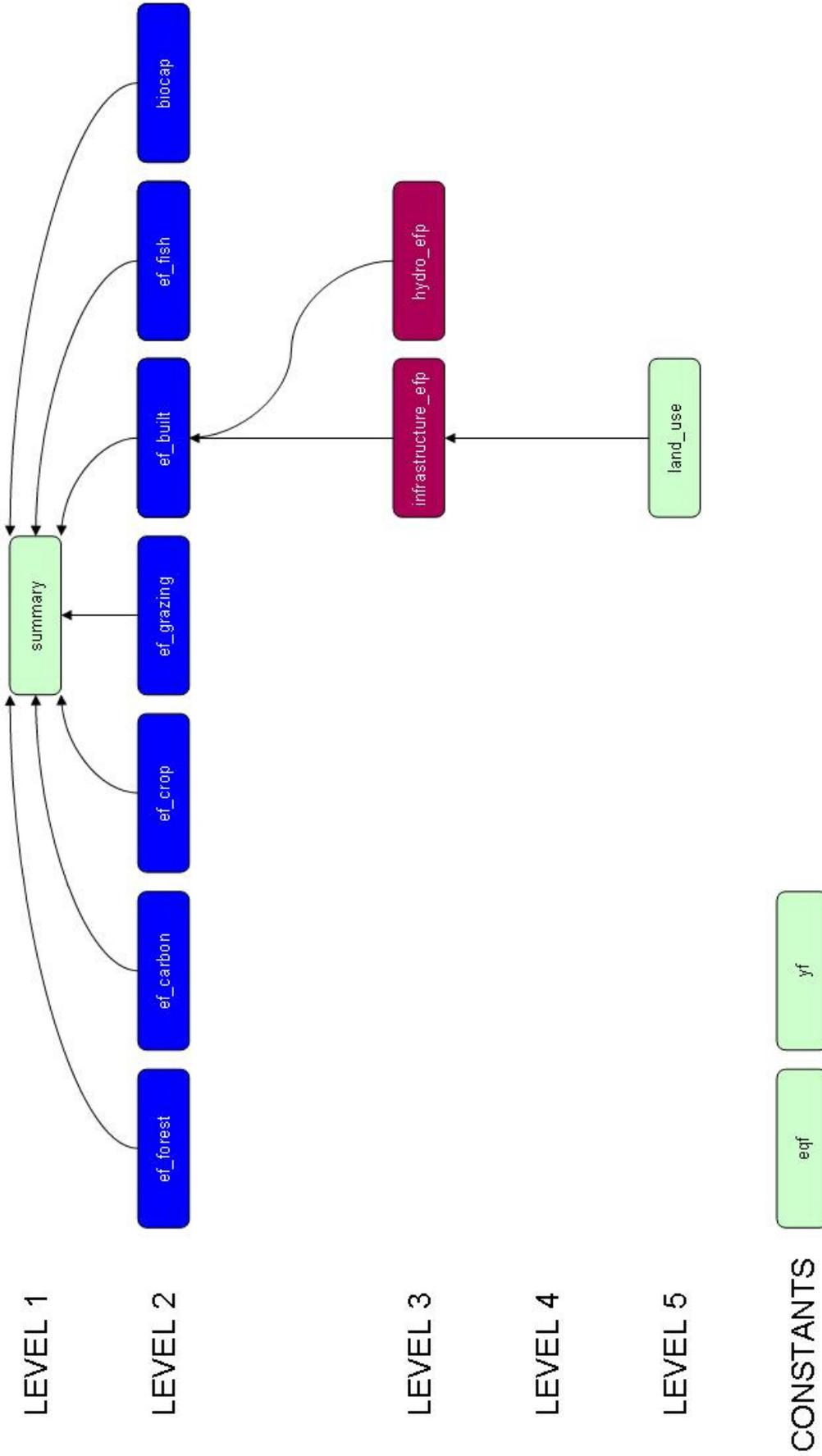


Figure 7-1
Built-up Land Footprint calculations. The Built-up Land Footprint has only two Level 3 worksheets. These are both Production Footprints, since the Built-up Land Footprint embodied in traded goods is not accounted for in *NFA 2008*. The *hydro_efp* worksheet

8.2 Worksheets

The built-up land section of the **NFA 2008** workbook contains two Level 3 worksheets, *infrastructure_efp* and *hydro_efp*. It shares its only Level 5 worksheet with the biocapacity calculation. Both of the built-up land Level 3 worksheets are colored maroon in **NFA 2008** and this guidebook. The calculation of built-up land biocapacity is treated separately in Chapter 9.

8.2.1 ef_built

Level 2 (1 built-up land worksheet at this level)

Ef_built summarizes the built-up land Footprints of production and consumption. Since the embodied Footprints of imports and exports are not reported for built-up land, the production and consumption Footprints are equal.

Layout: This worksheet contains one identifying column, 'Name,' which indicates either infrastructure or hydroelectric area. The following four columns report the Footprints of production, imports, exports, and consumption for infrastructure and hydro areas. Built-up land Footprints are reported in two categories: infrastructure area and hydroelectric area. Infrastructure includes all housing, transportation and industrial production while hydroelectric area reports an estimate of the area inundated for hydroelectric electricity production.

Data and Calculation: The Footprint of production is drawn from *infrastructure_efp* for the infrastructure area and from *hydro_efp* for the hydroelectric area. The final column in the *ef_built* table totals the Footprints of production, imports, exports, and consumption for the two considered land use types, infrastructure and hydro area. Again, the Footprint of consumption equals the Footprint of production.

Refers to: *infrastructure_efp* (L3), *hydro_efp*(L3)

Referenced by: *summary* (L1)

8.2.2 infrastructure_efp

Level 3 (2 built-up land worksheets at this level)

The *infrastructure_efp* worksheet reports the Footprint of areas occupied by human settlements and infrastructure.

Layout: *Infrastructure_efp* begins with an identifying column, labeled 'Name.' This is followed by a column reporting the area covered by infrastructure, labeled 'Area.' The next two columns provide the yield factor and equivalence factor for cropland, and are labeled 'Yield Factor' and 'EQF,' respectively. The final column, 'EF_p,' calculates the Footprint.

Data and Calculation: Infrastructure areas ('Area') are drawn from the *land_use* worksheet, which contains values from the Global Land Cover Classification Database (WRI Global Land Cover Classification Database) among others. Yield and equivalence factors are drawn from Level 1 *yf* and *eqf* worksheets, respectively. 'Yield' and 'EQF' values for cropland are used to calculate the Footprint of infrastructure, following **Equation 2-3**.

Refers to: *land_use* (L1), *yf*(Cnst), *eqf*(Cnst), WRI 2007

Referenced by: *ef_built* (L2)

8.2.3 hydro_efp

Level 3 (2 built-up land worksheets at this level)

The *hydro_efp* worksheet reports the built-up land Footprint of production associated with hydroelectric generation within a country.

Layout: *Hydro_efp* begins with an identifying column labeled 'Name.' The second column, 'Production,' reports the total consumption of hydroelectricity, in megawatt hours. The next two columns report the yield and equivalence factors for hydroelectricity production, and are labeled 'Yield' and 'EQF,' respectively. The final column, 'EF_p,' calculates the Footprint of production for hydroelectricity.

Data and Calculation: Hydroelectric generation values come from the Statistical Review of World Energy (British Petroleum 2007). The yield value is calculated as a world-average yield for hydroelectricity, based on an average from 32 large dams (Goodland 1997). The fourth column, 'EQF,' reports the equivalence factor drawn from the *eqf* worksheets. **NFA 2008** assigns an equivalence factor of 1 to hydroelectric area, reflecting the assumption that world average land is inundated by hydroelectric reservoirs. The last column shows the Footprint of production, 'EF_p,' calculated according to **Equation 2-3b**.

Refers to: *eqf* (Cnst)

Referenced by: *ef_built* (L2)

8.2.4 land_use

Level 5 (1 biocapacity worksheet at this level)

The *land_use* worksheet reports country specific areas of the major land use types considered in **NFA 2008**. It is part of the biocapacity calculation, but also contributes values to the built-up land Footprint calculation.

Relevance: *Land_use* serves as a source for areas covered by infrastructure.

Refers to: None

Referenced by: *infrastructure_efp* (L3)

See section 9.2.2 for full worksheet description.

9 Biocapacity

Color: Light Green

9.1 Description

9.1.1 Overview

Biocapacity refers to the amount of biologically productive land and water areas available within the boundaries of a given country. Biocapacity is calculated for each of the five major land types: cropland, grazing land (which also includes other wooded land), fishing grounds (marine and inland waters), forest, and built-up land (infrastructure and hydro). Built-up land biocapacity is included here because though built-up land does not generate resources, buildings and infrastructure do occupy the biocapacity of the land they cover. The carbon uptake land use type does not have biocapacity because **NFA 2008** assumes all carbon uptake is a demand on forest land biocapacity. Therefore, including carbon biocapacity in addition to forest land biocapacity would lead to double counting.

9.1.2 Data Sources

Data	Worksheet Referenced	Data Source
First source for land areas of cropland, grazing land, forest, other wooded land, inland waters, and built-up land. Limited to EU member countries.	<i>land_use</i> (CORINE2000)	Corine Land Cover 2000. European Topic Centre on Land Use and Spatial Information, 2000. Barcelona: EIONET. http://terrestrial.eionet.europa.eu/CLC2000/ (accessed October 2008).
Second source for data on cropland, grazing land, other wooded land, inland waters.	<i>land_use</i> (FAOSTAT)	FAO ResourceSTAT Statistical Database. http://faostat.fao.org/site/348/default.aspx (accessed January 2008).
Second source for built-up land areas.	<i>land_use</i> (GAEZ)	Global Agro-Ecological Zones. FAO and International Institute for Applied Systems Analysis 2000. http://www.fao.org/ag/agl/agll/gaez/index.htm . (accessed October 2008).
Third source for built-up land areas.	<i>land_use</i> (GLC)	Global Land Cover 2000. Institute for Environment and Sustainability, Joint Research Center and European Commission. Italy: IES. http://www.tem.jrc.it/glc2000/ (accessed October 2008).
Fourth source for built-up land areas.	<i>land_use</i> (SAGE)	Global Land Use Database. Center for Sustainability and the Global Environment, University of Wisconsin-Madison. 1992. http://www.sage.wisc.edu:16080/iamdata/ (accessed January 2007).
Only source for area of marine continental shelf.	<i>land_use</i> (WRI)	WRI Global Land Cover Classification Database. http://earthtrends.wri.org (accessed January 2007).
Area of marine EEZ. Not currently used in biocapacity calculation	<i>land_use</i> (SeaAroundUs)	Sea Around Us Project. Fisheries Centre, Pew Charitable Trusts and the University of British Columbia. 2008. http://www.searoundus.org/project.htm (accessed October 2008).

9.1.3 Notes

- The biocapacity calculations treat “Other Wooded Land” as grazing land.
- There is no biocapacity figure for carbon uptake. All other major land use types have a corresponding biocapacity calculation.
- Biocapacity for cropland is equal to Footprint because the yields are defined by human use

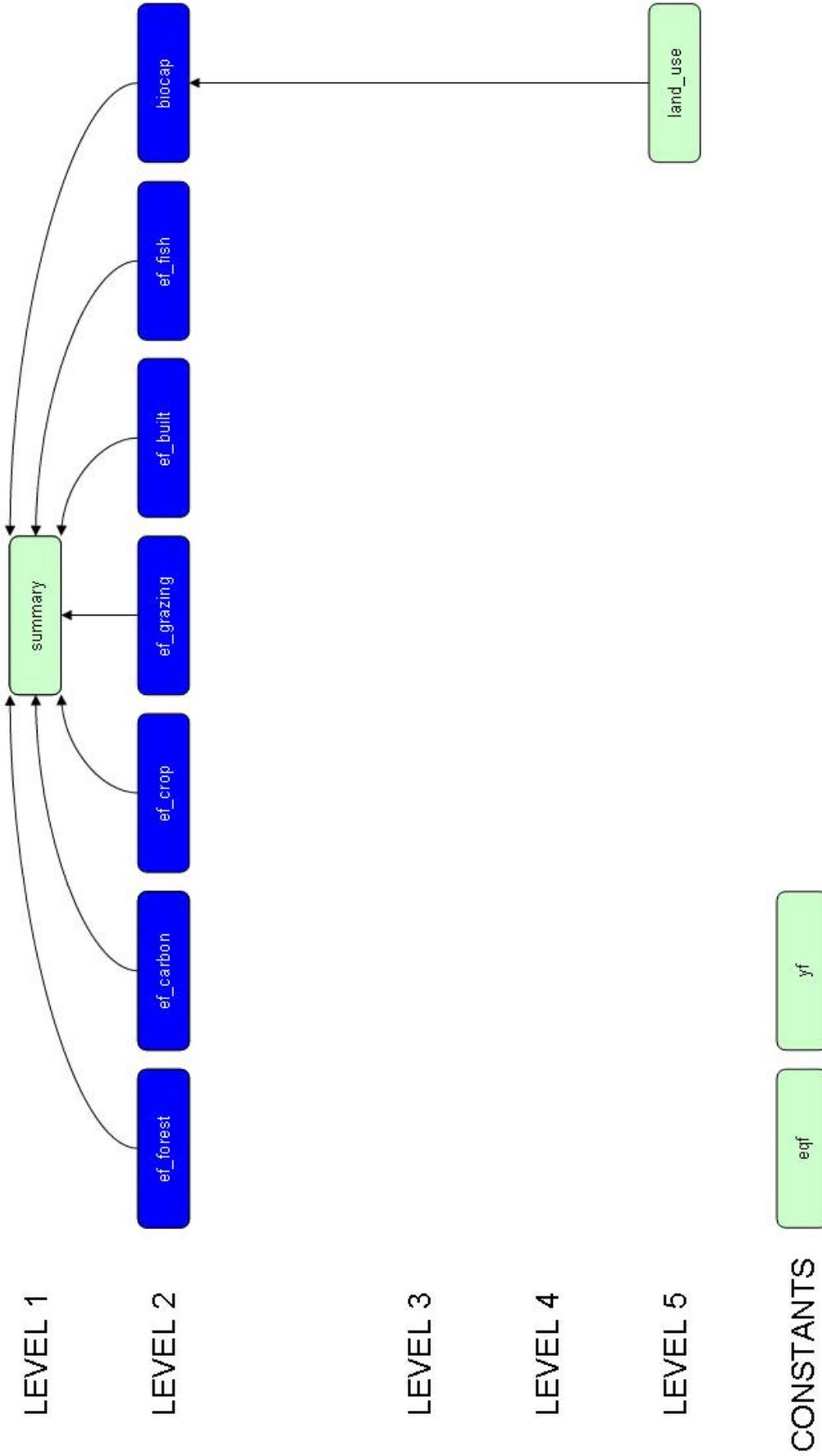


Figure 9-1
Biocapacity calculations. The *biocap* worksheet performs all biocapacity calculations. The only lower level worksheet in the biocapacity section of *NFA 2008* is the *land_use* worksheet. *Biocap* is the only Level 2 worksheet that performs any major calculations.

9.2 Worksheets

The biocapacity section of the *NFA 2008* workbook consists of one Level 5 worksheet, *land_use*, which provides data directly to the Level 2 *biocap* worksheet. Like the other Level 2 worksheets in the *NFA 2008* workbook, *biocap* is colored blue in both the *NFA 2008* workbook and this guidebook. *Land_use* is colored light green.

9.2.1 biocap

Level 2 (Only biocapacity worksheet at this level)

Biocap calculates the biocapacity for all bioproductive land types in the *NFA 2008* workbook.

Layout: The only identifying column, ‘Land Use Type,’ lists each of the land or land use type names. The following column, ‘Area,’ reports a country’s area in hectares of each land type. The last two columns list the yield factor and equivalence factor for each land use type.

Data and Calculation: Area data are drawn from the *land_use* worksheet. For each land or land use type except marine fishing grounds more than one data source may be available. For EU member countries included in the database, CORINE2000 (Corine Land Cover 2000) is used as the source for all area data except continental shelf areas. For non-EU members, ResourceSTAT (FAO ResourceSTAT Statistical Database) is the source for area data. Data on continental shelf areas are taken from the World Resources Institute (WRI Global Land Cover Classification Database).

Areas covered by hydroelectric development are included in the built-up land biocapacity calculation. However, country specific areas inundated are not available. These areas are instead estimated in the *hydro_eff* worksheet, based on an assumed average area inundated per MWh of generating capacity. The Footprint of hydroelectric power generation is estimated based on the assumption that hydroelectric plants operate at 45 percent of their rated generating capacity (IEA Hydropower FAQ).

The following table shows the prioritization of the data sets used in the biocapacity calculation, in decreasing order of preference from left to right. If no data are available for a particular land use type, the area is assumed to be zero.

Land or Land Use Type	Preferred data source	Data source 2 (if applicable)	Data source 3 (if applicable)	Data source 4 (if applicable)
Cropland	CORINE2000	FAOSTAT		
Grazing Land	CORINE2000	FAOSTAT		
Other Wooded Land	CORINE2000	FAOSTAT		
Forest	CORINE2000	FAOSTAT		
Inland Fishing Grounds	CORINE2000	FAOSTAT		
Marine Fishing Grounds	WRI			
Infrastructure	CORINE2000	GAEZ	GLC2000	SAGE

‘YF’ and ‘EQF’ values for all land use types except hydroelectric land are drawn from the *yf* and *eqf* worksheets, respectively. As hydro reservoirs are assumed to cover world average land, the yield and equivalence factors for hydroelectric land are set to 1.

For lack of comprehensive data on the productivity of inland waters, this is assumed to be equal to that of marine waters. Thus, the equivalence factors for the two fishery types are set equal. The yield factor for inland water is set to 1, assuming all inland waters to be equally productive. Yield and equivalence factors for the “Other Wooded Land” category are assumed equal to those for grazing land.

In the final column, ‘BC,’ biocapacity is calculated using **Equation 2-2**. The *summary* worksheet draws values from this column to report biocapacity totals.

Refers to: *yf* (Cnst), *eqf* (Cnst), *land_use* (L5), *hydro_eff* (L3)

Referenced by: *summary* (L1)

9.2.2 land_use

Level 5 (*Only biocapacity worksheet at this level*)

Land_use contains the source data on the areas devoted to each land use type. This worksheet often contains multiple possible sources for a single value, using the most robust dataset from which data are available.

Layout: The *land_use* worksheet begins with three identifying columns. The first, ‘Source,’ lists the data source. The second column, ‘Description,’ identifies the data point as it is described in the source. The third column, ‘Land Type,’ states the land use type the data applies to. The category of ‘Other wooded land’ is included in grazing land, and ‘infrastructure’ is used as the area for built-up land. For fishing grounds, the *land_use* worksheet lists both EEZ and continental shelf areas the latter of which is used in the fishing grounds biocapacity calculation.

Data and Calculation: The area values in this worksheet come from a variety of sources, identified within the worksheet. The most notable of these are CORINE 2000, FAOSTAT, and GLC 2000 (Corine Land Cover 2000; FAO ResourceSTAT Statistical Database; Global Land Cover 2000). There are two or more possible data sources for most of the land use types. These are used contingent on availability, in the order of preference specified above. The **NFA 2008** prioritizes the most reliable data sources.

Refers to: None

Referenced by: *biocap* (L2), *infrastructure_eff* (L2)

10 Yield Factors

Color: Green

10.1 Description

Yield factors reflect the relative productivity of national and world average hectares of a given land use type. Each country, in each year, has a yield factor for each land type. Yield factors are used in biocapacity calculations when biocapacity is reported in global hectares. Yield factors are not used in Footprint calculations.

For major land use types that produce only a single primary product, yield factors are calculated using **Equation 10-1**. This equation applies to grazing land, fishing grounds, and forest.

Equation 10-1
Yield Factors Simple Calculation

$$YF_N^L = \frac{Y_N^L}{Y_W^L}$$

Where:

- YF_N^L = Yield factor for a given country and land type, wha nha⁻¹.
- Y_N^L = Yield for a given country and land type, t nha⁻¹
- Y_W^L = World-average yield for a given land type, t wha⁻¹

Cropland produces more than one primary product. For this land use type, **Equation 10-2** is used.

Equation 10-2
Yield Factors Extended Calculation

$$YF_N^L = \frac{\sum A_W}{\sum A_N} \text{ where } A_N = \frac{P_N}{Y_N} \text{ and } A_W = \frac{P_N}{Y_W}$$

Where:

- YF_N^L = Yield factor for a given country and land type, wha nha⁻¹.
- A_N = Area harvested for a given quantity of product in a given country, nha⁻¹
- A_W = Area that would be required to produce a given quantity of product using world average land, wha⁻¹
- P_N = Amount of given product extracted or waste generated in a country, t yr⁻¹
- Y_N = National yield for product extraction, t nha⁻¹ yr⁻¹
- Y_W = World-average yield for product extraction, t wha⁻¹ yr⁻¹

10.2 Worksheets

The main yield factor calculations for each land type are shown in the *yf* worksheet. Additional calculations necessary to determine the yield factor for cropland are contained in the *yf_crop* worksheet.

10.2.1 *yf*

Constants

The *yf* worksheet calculates the yield factor for all land types in the *NFA 2008* workbook except for cropland, which is calculated in the *yf_crop* worksheet.

Layout: The only identifying column, 'Land type,' lists all of the land use types with the exception of carbon uptake land. Next, the 'NY' column reports the national yield for a land type, 'WY' reports the world-average yield for a land type, and 'YF' reports the yield factor for that land type.

Data and Calculation: Yield factors give the ratio of national to world-average yields for each land use type.

The grazing land yield is the ratio of national yield to world-average yield of tonnes dry matter produced on grazing land.

The yield factor for marine fishing grounds is the ratio of NPP per hectare in a country's exclusive economic zone to world average marine NPP (Sea Around Us Project 2008). The yield factor for inland fishing grounds is set equal to one, due to the absence of comprehensive productivity measurements for inland waters located in different countries.

The forest yield factor is the ratio of national yield to world-average yield of roundwood equivalent produced in forests.

The yield factor for infrastructure is set equal to the yield factor for cropland under the assumption that most infrastructure occupies previously productive cropland.

Refers to: *forest_yield_n* (L4), *forest_yield_w* (L4), *yf_crop* (Cnst)

Referenced by: *biocap* (L2), *infrastructure_efp* (L3)

10.2.2 *yf_crop*

Constants

The *yf_crop* worksheet calculates the yield factor for cropland.

Layout: This worksheet begins with two identifying columns: 'Name' and 'Code.' These report the product name and FAOSTAT code, respectively, for each product. Only primary products are included in this list. The 'Area_N' column shows the actual area harvested for the domestic production of each crop. The 'Area_w' column estimates the area that would be necessary to produce the domestically harvested tonnage of a given product using land with world-average yield.

The next column, 'Indicator,' contains a 1 if the particular crop is considered in calculating the cropland yield factor. The calculation of the cropland yield factor excludes crops grown for animal feed, as well as some aggregated crop categories.

The 'YF' column shows the calculated yield factor for each individual crop. The next two columns are labeled 'Area I-only-n' and 'Area I-only-w.' These columns repeat the values in the 'Area_N' and 'Area_w' columns, excluding crops that do not have a 1 in the 'Indicator' column.

Data and Calculation: The national area values are drawn from the *crop_yield_n* worksheet. The calculation of 'Area_w' is shown in **Equation 10-2**. The 'YF' column shows the yield factor for each individual agricultural product, calculated as 'Area_w' divided by 'Area_N.'

The last row of the *yf_crop* worksheet calculates a yield factor for all cropland. It sums the values in the 'Area I-only-n' and 'Area I-only-w' for all products, then in the next column divides the latter by the former. This results in the yield factor for cropland, the ratio of total domestic harvested land to the amount of world average cropland that would be required to grow the same bundle of crops. This value is reported in the *yf* worksheet, and is used in the biocapacity calculation.

Refers to: *crop_yield_n* (L4), *crop_yield_w* (L4), *crop_efp* (L3)

Referenced by: *yf* (Cnst)

11 Equivalence Factors

Color: Light Green

11.1 Description

Equivalence factors reflect the relative productivity of world average hectares of different land types. Equivalence factors are the same for all countries, and change slightly from year to year. Equivalence factors are used in both biocapacity and Footprint calculations when results are reported in global hectares.

Equivalence factors are calculated in a satellite workbook to *NFA 2008*. This equivalence factor workbook can be requested from Global Footprint Network. The description below is intended to provide a general overview of the more detailed calculation logic carried out in this supporting workbook.

The equivalence factors are currently calculated using suitability indexes from the Global Agro-Ecological Zones model combined with information about actual areas of cropland, forest, and grazing area from FAOSTAT (Global Agro-Ecological Zones; FAO ResourceSTAT Statistical Database). The GAEZ model divides all land globally into five categories, each of which is assigned a suitability score

- Very Suitable – 0.9
- Suitable – 0.7
- Moderately Suitable – 0.5
- Marginally Suitable – 0.3
- Not Suitable – 0.1

The equivalence factor calculation assumes that the most productive land is put to its most productive use. The calculations assume that the most suitable land available will be planted to cropland, the next most suitable land will be under forest, and the least suitable land will be grazing area. The equivalence factor is calculated as the ratio of the average suitability index for a given land type divided by the average suitability index for all land types. This calculation is shown schematically in **Figure 11-1**.

The equivalence factor for infrastructure area is set equal to the equivalence factor for cropland, reflecting the assumption that infrastructure occupies former cropland. The equivalence factor for hydro area is set equal to one, which assumes that hydro 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 on a single global hectare of marine area. The equivalence factor for inland water is set equal to the equivalence factor for marine area.

11.2 Worksheets

The *eqf* worksheet lists equivalence factors ('EQF') for each land use type. The supporting worksheet containing the equivalence factor calculations is available on request from Global Footprint Network.

11.2.1 eqf

Constants

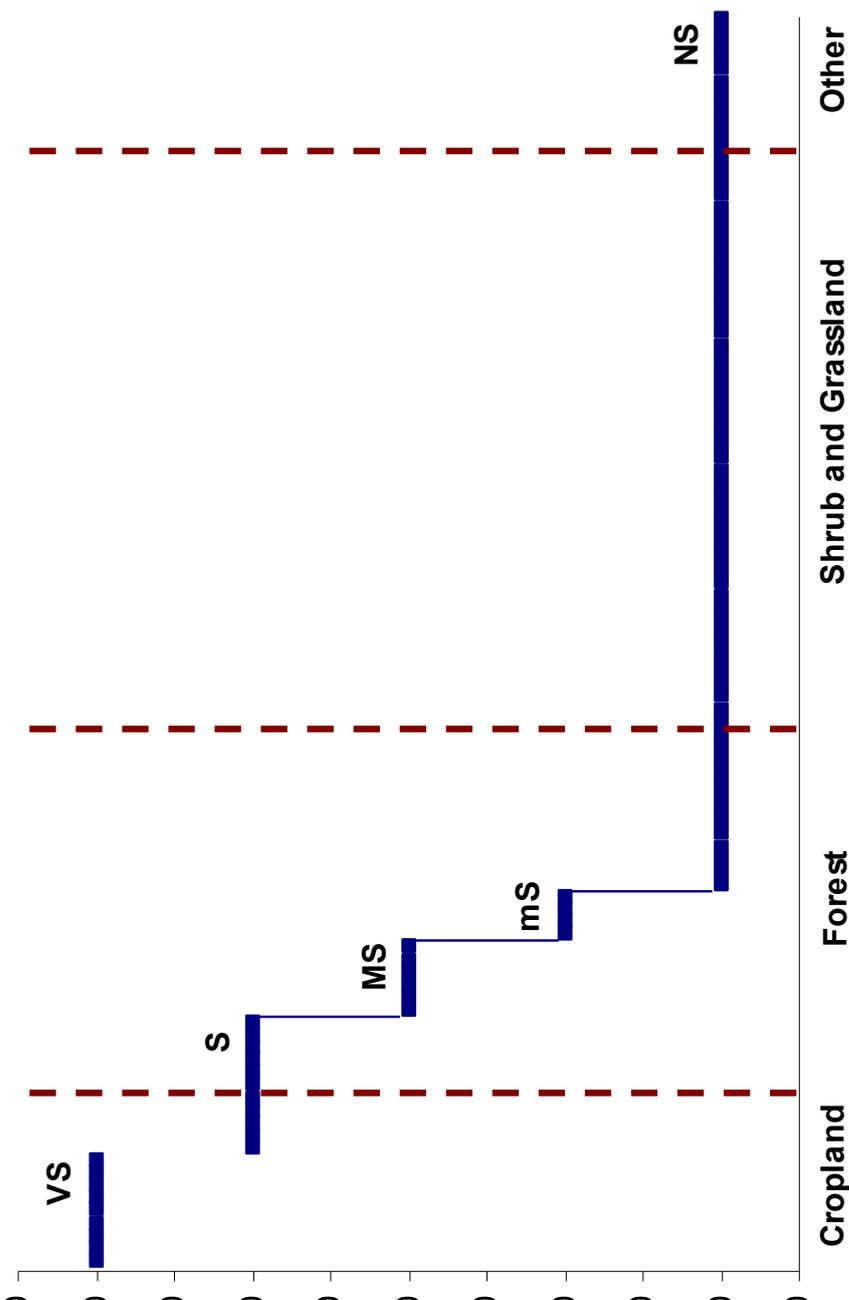
The *eqf* worksheet lists the equivalence factors for all land use types.

Layout: This worksheet begins with one identifying column: 'Land Type' which lists the major land use types, breaking fishing grounds in to 'Marine' and 'Inland Water' and dividing built-up land into 'Infrastructure' and 'Hydro.' The next column, 'EQF', lists the equivalence factors for all land use types.

Data and Calculation: The supporting calculation for these numbers is performed internally by Global Footprint Network, and the principles are described above.

Refers to: None

Referenced by: All Level 3 worksheets, *biocap* (L2)



12 Glossary

Acre: One U.S. acre is equal to 0.405 hectares. For U.S. audiences, Footprint results are often presented in global acres (ga), rather than global hectares (gha).

Biodiversity buffer: The amount of [biocapacity](#) set aside to maintain representative ecosystem types and viable populations of species. How much needs to be set aside depends on biodiversity management practices and the desired outcome.

Biological capacity, or biocapacity: The capacity of ecosystems to produce useful biological materials and 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, and thus increase the biocapacity of maize cropland). The biocapacity of an area is calculated by multiplying the actual physical area by the [yield factor](#) and the appropriate [equivalence factor](#). Biocapacity is usually expressed in [global hectares](#).

Biological capacity available per person (or per capita): There were 13.3 billion hectares of [biologically productive land and water](#) on this planet in 2005. Dividing by the number of people alive in that year, 6.5 billion, gives 2.1 [global hectares](#) per person. This assumes that no land is set aside for other species that consume the same biological material as humans.

Biologically productive land and water: The land and water (both marine and inland waters) area that supports significant photosynthetic activity and the accumulation of biomass used by humans. Non-productive areas as well as marginal areas with patchy vegetation are not included. Biomass that is not of use to humans is also not included. The total biologically productive area on land and water in 2005 was approximately 13.3 billion hectares.

Carbon Footprint: When used in Ecological Footprint studies, this term is synonymous with demand on [CO₂ area](#). The phrase “Carbon Footprint” has been picked up in the climate change debate. Several web-calculators use the phrase “Carbon Footprint”. Many just calculate tonnes of carbon, or tonnes of carbon per Euro, rather than demand on bioproductive area. The Ecological Footprint encompasses the carbon Footprint, and captures the extent to which measures for reducing the carbon Footprint lead to increases in other Footprint components.

CO₂ area (also CO₂ land): The demand on biocapacity required to sequester (through photosynthesis) the carbon dioxide (CO₂) emissions from fossil fuel combustion. Although fossil fuels are extracted from the Earth's crust and are not regenerated in human time scales, their use demands ecological services if the resultant CO₂ is not to accumulate in the atmosphere. The Ecological Footprint therefore includes the biocapacity, typically that of unharvested forests, needed to absorb that fraction of fossil CO₂ that is not absorbed by the ocean.

Consumption: Use of goods or of services. The term consumption has two different meanings, depending on context. As commonly used in regard to the Footprint, it refers to the use of goods or services. A consumed good or service embodies all the resources, including energy, necessary to provide it to the consumer. In full life-cycle accounting, everything used along the production chain is taken into account, including any losses along the way. For example, consumed food includes not only the plant or

animal matter people eat or waste in the household, but also that lost during processing or harvest, as well as all the energy used to grow, harvest, process and transport the food.

As used in [Input-Output analysis](#), consumption has a strict technical meaning. Two types of consumption are distinguished: intermediate and final. According to the (economic) [System of National Accounts](#) terminology, intermediate consumption refers to the use of goods and services by a business in providing goods and services to other businesses. Final consumption refers to non-productive use of goods and services by households, the government, the capital sector, and foreign entities.

Consumption components (also consumption categories): Ecological Footprint analyses can allocate total Footprint among consumption components, typically Food, Shelter, Mobility, Goods, and Services, often with further resolution into sub-components. Consistent categorization across studies allows for comparison of the Footprint of individual consumption components across regions, and the relative contribution of each category to the region's overall Footprint. To avoid [double counting](#), it is important to make sure that consumables are allocated to only one component or sub-component. For example, a refrigerator might be included in the food, goods, or shelter component, but only in one.

Consumption Footprint: The most commonly reported type of [Ecological Footprint](#). It is the area used to support a defined population's consumption. The consumption Footprint (in gha) includes the area needed to produce the materials consumed and the area needed to absorb the waste. The consumption Footprint of a nation is calculated in the National Footprint Accounts as a nation's [primary production Footprint](#) plus the Footprint of imports minus the Footprint of exports, and is thus, strictly speaking, a Footprint of apparent consumption. The national average or per capita Consumption Footprint is equal to a country's Consumption Footprint divided by its population.

Consumption Land Use Matrix: Starting with data from the National Footprint Accounts, a Consumption Land Use Matrix allocates the six major Footprint land uses (shown in column headings, representing the five [land types](#) and CO2 area) to the five Footprint [consumption components](#) (row headings). Each consumption component can be disaggregated further to display additional information. These matrices are often used as a tool to develop sub-national (e.g. state, county, city) Footprint assessments. In this case, national data for each cell is scaled up or down depending on the unique consumption patterns in the state, county or city.

Consumption Land Use Matrix

	Built-up Land	Carbon Footprint	Cropland	Grazing Land	Forest Land	Fishing Ground	Total
Food							
Shelter							
Mobility							
Goods							
Services							
Total							

Conversion factor: A generic term for factors that are used to translate a material flow expressed within one measurement system into another one. For example, a combination of two conversion factors — “[yield factors](#)” and “[equivalence factors](#)”— translates [hectares](#) into [global hectares](#). The [extraction rate](#) conversion factor translates a secondary product into [primary product](#) equivalents.

Conversion Factor Library: See [Footprint Intensity Table](#).

Daughter product: The product resulting from the processing of a [parent product](#). For example wood pulp, a secondary product, is a daughter product of roundwood. Similarly, paper is a daughter product of wood pulp.

Double counting: In order not to exaggerate human demand on nature, Footprint Accounting avoids double counting, or counting the same Footprint area more than once. Double counting errors may arise in several ways. For example, when adding the Ecological Footprints in a production chain (e.g., wheat farm, flour mill, and bakery), the study must count the cropland for growing wheat only once to avoid double counting. Similar, but smaller, errors can arise in analyzing a production chain when the end product is used to produce the raw materials used to make the end product (e.g. steel is used in trucks and earthmoving equipment used to mine the iron that is made into the steel). Finally, when land serves two purposes (e.g. a farmer harvests a crop of winter wheat and then plants corn to harvest in the fall), it is important not to count the land area twice. Instead, the [yield factor](#) is adjusted to reflect the higher bioproductivity of the double-cropped land.

Ecological debt: The sum of annual ecological deficits. Humanity's Footprint first exceeded global biocapacity in the mid-1980s, and has done so every year since. By 2005 this annual overshoot had accrued into an ecological debt that exceeded 2.5 years of the Earth's total productivity.

Ecological deficit/reserve: The difference between the [biocapacity](#) and [Ecological Footprint](#) of a region or country. An ecological deficit occurs when the Footprint of a population exceeds the biocapacity of the area available to that population. Conversely, an ecological reserve exists when the biocapacity of a region or country exceeds the Footprint of its population. If there is a regional or national ecological deficit, it means that the region or country is either importing biocapacity through trade, liquidating its own ecological assets, or emitting wastes into a global commons such as the atmosphere. In contrast, the global ecological deficit cannot be compensated through trade, and is equal to [overshoot](#).

Ecological Footprint: A measure of how much [biologically productive land and water](#) an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices. The Ecological Footprint is usually measured in [global hectares](#). Because trade is global, an individual or country's Footprint includes land or sea from all over in the world. Ecological Footprint is often referred to in short form as Footprint. "Ecological Footprint" and "Footprint" are proper nouns and thus should always be capitalized.

Ecological Footprint Standards: Specified criteria governing methods, data sources and reporting to be used in Footprint studies. Standards are established by the Global Footprint Network Standards Committees, composed of scientists and Footprint practitioners from around the world. Standards serve to produce transparent, reliable and mutually comparable results in studies done throughout the Footprint Community. Where Standards are not appropriate, Footprint [Guidelines](#) should be consulted. For more information, consult www.footprintstandards.org.

Ecological reserve: See [ecological deficit/reserve](#).

Embodied energy: Embodied energy is the energy used during a product's entire life cycle in order to manufacture, transport, use and dispose of the product. Footprint studies often use embodied energy when tracking the trade of goods.

Energy Footprint: The sum of all areas used to provide non-food and non-feed energy. It is the sum of [CO₂ area](#), hydropower land, forest for fuelwood, and crop land for fuel crops.

Equivalence factor: A [productivity](#)-based scaling factor that converts a specific [land type](#) (such as cropland or forest) into a universal unit of biologically productive area, a [global hectare](#). For land types (e.g. cropland) with [productivity](#) higher than the average productivity of all [biologically productive land and water](#) area on Earth, the equivalence factor is greater than 1. Thus, to convert an average hectare of cropland to global hectares, it is multiplied by the cropland equivalence factor of 2.64. Pasture lands, which have lower productivity than cropland, have an equivalence factor of 0.50 (see also [yield factor](#)). In a given year, equivalence factors are the same for all countries.

Extraction rate: A processing factor comparing the quantity of a [parent product](#) to the quantity of the resulting [daughter product](#). When a parent product is processed its mass changes. For example, when wheat is processed into white flour, the bran and germ are stripped, lessening its mass. Therefore, in order to calculate the number of hectares needed to produce a given mass of flour, an extraction rate is needed. This extraction rate in this example is the ratio of tonnes of flour divided by the tonnes of wheat processed to produce the flour.

Footprint intensity: The number of global hectares required to produce a given quantity of resource or absorb a given quantity of waste, usually expressed as global hectares per tonne. The National Footprint Accounts calculate a primary Footprint Intensity Table for each country, which includes the global hectares of primary land use type needed to produce or absorb a tonne of product (i.e., global hectares of cropland per tonne of wheat, global hectares of forest per tonne carbon dioxide).”

Footprint Intensity Table: A collection of the [primary](#) and [secondary](#) product Footprint intensities from the [National Footprint Accounts](#). Footprint intensity is usually measured in gha per tonne of product or waste (CO₂). The Footprint Intensity Table is maintained by Global Footprint Network, supported by the Network's National Accounts Committee.

Footprint-neutral or negative: Human activities or services that result in no increase or a net reduction in humanity's [Ecological Footprint](#). For example, the activity of insulating an existing house has a Footprint for production and installation of the insulation materials. This insulation in turn reduces the energy needed for cooling and heating this existing house. If the Footprint reduction from this energy cutback is equal to or greater than the original Footprint of insulating the house, the latter becomes a Footprint-neutral or negative activity. On the other hand, making a new house highly energy efficient does not by itself make the house Footprint-neutral, unless it at the same time causes a reduction in other existing Footprints. This Footprint reduction has to be larger than the Footprint of building and operating the new house.

Global hectare (gha): A [productivity](#)-weighted area used to report both the biocapacity of the earth, and the demand on biocapacity (the Ecological Footprint). The global hectare is normalized to the area-weighted average productivity of [biologically productive land and water](#) in a given year. Because different land types have different productivity, a global hectare of, for example, cropland, would occupy a smaller physical area than the much less biologically productive pasture land, as more pasture would be needed to provide the same biocapacity as one hectare of cropland. Because world bioproductivity varies slightly from year to year, the value of a gha may change slightly from year to year.

Guidelines (for Footprint studies): Suggested criteria governing methods, data sources and reporting for use when Footprint [Standards](#) are not appropriate or not yet developed.

Hectare: 1/100th of a square kilometre, 10,000 square meters, or 2.471 acres. A hectare is approximately the size of a soccer field. See also [global hectare](#) and [local hectare](#).

IO (Input-Output) analysis: Input-Output (IO, also I-O) analysis is a mathematical tool widely used in economics to analyze the flows of goods and services between sectors in an economy, using data from [IO tables](#). IO analysis assumes that everything produced by one industry is consumed either by other industries or by final consumers, and that these consumption flows can be tracked. If the relevant data are available, IO analyses can be used to track both physical and financial flows. Combined economic-environment models use IO analysis to trace the direct and indirect environmental impacts of industrial activities along production chains, or to assign these impacts to final demand categories. In Footprint studies, IO analysis can be used to apportion Footprints among production activities, or among categories of final demand, as well as in developing [Consumption Land Use Matrices](#).

IO (Input-Output) tables: IO tables contain the data that are used in [IO analysis](#). They provide a comprehensive picture of the flows of goods and services in an economy for a given year. In its general form an economic IO table shows *uses* — the purchases made by each sector of the economy in order to produce their own output, including purchases of imported commodities; and *supplies* — goods and services produced for intermediate and final domestic consumption and exports. IO tables often serve as the basis for the economic National Accounts produced by national statistical offices. They are also used to generate annual accounts of the Gross Domestic Product (GDP).

Land type: The Earth's approximately 13.4 billion hectares of [biologically productive land and water](#) are categorized into five types of surface area: cropland, grazing land, forest, fishing ground, and built-up land. Also called "area type".

Life cycle analysis (LCA): A quantitative approach that assess a product's impact on the environment throughout its life. LCA attempts to quantify what comes in and what goes out of a product from “cradle to grave,” including the energy and material associated with materials extraction, product manufacture and assembly, distribution, use and disposal, and the environmental emissions that result. LCA applications are governed by the ISO 14040 series of standards (<http://www.iso.org>).

Local hectare: A productivity-weighted area used to report both the biocapacity of a local region, and the demand on biocapacity (the Ecological Footprint). The local hectare is normalized to the area-weighted average productivity of the specified region's [biologically productive land and water](#). Hence, similar to currency conversions, Ecological Footprint calculations expressed in global hectares can be converted into local hectares in any given year (e.g. Danish hectares, Indonesian hectares) and vice versa. The number of Danish hectares equals the number of bioproductive hectares in Denmark – each Danish hectare would represent an equal share of Denmark's total biocapacity.

National Footprint Accounts: The central data set that calculates the [Footprints](#) and [biocapacities](#) of the world and roughly 150 nations from 1961 to the present (generally with a three-year lag due to data availability). The ongoing development, maintenance and upgrades of the National Footprint Accounts are coordinated by Global Footprint Network and its 100-plus [partners](#).

Natural capital: Natural capital can be defined as all of the raw materials and natural cycles on Earth. Footprint analysis considers one key component, *life-supporting* natural capital, or ecological capital for short. This capital is defined as the stock of living ecological assets that yield goods and services on a continuous basis. Main functions include resource production (such as fish, timber or cereals), waste assimilation (such as CO₂ absorption or sewage decomposition) and life-support services (such as UV protection, biodiversity, water cleansing or climate stability).

Overshoot: Global overshoot occurs when humanity's demand on nature exceeds the biosphere's supply, or regenerative capacity. Such overshoot leads to a depletion of Earth's life-supporting [natural capital](#) and a build-up of waste. At the global level, [ecological deficit](#) and overshoot are the same, since

there is no net-import of resources to the planet. Local overshoot occurs when a local ecosystem is exploited more rapidly than it can renew itself.

Parent product: The product processed to create a [daughter product](#). For example wheat, a [primary product](#), is a parent product of flour, a secondary product. Flour, in turn, is a parent product of bread.

Planet equivalent(s): Every individual and country's [Ecological Footprint](#) has a corresponding Planet Equivalent, or the number of Earths it would take to support humanity's Footprint if everyone lived like that individual or average citizen of a given country. It is the ratio of an individual's (or country's per capita) Footprint to the per capita [biological capacity available on Earth](#) (2.1 gha in 2005). In 2005, the world average Ecological Footprint of 2.7 gha equals 1.31 Planet equivalents.

http://www.footprintnetwork.org/gfn_sub.php?content=glossary-ftn1 **Primary product:** In Footprint studies, a primary product is the least-processed form of a biological material that humans harvest for use. There is a difference between the raw product, which is all the biomass produced in a given area, and the primary product, which is the biological material humans will harvest and use. For example, a fallen tree is a raw product that, when stripped of its leaves and bark, results in the primary product of roundwood. Primary products are then processed to produce secondary products like wood pulp and paper. Other examples of primary products are potatoes, cereals, cotton and forage. Examples of secondary products are kWh of electricity, bread, clothes, beef and appliances.

Primary production Footprint (also primary demand): In contrast to the [consumption Footprint](#), a nation's primary production Footprint is the sum of the Footprints for all of the resources harvested and all of the waste generated within the defined geographical region. This includes all the area within a country necessary for supporting the actual harvest of primary products (cropland, pasture land, forestland and fishing grounds), the country's built-up area (roads, factories, cities), and the [area](#) needed to absorb all fossil fuel carbon emissions generated within the country. In other words, the forest Footprint represents the area necessary to regenerate all the timber harvested (hence, depending on harvest rates, this area can be bigger or smaller than the forest area that exists within the country). Or, for example, if a country grows cotton for export, the ecological resources required are not included in that country's consumption Footprint; rather, they are included in the consumption Footprint of the country that imports the t-shirts. However, these ecological resources *are* included in the exporting country's primary production Footprint.

Productivity: The amount of biological material useful to humans that is generated in a given area. In agriculture, productivity is called [yield](#).

Secondary product: All products derived from primary products or other secondary products through a processing sequence applied to a primary product.

Tonnes: All figures in the National Footprint Accounts are reported in metric tonnes. One metric tonne equals 1000 kg, or 2205 lbs.

Yield: The amount of primary product, usually reported in tonnes per year, that humans are able to extract per area unit of [biologically productive land or water](#).

Yield factor: A factor that accounts for differences between countries in [productivity](#) of a given [land type](#). Each country and each year has yield factors for cropland, grazing land, forest, and fisheries. For example, in 2005, German cropland was 2.3 times more productive than world average cropland. The German cropland yield factor of 2.3, multiplied by the cropland [equivalence factor](#) of 2.6, converts German cropland hectares into [global hectares](#): one hectare of cropland is equal to 6.0 gha.

http://www.footprintnetwork.org/gfn_sub.php?content=glossary - ftoref1Note that primary product and primary production Footprint are Footprint-specific terms. They are not related to, and should not be confused with, the ecological concepts of primary production, gross primary productivity (GPP) and net primary productivity (NPP).

Appendix A: Notes on Tables

- Comments are included as explanatory notes within tables where appropriate, and, under Microsoft Excel default settings, are indicated by a small red triangle in the upper right corner of a cell.
- All cells within a given column have the same formula unless otherwise indicated by a comment.
- To aid in formula writing, especially in applying the VLOOKUP() formulas common throughout the *NFA 2008* workbook, tables are often assigned a named range. The named ranges are given the same name as the worksheet on which they appear. The *forest_efp* worksheet, for example, contains a single table with the defined name forest_efp.

In worksheets where the first column contains the record name and the second column contains the record code, the table is defined to begin at with the second column, not the first. This is to facilitate VLOOKUP() functions which perform the lookup based on the record's code number instead of its name.

- Throughout the *NFA 2008* workbook, conditional formatting has been used to hide error values and zero values when they are present in table records. This formatting is intended for ease of reading. To view actual error or zero values in a cell, highlight the cells that appear blank, and the error or zero values will be visible as white text.
- Many columns contain nested functions that convert error values to zeroes. These formulas can be quite long, and take the form of an ISERROR() function nested within an IF() statement. An example of this type of error checking can be found in the EF_p column of the *forest_efp* worksheet.
- In cases where a column has the same value for all records (e.g., an equivalence factor column in a table covering only a single land use type), the first record always contains the complete formula to determine the appropriate value. Subsequent records may refer to the appropriate cell in the first record instead of repeating an identical formula. This design avoids unnecessary software overhead in the *NFA 2008* workbook.

Appendix B: Equations

(1) Equation 2-1: Calculation of Ecological Footprint of Consumption (section 2.2.2)

The six *ef_* worksheets apply an identical formula to calculate the Ecological Footprint of consumption from the Footprints of production, imports, and exports. For any given record, the Footprint of consumption is calculated according to **Equation 2-1**.

Equation 0-1

Calculation of Ecological Footprint of Consumption

$$EF_C = EF_P + EF_I - EF_E$$

Where:

EF_C = Footprint of consumption associated with product or waste

EF_P = Footprint of production associated with product or waste

EF_I = Footprint of imports associated with product or waste

EF_E = Footprint of exports associated with product or waste

(2) Equation 2-2: Calculation of biocapacity for Single Land Type (section 2.2.2)

The single *biocap* worksheet uses data on area, yield factors, and equivalence factors to calculate the biocapacity of each land type. The calculation of biocapacity follows **Equation 2-2**.

Equation 0-2

Calculation of biocapacity for Single Land Type

$$BC = A \cdot YF \cdot EQF$$

Where:

BC = biocapacity of a given land type, gha

A = Area of a given land type within a country, nha

YF = Yield factor of a given land type within a country, wha nha⁻¹

EQF = equivalence factor for given land type, gha wha⁻¹.

(3) Equation 2-3(b): Ecological Footprint of Yearly Product Extraction or Waste Generation (section 2.2.3)

In calculating Footprints of production, imports, and exports, Level 3 worksheets rely on the basic Ecological Footprint formula, which can be expressed as follows:

Equation 0-3

Ecological Footprint of Yearly Product Extraction or Waste Generation

$$EF = \frac{P}{Y_N} \cdot YF \cdot EQF$$

Where:

- EF = Ecological Footprint associated with product or waste, gha
- P = amount of product extracted or waste generated, t yr⁻¹
- Y_N = national-average yield for product extraction or waste absorption, t nha⁻¹ yr⁻¹
- YF = Yield factor of a given land type within a country, wha nha⁻¹
- EQF = equivalence factor for given land type, gha wha⁻¹.

Note that in **Equation 2-3**, because the Yield Factor is defined as national divided by world yield, the national-average yields cancel out (see Chapter 10). Thus, the basic Ecological Footprint formula can be expressed more succinctly in the following for

Equation 0-3b
Ecological Footprint of Yearly Product Extraction or Waste Generation (Simplified)

$$EF = \frac{P}{Y_w} \bullet EQF$$

Where:

- Y_w = world-average yield for product extraction or waste absorption, t wha⁻¹ yr⁻¹

This formula is slightly modified for some calculations, such as the calculation of the Footprint of hydroelectric electricity. Modifications to this standard formula are noted in the chapters on specific land use types.

(4) Equation 2-4: Calculation for Yield of Daughter Products (section 2.2.4)

World average extraction rates are currently used throughout *NFA 2008* to convert secondary products into their parent product equivalents. They relate to processed products only and indicate the amount of the primary product embodied in the daughter product. Yields of daughter products are calculated using **Equation 2-4**.

Equation 0-4
Calculation for Yield of Daughter Products

$$Y^D = Y^P \bullet EXTR$$

Where:

- Y^D = Yield of daughter product, (t daughter) ha⁻¹ yr⁻¹
- Y^P = Yield of parent product, (t parent) ha⁻¹ yr⁻¹
- EXTR = Extraction rate, (t daughter) (t parent)⁻¹

(5) Equation 6-1: Primary Productivity Required for Yield of Aquatic Species (section 6.2.7)

The PPR column in *fish_yield_w* is calculated according to **Equation 6-1** (Pauly and Christensen 1995).

Equation 0-4
PPR for Yield of Aquatic Species

$$PPR = CC * DR * \left(\frac{1}{TE} \right)^{(TL-1)}$$

Where:

- PPR = Primary production required, t C (t product)⁻¹
 TE = Transfer efficiency of aquatic ecosystems, t feed (t product)⁻¹
 = 10% (Pauly and Christensen 1995).
 TL = Average fractional trophic level for given species
 DR = Discard rate of bycatch
 = 1.27, currently applied to all fish species (Pauly and Christensen 1995).
 CC = Carbon content of fish biomass, per unit wet weight
 = 1/9 (Pauly and Christensen 1995).

(6) Equation 6-2: Yield for Aquatic Species (section 6.2.7)

Yield for the fishing grounds Footprint is calculated according to **Equation 6-2**.

Equation 6-2

Yield for Aquatic Species

$$\text{Yield} = \frac{1}{PPR} * APP$$

Where:

- PPR = Primary Productivity Requirement, as calculated in **Equation 6-1**.
 APP = Available Primary Productivity, the amount of primary productivity that can be sustainably harvested from each hectare of continental shelf area. This is calculated from an estimate of sustainable harvest (Gulland 1971), multiplied by the PPR for world average harvested fish and divided by the area of the continental shelf (World Resources Institute Global Land Cover Classification Database).

(7) Equation 10-1: Yield Factors Simple Calculation (section 10.1)

For major land use types that produce only a single primary product, yield factors are calculated using **Equation 10-1**. This equation applies to grazing land, fishing grounds, and forest.

Equation 0-5

Yield Factors Simple Calculation

$$YF_N^L = \frac{Y_N^L}{Y_W^L}$$

Where:

- YF_N^L = Yield factor for a given country and land type, wha nha⁻¹.
 Y_N^L = Yield for a given country and land type, t nha⁻¹
 Y_W^L = World-average yield for a given land type, t wha⁻¹

(8) Equation 10-2: Yield Factors Extended Calculation (section 10.1)

Equation 10-2 is used for cropland, which produces more than one primary product.

Equation 0-6
Yield Factors Extended Calculation

$$YF_N^L = \frac{\sum A_w}{\sum A_N} \quad \text{where} \quad A_N = \frac{P_N}{Y_N} \quad \text{and} \quad A_w = \frac{P_N}{Y_w}$$

Where:

- YF_N^L = Yield factor for a given country and land type, wha nha^{-1} .
- A_N = Area harvested for a given quantity of product in a given country, nha^{-1}
- A_w = Area that would be required to produce a given quantity of product using world average land, wha^{-1}
- P_N = Amount of given product extracted or waste generated in a country, t yr^{-1}
- Y_N = National yield for product extraction, $\text{t nha}^{-1} \text{ yr}^{-1}$
- Y_w = World-average yield for product extraction, $\text{t wha}^{-1} \text{ yr}^{-1}$

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