

# Working Guidebook to the National Footprint Accounts 2014



Research & Standards Department

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## Working Guidebook to the National Footprint Accounts 2014 Edition

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Version 1

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## Abbreviations

BC	Biocapacity
Constants	Constants Level Worksheet
EF	Ecological Footprint
EF <sub>E</sub>	Ecological Footprint of Exports
EF <sub>I</sub>	Ecological Footprint of Imports
EF <sub>P</sub>	Ecological Footprint of Production
EQF	Equivalence factor
gha	Global hectares
IYF	Intertemporal Yield Factor
L1	Level 1 Worksheet
L2	Level 2 Worksheet
L3	Level 3 Worksheet
L4	Level 4 Worksheet
L5	Level 5 Worksheet
m <sup>3</sup>	Cubic meters
m <sup>3</sup> rwe	Cubic meters roundwood equivalent
NFA	National Footprint Accounts
nha	National-average hectare (for a given land use type)
NPP	Net Primary Production
PPR	Primary Production Requirement (for fish species)
t	Metric tonnes
wha	World average hectare (for a given land use type)
YF	Yield Factor
IEA	International Energy Agency
UN Comtrade	United Nations Commodity Trade Statistics Database

# 1 Introduction

The Guidebook accompanies the National Footprint Accounts 2014 Edition (hereafter *NFA 2014*).

## 1.1 About the NFA 2014

The calculation of the National Footprint Accounts for a single country and year currently utilizes approximately 6,000 data points. The NFA 2014 Edition has been calculated for 232 countries and territories in the world, for all years between 1961 and 2008. Thus, there are approximately 61 million data points on which the National Footprint Accounts depend.

## 1.2 About the Guidebook

The Guidebook documents the collection of spreadsheets that perform the calculations in the *NFA 2014*. It is intended to be used alongside a copy of the *NFA 2014* workbook. Global Footprint Network provides licensed copies of this workbook in Microsoft Excel format. Free Academic Editions include workbooks for Hungary in 2008 and the World in 2008. Research and project licenses are available for approximately 150 countries for 1961 to 2008.

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/en/index.php/GFN/page/licenses1> or may be obtained by contacting Global Footprint Network directly ([data@footprintnetwork.org](mailto:data@footprintnetwork.org), or +1.510.839.8879).

The Guidebook assumes the reader possesses an intermediate to advanced understanding of Ecological Footprint accounting and methodology. Users interested in the results or methodology of the National Footprint Accounts are advised to first consult the Ecological Footprint Atlas 2010 (Ewing et al. 2010a) (<http://www.footprintnetwork.org/atlas>) and National Footprint Accounts methodology papers (Borucke et al. 2013; Ewing et al. 2010b; Ewing et al. 2008; Kitzes et al. 2007; Galli et al., 2007; Kitzes et al. 2006; Wackernagel et al. 2005; Monfreda et al. 2004; Wackernagel et al. 2002) before reading the Guidebook.

# 2 Structure of the NFA 2014

- 2.1 The workbook *NFA 2014* shows all steps of a national Ecological Footprint and biocapacity calculation, from raw data to the aggregate Footprint and biocapacity. The workbook contains 106 individual worksheets. Throughout the Guidebook, worksheet and table names are indicated by italics and column names or individual cells are indicated with single quotation marks ('). In the *NFA 2014* workbook, cells containing values obtained from raw data sources or calculations outside the workbook are colored light grey. The individual sources for these data points are listed in the Guidebook.

## 2.2 Worksheets in NFA 2014

The calculations in the *NFA 2014* are arranged in a hierarchy with five levels. Generally, the worksheets on each level draw on the results of lower level calculations. Level 1 contains only one worksheet, *summary*, which presents Footprint and biocapacity totals by land use type. At the bottom of the hierarchy, Level 5 worksheets contain raw data drawn from outside the *NFA 2014* workbook. The majority of Level 5 worksheets do not contain any calculations, but rather serve as data sources for calculations in higher level worksheets. The following sections provide more detailed descriptions of each worksheet level.

Worksheets are named descriptively according to their function within the Footprint and biocapacity calculation sequences. Chapters 3-9 contain full descriptions of each of the worksheets, listing calculations, data sources, dependencies, and outputs.

In addition to being divided into levels, worksheets are organized in groups which generally follow the various land use types within the Ecological Footprint. The five land use types are cropland, grazing land, fishing grounds, forest land (which serves two Footprint categories: carbon Footprint and forest products Footprint), and built-up land. Each of these six land use types has a single Level 2 worksheet, and an associated group of Level 3, 4 and 5 worksheets. In addition to the six land use types, there is a group of constants worksheets that list fundamental constants used across many worksheets. The *NFA 2014* workbook also contains a seventh Level 2 worksheet that performs the biocapacity calculations for all land use types. Figure 3-1 shows an example of this hierarchical structure for carbon.

The Guidebook uses both worksheet levels and land use types as organizational frameworks for explaining the Ecological Footprint accounting framework. The Guidebook begins with the Level 1 and 2 worksheets, providing the broadest overview of the model first. The Guidebook then proceeds through each 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.

Worksheets are color-coded to aid in understanding their groupings. This color-coding is consistent between the actual worksheet tabs in the *NFA 2014* workbook and to the figures throughout the Guidebook.

Each chapter in the 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.

Within the text of each chapter, each worksheet is described as shown in Figure 2-1 below. There is a one sentence summary of the worksheet, the level of the worksheet is identified, and the layout and supporting data and calculations are described in detail. Finally, references to other sheets are identified at the bottom.

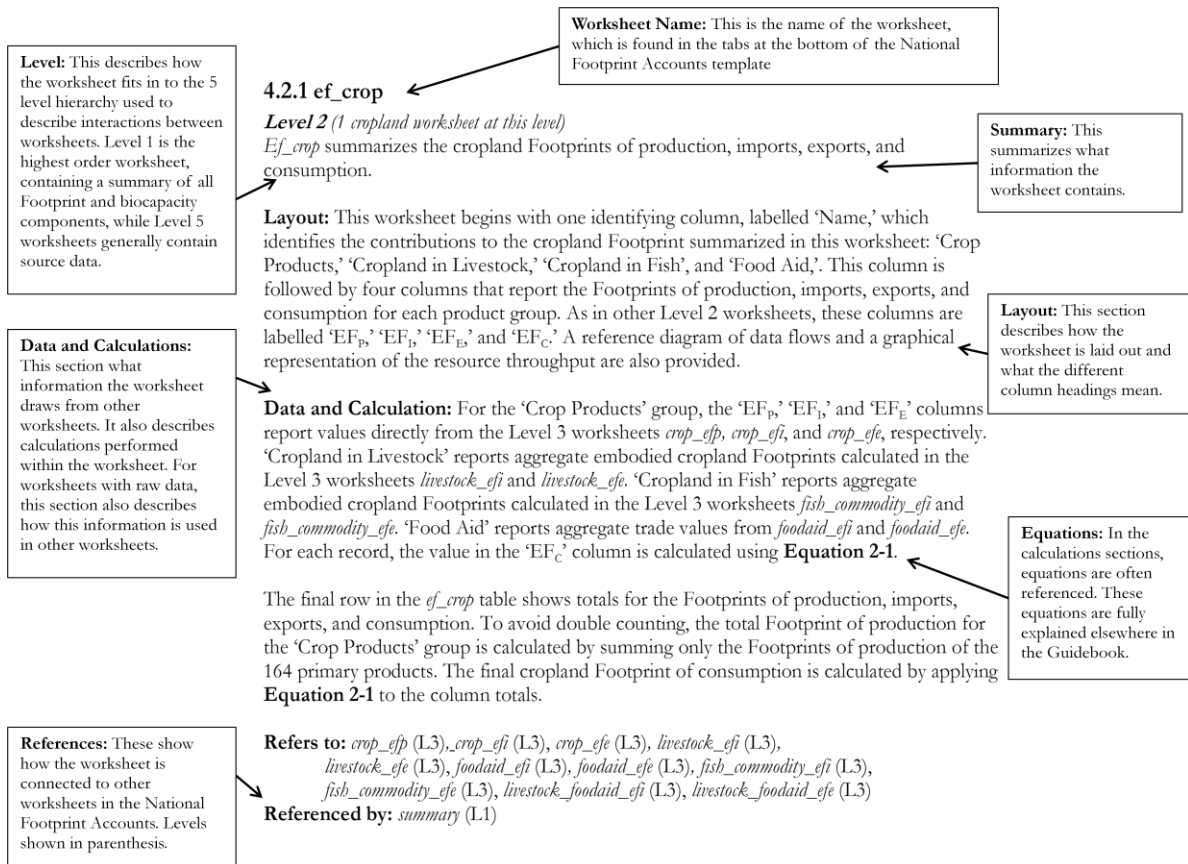


Figure 2-1: Worksheet description: this shows how worksheets are described in the Guidebook.

## 2.2.1 Level 1 Worksheets

Color: Dark Blue

There is only one Level 1 worksheet, called 'summary'. It is at the apex of the hierarchical organization of worksheets comprising *NFA 2014* and summarizes the Ecological Footprint and biocapacity calculations for the country and year displayed. The *summary* worksheet does not pertain to one particular land use type, and it is described in detail here.

### summary worksheet

#### **Level 1** (Only worksheet at this level)

The *summary* worksheet combines the calculated Ecological Footprint and biocapacity for all land use types.

**Layout:** The *summary* worksheet contains three tables and two charts. The first two tables contain rows corresponding to each 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 land use type, while the second reports a country's Footprint and biocapacity per capita.

Below these two tables there is a third, smaller table that provides a broad overview of the results of the national Ecological Footprint calculation in both total area and area per person. The first two rows report biocapacity and Footprint of production for the specific country and the world. The next row shows the net imports of the Footprint (this doesn't apply for World), and the fourth row summarizes the Footprint of

consumption. The row labelled BC - EF<sub>p</sub> shows the biocapacity minus the Ecological Footprint of production, which represents the unused domestic biocapacity. The final row, BC - EF<sub>c</sub>, only applies to the individual country and represents the net biocapacity that the country has available after accounting for the amount taken by consumption. Negative values for either two rows, conversely, indicate there is no reserve, but rather a deficit.

To the right of this table is a simple tally of the number of planets required if everyone lived like the residents of the selected country.

At the bottom of the sheet, the left chart illustrates the relative sizes of the Footprint of Production, Footprint of Consumption, Footprint of Imports, Footprint of Exports, and biocapacity. The pie chart to the right shows the relative contributions of each land type to the Footprint of Consumption.

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](mailto: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 land use type. Biocapacity for each 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. Please see Section 10 for further information.

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

The calculations in the top four rows of 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 the *world\_results* table. The final two rows are drawn from the top section of the table.

**Refers to:** *ef\_crop* (L2), *ef\_grazing* (L2), *ef\_fish* (L2), *ef\_forest* (L2), *ef\_carbon* (L2), *ef\_built* (L2), *biocap* (L2), *popstat\_n*, *world\_results*

**Referenced by:** None

### 2.2.2 Level 2 Worksheets

*Color: Blue*

The Level 2 worksheets summarize the Footprints of Production (EF<sub>p</sub>), Imports (EF<sub>i</sub>), Exports (EF<sub>e</sub>) and Consumption (EF<sub>c</sub>). There are seven worksheets in total: one worksheet for each of the six land use types; and a single worksheet for biocapacity, which calculates biocapacity for every land use type except carbon (currently assigned a biocapacity of zero; see Chapter 7). The worksheets that report the Footprints for the six land use types are named with a prefix of *ef\_*



followed by the name of the land use type. All level 2 worksheets rely on calculations from associated lower level worksheets.

- *ef\_carbon* summarizes the carbon Footprint of fossil fuel combustion (both domestically emitted and embodied in traded goods) and an additional bunker fuel carbon accounting, as well as electricity trade. For the world as a whole, this worksheet also includes an estimate of land use change, unsustainable biofuels, and cement production.
- *ef\_crop* summarizes the Footprint of cropland embodied in crop products and food aid as well as in livestock and fish products (fodder and fish food).
- *ef\_grazing* summarizes the Footprint of pasture grass embodied in livestock products.
- *ef\_fish* summarizes the Footprint of marine and inland water areas embodied in fish and other aquatic products as well as in food aid and fishmeal.
- *ef\_forest* summarizes the forest products Footprint embodied in primary and processed forest products.
- *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 land use types.

The structure of each 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 input types) that make up each land use type. The final row in each table sums the Footprints of all sub-components to calculate a total Footprint for that land use type. These totals are used in the *summary* worksheet. To the right of the aggregated table is a graphical representation of the flows of data that comprise each row, and below the table is a chart illustrating the overall resource throughput of each land type.

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

Where:

- EF<sub>C</sub> = Footprint of consumption associated with a product or waste
- EF<sub>P</sub> = Footprint of production associated with product or waste
- EF<sub>I</sub> = Footprint of imports associated with product or waste
- EF<sub>E</sub> = Footprint of exports associated with product or waste

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

The single *biocap* worksheet summarizes the biocapacity calculation for each land use type, using data on area (A), yield factors (YF), intertemporal yield factors (IYF), and equivalence factors (EQF). Below the table and the data flow graphics is a pie chart illustrating the relative composition of domestic biocapacity. The calculation of biocapacity follows **Equation 2-2**.

**Equation 2-2**  
 Calculation of Biocapacity for Single Land Use Type

$$BC = A * YF * IYF * EQF$$

Where:

- BC = Biocapacity of a given land use type, gha
- A = Area of a given land use type within a country, nha
- YF = Yield factor of a given land use type within a country, wha nha<sup>-1</sup>
- IYF = Intertemporal Yield factor of a given land use type (unitless)
- EQF = Equivalence factor for given land use type, gha wha<sup>-1</sup>.

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

### 2.2.3 Level 3 Worksheets

*Color: According to land use type*

In general, Level 3 worksheets convert tonnes of a product into the number of global hectares necessary to provide that product. Data used by Level 3 worksheets are usually drawn from Level 4 or 5 worksheets. With some caveats, Level 3, 4, and 5 worksheets hold a single table with multiple fields (columns) and records (rows). The top of each worksheet contains information such as links to the summary worksheet, and links to worksheets that reference or refer to this worksheet.

The first data 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 FAO, the Harmonized System 2002 (HS2002) or the SITC Revision 1 classification systems from the United Nations Statistical Division.

When necessary, a column labelled 'Unit' may be used to indicate the units of a record, and a column labelled 'Primary/Derived,' may be used to indicate whether the record describes a primary product or a product derived from a primary product.

Level 3 worksheets are described in more detail in the chapters associated with their respective land use types. The type of data contained in a Level 3 worksheet can be determined by its name.

Most Level 3 worksheets begin with the name of the 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).

For example, *fossil\_efp*, and *bunker\_efp* report the Footprints of production for fossil fuel carbon and bunker fuels, respectively. These two Footprints of productions are summed in the Level 2 worksheet *ef\_carbon* to obtain the total Footprint of production for the carbon Footprint.

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

$$EF_p = \frac{P}{Y_N} * YF * EQF * IYF$$

Where:

- EF<sub>p</sub> = Ecological Footprint associated with a product or waste, gha
- P = Amount of product extracted or waste generated, t yr<sup>-1</sup>
- Y<sub>N</sub> = National-average yield for product extraction or waste absorption, t nha<sup>-1</sup> yr<sup>-1</sup>
- YF = Yield factor of a given land use type within a country, wha nha<sup>-1</sup>
- EQF = Equivalence factor for given land use type, gha wha<sup>-1</sup>
- IYF = Intertemporal Yield factor of a given land use type, (unitless)

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)

$$EF_p = \frac{P}{Y_w} * EQF * IYF$$

Where:

- Y<sub>w</sub> = World-average yield for product extraction or waste absorption, t wha<sup>-1</sup> yr<sup>-1</sup>

**Equation 2-3b** reflects the actual implementation of Ecological Footprint calculations in **NFA 2014**. 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 land use type*

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

- Name of a 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 2014*, 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*).

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 grazing land, fishing grounds, forest land, and carbon Footprint (Zaks et al. 2007, [SeaAroundUs](#), [TBFRA 2000](#)). Crop yields are unique in that they are calculated as actual production divided by harvested area; thus, harvest yields and regeneration rates are taken to be identical.

A variety of secondary and tertiary products (derived products) are also included in the Ecological Footprint calculations. For any derived product, yield is calculated by multiplying the yield of the primary product ( $Y^P$ ) by the extraction rate (EXTR) of the derived product. World average extraction rates are currently used throughout *NFA 2014* to convert secondary products into their primary product equivalents. Extraction rates indicate the amount of the primary product embodied in the derived product. Yields of derived products are calculated using **Equation 2-4**.

### Equation 2-4

Calculation for Yield of Derived Products

$$Y^D = Y^P * EXTR$$

Where:

- $Y^D$  = Yield of derived product, (t derived) ha<sup>-1</sup> yr<sup>-1</sup>  
 $Y^P$  = Yield of primary product, (t primary) ha<sup>-1</sup> yr<sup>-1</sup>  
EXTR = Extraction rate, (t derived) (t primary)<sup>-1</sup>

The use of world average extraction rates overestimates the Footprint of exports for countries that produce derived products more efficiently than the world average, which in turn underestimates the Footprint of consumption. Conversely, for countries which produce derived products less efficiently than the world average, the Footprint of consumption is overestimated. Country-specific extraction rates could provide a greater level of accuracy in calculations of the Footprints of exports and consumption, but are not currently implemented. The Footprint of

production on the other hand is not affected by extraction rates, since derived 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 2014* methodology does not use full bilateral trade data.

Finally, there are few cases where multiple derived products are created simultaneously from the same primary 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 simultaneously derived products, as doing so would lead to a double-counting of the total primary product used. As a consequence, the total amount of embedded primary product is split among each simultaneously derived product through Footprint Allocation Factors (FAFs). These are estimated using the relative commercial values of the derived products to allocate the Footprint of their shared primary product between them (Borucke et al. 2012).

### 2.2.5 Level 5 Worksheets

*Color: According to 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. When the various products in a table are reported in different units, 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 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 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. They are mostly grouped with each relevant colored-tab section of land type worksheets, together with the level 3, 4, and 5 worksheets for that land type.

The names of constants worksheets generally begin with the prefix *cnst\_* followed by the name of a land use type. These worksheets contain constants that are used by Level 3 and 4 worksheets in their calculations. Those constants worksheets that are used exclusively for one component of *NFA 2014* are named with the prefix *cnst\_* followed by the corresponding 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). Only *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.
- *yf* contains intertemporal yield factors to equilibrate yields within a land use type across time.
- *bioproductive\_area* contains land area data used to calculate biocapacity.
- *const\_area\_EEZ* contains area and other data on the Exclusive Economic Zone in the oceans around each country
- *const\_area\_shelf* provides the area in km<sup>2</sup> for year 2000 of the continental shelf of every country
- *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.
- *constant\_crop\_water* contains the water content of crops
- *cnst\_crop\_feed* contains the quantity, fraction, and intensity of market feed crops, grass crops, and residues
- *constant\_ag\_extr* contains the quantities and values of agricultural extract products
- *const\_grazing\_npp* has the net primary productivity and pasture area of every country
- *constant\_feed\_region* contains the FAO feed region for every country
- *constant\_livestock\_residue* calculates the crop residue feed conversion ratio for major crops
- *constant\_livestock\_demand* contains the species-specific daily feed intake for livestock in each major region of the world
- *cnst\_fish* contains information on the amount of primary productivity in the continental shelf, a by-catch discard rate, and transfer efficiency up the food chain.
- *constant\_aquafeed\_factors* has the fish meal, fish oil, and feed intensity for aquaculture products
- *constant\_fish\_extr* reports the FAO extraction rate for fish products

- *constant\_fish\_trophic* reports the trophic level for fish species
- *constant\_forest\_extr* lists information about forest product extraction rates
- *constant\_forest\_increment* contains the net annual increment for forests in every country
- *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 national 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 the national or world population, depending on the worksheet.

**Data and Calculation:** These worksheets do not contain any calculations. Populations are reported in thousands units, and are drawn from the PopSTAT database (FAO PopSTAT Statistical Database). The data from these worksheets is accessed by the *summary* worksheet to estimate per capita values.

**Refers to:** None

**Referenced by:** *summary* (L1)

# 3 Carbon Footprint

*Color: Aquamarine*

## 3.1 Description

### 3.1.1 Overview

The carbon Footprint represents the area of forest land required to uptake anthropogenic carbon dioxide emissions. The *NFA 2014* workbook calculates the Footprint of carbon dioxide emissions using several parameters including domestic fossil fuel combustion and electricity use, embodied carbon in traded items and electricity, 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 footprint intensity of carbon which in turn is a conversion factor derived using factors representing the yield of the productive land that is required to absorb the carbon dioxide emissions, the carbon absorbed in the oceans, an equivalence factor for carbon as a land type and an adjustment factor for temporal changes in yield from the forest.

The International Energy Agency (IEA) tracks various countries' carbon dioxide emissions from fossil fuel combustion across 45 different economic sectors. These data are used in *NFA 2014* 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 in the form of International Aviation bunker fuel and International Marine bunker fuels which are aggregated to "bunker fuel." These emissions are allocated to countries according to their respective domestic fossil fuel combustion by the proportion of national to world imports. Emissions other than those from fossil fuels are only included in the world total carbon Footprint.



### 3.1.2 Data Sources

Data	Worksheet	Data Source
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 <sub>2</sub> Emissions. In Trends: A Compendium of Data on Global Change. Oak Ridge, TN: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory and U.S. Department of Energy.
Emissions from fossil fuels, by country and economic sector	<i>iea_fossil_n</i>	IEA CO <sub>2</sub> Emissions from Fuel Combustion Database. 2010. <a href="http://wds.iea.org/wds/">http://wds.iea.org/wds/</a> (accessed 2013).
International trade quantities by commodity	<i>comtrade_n</i>	UN Commodity Trade Statistics Database. <a href="http://comtrade.un.org/">http://comtrade.un.org/</a> (accessed 2013).
Carbon sequestration factor; Ocean Uptake Fraction;	<i>cnst_carbon</i>	IPCC. 2006. <i>2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture Forestry and Other Land Use</i> . <a href="http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html">http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html</a> (accessed 2013). S. Khatiwala Univ. of Columbia (email correspondence)
Carbon intensity of total primary energy supply	<i>cnst_carbon</i>	Estimates based on data from IEA CO <sub>2</sub> Emissions from Fuel Combustion Database. 2013. <a href="http://wds.iea.org/wds/">http://wds.iea.org/wds/</a> (accessed 2013).
National and regional electricity carbon intensity values	<i>cnst_carbon</i>	International Energy Agency. 2010. Key World Energy Statistics. Paris: International Energy Agency (accessed 2013).
International trade in electricity	<i>electricity_trade</i>	International Energy Agency. 2010. Key World Energy Statistics. Paris: International Energy Agency (accessed 2013).
Embodied energy of traded commodities	<i>carbon_efi(for imports), carbon_efe(for exports)</i>	Global Footprint Network internal database, available upon request. Database compiled using data from Hammond and Jones (2008), Thormark (2002), Interfacultaire Vakgroep Energie en Milieukunde Energy Analysis Program (IVEM 1999), and a collection of LCA data from the Stockholm Environment Institute at York University.

Emissions from gas flaring and sources other than fossil fuels	<i>other_co2_eff</i>	<a href="#">International Energy Agency</a> . 2010. CO2 Emissions from Fuel Combustion. (accessed 2013).
Emissions from International Transport Bunker Fuels	<i>bunker_eff</i> (calculated in MySQL)	IEA International Aviation Bunkers and International Marine Bunkers
Ocean sequestration	<i>cnst_carbon</i>	<p>Khatiwala, S., Primeau, F., Hall, T. 2009. Reconstruction of the history of anthropogenic CO<sub>2</sub> concentrations in the ocean. <i>Nature</i> 462, 346-350.</p> <p>Denman, K. L. et al. in <i>Climate Change 2007 — The Physical Science Basis</i> (eds Solomon, S. et al.) 499–587 (Cambridge Univ. Press, 2007).</p>

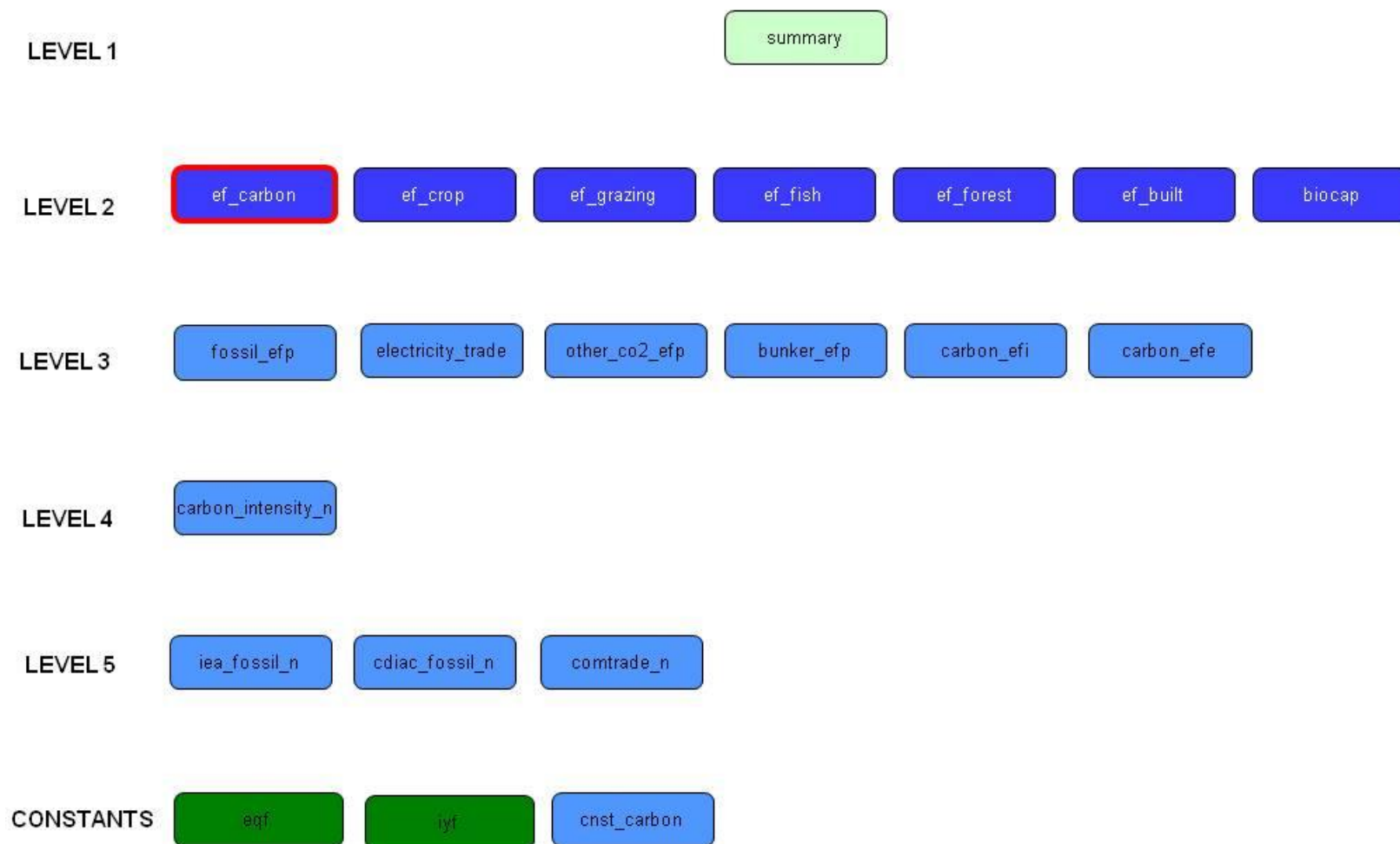
**Table 1. Worksheets and Data Sources for Carbon Footprint**

### 3.1.3 Notes

- Unlike elsewhere in *NFA 2014*, 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 energy figures by the world average carbon intensity for primary energy production in case of imports and carbon intensity derived from Domestic Total Primary Energy Supply as calculated in the NFA template in case of exports.
- 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 2014* are world averages.
- Embodied carbon emissions in traded electricity are calculated by multiplying the traded amount by either the average carbon intensity of the region from where electricity is imported (for imports) or the weighted average of production and imports intensities (for exports).
- 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. This is represented by the section on Bunker Fuel

where International Transport Emissions data (which itself the sum of International Aviation Bunker Fuel and International Marine Bunker Fuel data from IEA) is aggregated for all countries and re-allocated to individual countries by the proportion of global trade in tonnes as calculated from UN Comtrade.

- **NFA 2014** 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, estimated by the IPCC 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 (for example, we do not know which country receives the Footprint of the carbon released when Amazonian forest is cleared).



**Figure 3-1**

*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, from non fossil fuel sources, and traded electricity.

## 3.2 Worksheets

Figure 3-1 shows the relations between the worksheets in the carbon Footprint section of *NFA 2014*.

The carbon Footprint section of *NFA 2014* is summarized in the Level 2 worksheet. *ef\_carbon* is where the summary worksheet gets its data. All lower level carbon worksheets are colored aquamarine. The carbon section of *NFA 2014* contains six Level 3 worksheets viz. *fossil\_efp*, *electricity\_trade*, *other\_co2\_efp*, *bunker\_efp*, *carbon\_efi*, *carbon\_efe*, where amount of carbon emitted for every activity is converted to their respective gha value, one Level 4 worksheet *carbon\_intensity\_n*, which contains intensity factors, three Level 5 worksheets viz. *comtrade\_n*, *iea\_fossil\_n*, *cdiac\_fossil\_n*, which contain national values as derived from datasets and one Constants worksheet ie. *cnst\_carbon*. The structure and function of each of these worksheets is described below.

### 3.2.1 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,’ ‘Other Sources,’ ‘Traded Electricity,’ 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 2014*, these are labelled (‘EF<sub>p</sub>’), (‘EF<sub>I</sub>’), (‘EF<sub>E</sub>’) and (‘EF<sub>C</sub>’), respectively.

Note that – aside from electricity trade - 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<sub>I</sub>’ and ‘EF<sub>E</sub>’ columns, while ‘Traded Electricity’ only includes import, export, and consumption values. ‘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<sub>p</sub>,’ ‘EF<sub>I</sub>,’ and ‘EF<sub>E</sub>’ columns report values aggregated from the Level 3 worksheets *fossil\_efp*, *carbon\_efi*, and *carbon\_efe*, respectively. The ‘EF<sub>C</sub>’ column for this category is calculated according to **Equation 2-1**. The two categories ‘Other Sources’ and ‘Bunker Fuel’ do not involve traded commodities so that ‘EF<sub>C</sub>’ is equal to ‘EF<sub>p</sub>’ for each. The ‘Traded Electricity’ category contains only ‘EF<sub>I</sub>,’ and ‘EF<sub>E</sub>,’ values, and these are used in the final ‘Total’ row calculation.

When calculating the global total carbon Footprint, the ‘Other Sources’ category draws its ‘EF<sub>p</sub>’ value from the Level 3 worksheet *other\_CO2\_efp*. For individual countries, the Footprint of production for this category is set to zero. While ideally non-fossil fuel emissions contained in the ‘Other Sources’ category 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<sub>p</sub>' value from the Level 3 worksheet *bunker\_efp*, 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.

The 'Traded Electricity' category draws its 'EF<sub>I</sub>' and 'EF<sub>E</sub>' values from the Level 3 worksheet *electricity\_trade*, accounting for the emissions embodied in traded electricity.

**Refers to:** *fossil\_efp* (L3), *bunker\_efp* (L3), *carbon\_efi* (L3), *electricity\_trade* (L3), *carbon\_efe* (L3), *other\_CO2\_efp* (L3)

**Referenced by:** *summary* (L1)

### 3.2.2 fossil\_efp

**Level 3** (6 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 labelled 'Production' and 'Yield' for consistency with other parallel level 3 sheets in **NFA 2014**. However, in the carbon Footprint section these show emissions and world average carbon uptake per hectare, respectively. The next column is labelled 'EQF' and contains the equivalence factor for forest land. Next, 'YF' lists the intertemporal yield factor which is given the value of 1 for all commodities. Finally, the column labelled 'EF<sub>p</sub>' calculates the carbon Footprint of emissions from each of the 45 sectors and sector summaries.

**Data and Calculation:** 'Production' for the 'CO<sub>2</sub> Sectoral Approach' is drawn from *iea\_fossil\_n* or *cdiac\_fossil\_n*, depending on data availability for the country (IEA CO<sub>2</sub> 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 'YF' column provides the intertemporal yield factors. The 'EF<sub>p</sub>' column is calculated according to **Equation 2-3**.

Total CO<sub>2</sub> production (emissions) is reported in the first record (row), named 'CO<sub>2</sub> Sectoral Approach'. This datum is used to calculate the fossil fuel Footprint of production, which is then used in *ef\_carbon*.

**Refers to:** *iea\_fossil\_n* (L5), *cnst\_carbon*, *eqf*, *cdiac\_fossil\_n* (L5), *iyf*  
**Referenced by:** *ef\_carbon* (L2), *carbon\_intensity\_n* (L4)

### 3.2.3 bunker\_efp

**Level 3** (6 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:** The aggregation to calculate total bunker fuels is done outside of the NFA template in the internal Global Footprint Network database where International Aviation Bunker Fuels and International Marine Bunker Fuels are added for every country and then re-allocated. This addition, known as the bunker fuel Footprint of production, is calculated in the last row of the table, named 'Bunker EF'

The bunker fuels addition is calculated by multiplying the fossil fuel Footprint of production - drawn from *cnst\_carbon* - 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 anthropogenic carbon dioxide emissions.

**Refers to:** *cnst\_carbon* (Constants)

**Referenced by:** *ef\_carbon* (L2)

### 3.2.4 other\_CO2\_efp

**Level 3** (6 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, 'Unit' 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 (International Energy Agency CO<sub>2</sub> 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 scientifically robust method 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:** *cnst\_carbon* (Constants)

**Referenced by:** *ef\_carbon* (L2)



### 3.2.5 carbon\_efi

**Level 3** (6 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 'SITC-1 Code,' which provide a descriptive name and the United Nations SITC rev.1 code for identifying commodities, respectively, for each product category.

The third column, 'Imports,' gives the total imported quantity for each product category. This is followed by a column labelled 'EmbEn,' which lists the average embodied energy per tonne of each product group. The 'Energy<sub>I</sub>' 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 labelled 'EF<sub>I</sub>,' and calculates the embodied Footprint of imports for each of the 625 categories of traded goods.

**Data and Calculation:** 'Imports' is drawn directly from *comtrade\_n*. The values in 'EmbEn' column are drawn from a supporting Global Footprint Network database (see Table 1). 'Energy<sub>I</sub>' is calculated by multiplying 'Imports' 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 primary energy production. This is reflected in the column 'ImportsCO2' where CO2 emissions are calculated by multiplying 'Energy<sub>I</sub>' by a constant drawn from *cnst\_carbon*: 'World Primary Energy Carbon Intensity.' 'EF<sub>I</sub>' is then calculated by multiplying 'ImportsCO2' by the Footprint intensity of carbon, drawn from *cnst\_carbon*.

The last row in *carbon\_efi* sums the Footprint 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* (Constants)

**Referenced by:** *ef\_carbon* (L2), *carbon\_intensity\_n* (L4)

### 3.2.6 carbon\_efe

**Level 3** (6 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 'SITC-1 Code,' which provide a descriptive name and the SITC rev.1 code, respectively, for each product category.

The third column, 'Exports,' gives the total imported quantity for each product category. This is followed by a column labelled '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 'Energy<sub>I</sub>' column calculates the total embodied energy in the exported goods. The next column, 'ExportsCO2,' then converts this energy amount into equivalent carbon dioxide emissions. The final column is labelled 'EF<sub>E</sub>' and calculates the embodied Footprint of imports for each of the 625 categories of traded goods.

**Data and Calculation:** ‘Exports’ is drawn directly from *comtrade\_n*. The values in ‘EmbEn’ are The values in ‘EmbEn’ column are drawn from a supporting Global Footprint Network database (see Table 1). ‘Energy<sub>E</sub>’ is calculated by multiplying ‘Exports’ by ‘EmbEn’ for each traded good.

The carbon emissions associated with internationally traded items are calculated based on the global average carbon intensity for primary energy production. ‘ExportsCO2’ is calculated by multiplying ‘EF<sub>I</sub>’ by the carbon intensity value of exports drawn from the *carbon\_intensity\_n* worksheet. ‘EF<sub>E</sub>’ is then calculated by multiplying ‘ExportsCO2’ by the Footprint intensity of carbon, drawn from *cnst\_carbon*.

The last row in *carbon\_efe* sums ‘EF<sub>E</sub>’ 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* (Constants), *carbon\_intensity\_n* (L4)

**Referenced by:** *ef\_carbon* (L2)

### 3.2.7 electricity\_trade

**Level 3** (6 carbon worksheets at this level)

The *electricity\_trade* worksheet calculates the footprint of Imported and Exported Electricity.

**Layout:** The *electricity\_trade* worksheet begins with the column ‘Name’. The second column is ‘Energy’ for which the data come from Comtrade “Electric Energy” S1-3510, IEA, and CDIAC; the third column is ‘CO2 Energy Intensity’; the fourth is ‘Emissions’ and the fifth column is the ‘Footprint’. The Electricity Production row does not have an associated footprint calculated in *electricity\_trade*, but the Energy and Emissions categories for Electricity Production are used in the calculation of Emissions of Electricity Exports. This latter characteristic is due to an update in the methodology.

**Data and Calculation:** The ‘Footprint’ for Electricity Exports and Imports is calculated as the product of Emissions and the Footprint Intensity of Carbon converted to appropriate units. The Emissions of Electricity Imports is calculated as the product of the ‘Energy’ column and a Regional Electricity Carbon Intensity factor obtained from the *cnst\_carbon* worksheet. However, the Emissions of ‘Electricity Exports’ are a product of the ‘Energy’ of Electricity Exports and the ratio of the sum of Imported and Produced Emissions over the sum of Imported and Produced Energy. The ratio is the national carbon intensity for electricity [Mt CO<sub>2</sub>/GWh].

**Refers to:** *cnst\_carbon* (Constants)

**Referenced by:** *ef\_carbon* (L2)

### 3.2.8 carbon\_intensity\_n

**Level 4** (1 carbon worksheet at this level)

The *carbon\_intensity\_n* worksheet calculates carbon intensity at the national level.

**Layout:** The *carbon\_intensity\_n* worksheet begins with the column ‘Name’. The next column ‘Energy’ contains the energy in Gigajoules of each row.

‘Carbon Intensity’ is the amount in tonnes of CO<sub>2</sub> per gigajoule of energy produced. ‘Total Emissions’ is the final column and reflects the total amount of CO<sub>2</sub> emitted per year. Total Emissions for Exports is not calculated because no export data is available. The only value in the worksheet referred to by other worksheets is ‘Carbon Intensity of Exports’.

**Data and Calculation:** The calculation for the Carbon Intensity for Exports (cell C9) is the ratio of the sum of the Total Emissions of Imports and Domestic TPES and the sum of the Energy of Imports and Domestic TPES. The ‘Energy’ column for both Imports and Exports is calculated as the sum of the energies of all commodities in the ‘carbon\_efi’ and ‘carbon\_efe’ worksheets, respectively. The ‘Energy’ column of Domestic TPES is reported as the total primary energy supply for a nation, or if that is not reported, it’s calculated as the ratio between Total Emissions and CO<sub>2</sub> Energy Intensity. The ‘Total Emissions’ for Imports is the product of ‘Energy’ and ‘Carbon Intensity’, and the ‘Total Emissions’ for Domestic TPES is the total sum of Production in the ‘CO<sub>2</sub> Sectoral Approach’.

**Refers to:** *carbon\_efe* (L3), *carbon\_efi* (L3), *fossil\_efp* (L3), *cnst\_carbon* (Constants)

**Referenced by:** *carbon\_efe* (L3)

### 3.2.9 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 ‘SITC-1 Code,’ which give a descriptive name and the SITC rev. 1 code, respectively, for each product category. The following two columns, ‘Imports’ and ‘Exports,’ 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). The worksheet *comtrade\_n* contains no calculations.

**Refers to:** None

**Referenced by:** *carbon\_efi* (L3), *carbon\_efe* (L3)

### 3.2.10 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 CO<sub>2</sub> Emissions from Fossil Fuel Combustion Database).

**Layout:** This worksheet consists of two columns, labelled ‘Name’ and ‘Production-CO<sub>2</sub>.’ 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-CO<sub>2</sub>’ gives the CO<sub>2</sub> emissions for each listed sector, drawn directly from the IEA (IEA CO<sub>2</sub> Emissions from Fossil Fuel Combustion Database). Like most Level 5 worksheets, *iea\_fossil\_n* contains no calculations.

**Refers to:** None

**Referenced by:** *fossil\_eff* (L3)

### 3.2.11 *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 (CDIAC) (Marland et al. 2007). The data in 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-CO<sub>2</sub>.'

**Data and Calculation:** 'Production-C' is drawn from a CDIAC study (Marland et al. 2007). 'Production-CO<sub>2</sub>' is calculated by dividing 'Production-C' by the constant ratio of carbon to carbon dioxide (drawn from *cnst\_carbon*) and converting units from kilo tonnes to mega-tonnes.

**Refers to:** *cnst\_carbon* (Constants)

**Referenced by:** *fossil\_eff* (L3)

### 3.2.12 *cnst\_carbon*

**Constants** (*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 records, 'C to CO<sub>2</sub> Ratio' contains a simple unit conversion.

'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).

'Ocean Uptake Fraction' reflects the percentage of global fossil fuel carbon emissions that are sequestered by oceans. Currently, the calculation is performed outside of the template. 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.

'National Electricity Carbon Intensity', 'Regional Electricity Carbon Intensity', and 'World Primary Energy Carbon Intensity' are taken directly from International Energy Agency (IEA CO<sub>2</sub> 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:** *eqf* (Constants)

**Referenced by:** *fossil\_eff* (L3), *other\_CO2\_eff* (L3), *carbon\_efi* (L3), *carbon\_efe* (L3),  
*carbon\_intensity\_n* (L4), *cdiac\_fossil\_n* (L4), *electricity\_trade* (L3), *bunker\_eff* (L3)

## 4 Cropland Footprint

Color: Light Orange

### 4.1 Description

#### 4.1.1 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 cropped grasses 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 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 2014** workbook tracks the production of 164 categories of agricultural products. The 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 February 2010 (FAO ProdSTAT Statistical Database). The tradestat worksheet contains 570 for the **NFA 2014 Edition**.

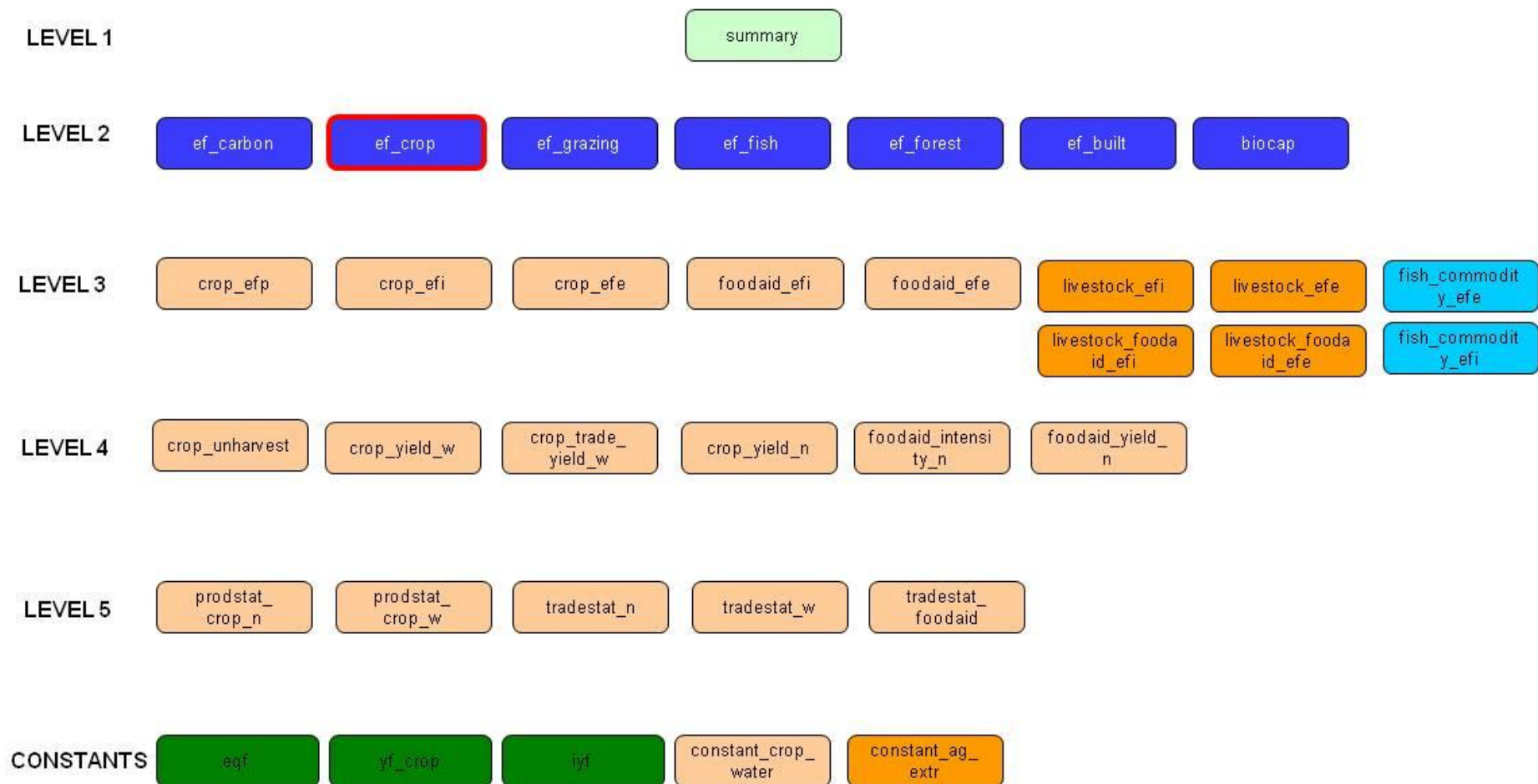
#### 4.1.2 Data Sources

Data	Worksheet	Data Source
Production (tonnes yr <sup>-1</sup> ) and area (ha)	<i>prodstat_crop_w</i> , <i>prodstat_crop_n</i>	FAO ProdSTAT Statistical Database. <a href="http://faostat.fao.org/site/526/default.aspx">http://faostat.fao.org/site/526/default.aspx</a> (accessed 2013).
Imports and exports (1000 t yr <sup>-1</sup> )	<i>tradestat_n</i> <i>tradestat_foodaid</i>	FAO TradeSTAT Statistical Databases. <a href="http://faostat.fao.org/site/406/default.aspx">http://faostat.fao.org/site/406/default.aspx</a> (accessed 2013).
Technical conversion factors for derived agricultural products	<i>extraction rate calculation in cnst_ag_extr</i>	FAO Technical Conversion Factors for Agricultural Commodities (v beta 1.g). <a href="http://www.fao.org/es/ess/tcf.asp">http://www.fao.org/es/ess/tcf.asp</a> (accessed 2013)
Agricultural commodity prices	<i>extraction rate calculations in cnst_ag_extr</i>	FAO TradeSTAT Statistical Database
Water content of crops (%)	<i>cnst_crop_water</i>	Fridolin Krausmann, IFF, Wien, Austria (personal communication)

#### 4.1.3 Notes

- FAOSTAT codes in the cropland section of **NFA 2014** are based on both the HS2002 classification and the FAO HS+ classification.

- The products included in the cropland Footprint calculation include crops used for direct human 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\_unharvest* 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 2014*** includes a subsection on livestock trade, which accounts for both the embodied cropland and grazing land Footprints in traded livestock products and food aid.





**Figure 4-1** *Cropland Footprint calculations*. In addition to the three Level 3 worksheets (*\_efp*, *\_efi*, and *\_efe*), the cropland section includes a worksheet *crop\_unharvest* that calculates a “tax” intended to account for unharvested cropland. The four Level 3 sheets in the livestock trade section of *NFA 2014* contain calculations of the cropland Footprint embodied in traded livestock and derived livestock products. Unlike those for the other 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.

## 4.2 Worksheets

**Figure 4-1** 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 2014** workbook uses seven Level 3 worksheets (two of which are from the grazing land section), six Level 4, five Level 5 worksheets and one Constants level worksheet. The two Level 3 worksheets in the livestock trade section, which include traded crop products embodied in livestock, are colored yellow. All other worksheets in the cropland section of the **NFA 2014** workbook are colored light orange. The structure and function of each of these worksheets is described below.

### 4.2.1 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, labelled ‘Name,’ which identifies the contributions to the cropland Footprint summarized in this worksheet: ‘Crop Products,’ ‘Cropland in Livestock,’ ‘Cropland in Fish,’ and ‘Food Aid.’. 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 labelled ‘EF<sub>P</sub>,’ ‘EF<sub>I</sub>,’ ‘EF<sub>E</sub>,’ and ‘EF<sub>C</sub>.’ A reference diagram of data flows and a graphical representation of the resource throughput are also provided.

**Data and Calculation:** For the ‘Crop Products’ group, the ‘EF<sub>P</sub>,’ ‘EF<sub>I</sub>,’ and ‘EF<sub>E</sub>,’ columns report values directly from the Level 3 worksheets *crop\_efp*, *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*. ‘Cropland in Fish’ reports aggregate embodied cropland Footprints calculated in the Level 3 worksheets *fish\_commodity\_efi* and *fish\_commodity\_efe*. ‘Food Aid’ reports aggregate trade values from *foodaid\_efi* and *foodaid\_efe*. For each record, the value in the ‘EF<sub>C</sub>,’ 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 the 164 primary products. The final cropland Footprint of consumption is calculated by applying **Equation 2-1** to the column totals.

**Refers to:** *crop\_efp* (L3), *crop\_efi* (L3), *crop\_efe* (L3), *livestock\_efi* (L3),  
*livestock\_efe* (L3), *foodaid\_efi* (L3), *foodaid\_efe* (L3), *fish\_commodity\_efi* (L3),  
*fish\_commodity\_efe* (L3), *livestock\_foodaid\_efi* (L3), *livestock\_foodaid\_efe* (L3)

**Referenced by:** *summary* (L1)

### 4.2.2 crop\_efp

**Level 3** (5 cropland worksheets at this level)

*crop\_efp* calculates the Footprint of production of 164 crop products.

**Layout:** *crop\_eff* begins with three identifying columns, 'Name,' 'FAO Code,' and 'HS+ Code.' These report the name, the FAOSTAT classification code, and HS+ classification code. The next two columns, labelled 'Production' and 'Yield,' show the production quantities and yields for domestically produced goods. The 'EQF' column provides the equivalence factor for cropland. The 'YF' column provides the intertemporal yield factors. The final column, labelled 'EF<sub>p</sub>,' uses the values in the preceding four columns to calculate the Footprint of productions for each crop included in this worksheet.

**Data and Calculation:** 'Production' is drawn from *prodstat\_crop\_n*. 'Yield' is drawn from *crop\_yield\_w*. 'EQF' is drawn from the *eqf* worksheet. 'YF' is drawn from the *yif* worksheet. The 'EF<sub>p</sub>,' column is calculated according to **Equation 2-3b**.

**Refers to:** *prodstat\_crop\_n* (L5), *crop\_yield\_w* (L4), *eqf* (Constants), *yif* (Constants)

**Referenced by:** *ef\_crop* (L2), *grass\_supply\_n* (L4), *yf\_crop* (Constants)

### 4.2.3 crop\_efi

**Level 3** (5 cropland worksheets at this level)

*crop\_efi* calculates the Footprint of imports for 413 agricultural products.

**Layout:** *Crop\_efi* begins with three identifying columns, 'Name,' 'FAO Code,' and 'HS+ Code.' The next two columns, labelled 'Imports' and 'Yield,' show import quantities and world-average yields for imported products. The 'EQF' column gives the equivalence factor for cropland. The 'YF' column gives the intertemporal yield factor. The final column, labelled 'EF<sub>i</sub>,' uses the values in the preceding four columns to calculate the Footprint of imports for each product. Note that the list in this worksheet contains a large number of derived agricultural goods, and is not identical to that in the *crop\_eff* worksheet.

**Data and Calculation:** 'Imports' 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 2014**. 'EQF' is drawn from the *eqf* worksheet. 'YF' is drawn from the *yif* worksheet. The 'EF<sub>i</sub>' column is calculated by applying **Equation 2-3b**.

**Refers to:** *tradedstat\_n* (L5), *crop\_trade\_yield\_w* (L4), *eqf* (Constants), *yif* (Constants)

**Referenced by:** *ef\_crop* (L2)

### 4.2.4 crop\_efe

**Level 3** (5 cropland worksheets at this level)

*crop\_efe* calculates the Footprint of exports of 413 agricultural products.

**Layout:** *Crop\_efe* begins with three identifying columns, 'Name,' 'FAO Code,' and 'HS+ Code.' The next two columns, labelled 'Exports' and 'Yield,' show export quantities and world-average yields for imported products. The 'EQF' column gives the equivalence factor for cropland. The 'YF' column gives the intertemporal yield factor. The final column, labelled 'EF<sub>E</sub>,' uses the values in the preceding four 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 2014*. ‘EQF’ is drawn from the *eqf* worksheet. The ‘EF<sub>E</sub>’ column is calculated by applying **Equation 2-3b**.

**Refers to:** *tradedstat\_n* (L5), *crop\_trade\_yield\_w* (L4), *eqf* (Constants), *iyf* (Constants)

**Referenced by:** *ef\_crop* (L2)

#### 4.2.5 *foodaid\_efi*

**Level 3** (*5 cropland worksheets at this level*)

*Foodaid\_efi* calculates the Footprint of imports of 16 agricultural products. Data was obtained from FAOSTAT website which in turn obtains data from [World Food Programme](#) website.

**Layout:** *Foodaid\_efi* begins with two identifying columns, ‘Aggregate Name’ and ‘FAO Code.’ These report the food type name and the FAOSTAT classification code. The next two columns, labelled ‘Imports’ and ‘Intensity,’ show import quantities and world-average yields for imported products. The final column, labelled ‘EF<sub>I</sub>,’ uses the values in the preceding two columns to calculate the Footprint of imports for each aggregate name.

**Data and Calculation:** ‘Imports’ is drawn from the *tradedstat\_foodaid* worksheet. ‘Intensity’ is drawn from *foodaid\_intensity\_n* as world-average intensities are used for all imports and exports in the cropland section of *NFA 2014*. The ‘EF<sub>I</sub>’ column is calculated by applying **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values.

**Refers to:** *foodaid\_intensity\_n* (L4), *tradedstat\_foodaid* (L5)

**Referenced by:** *ef\_crop* (L2)

#### 4.2.6 *foodaid\_efe*

**Level 3** (*5 cropland worksheets at this level*)

*Foodaid\_efe* calculates the Footprint of exports of 16 agricultural products. Data was obtained from FAOSTAT website which in turn obtains data from [World Food Programme](#) website.

**Layout:** *Foodaid\_efe* begins with two identifying columns, ‘Aggregate Name’ and ‘FAO Code.’ These report the food type name and the FAOSTAT classification code. The next two columns, labelled ‘Exports’ and ‘Intensity,’ show import quantities and world-average yields for exported products. The final column, labelled ‘EF<sub>E</sub>,’ uses the values in the preceding two columns to calculate the Footprint of exports for each aggregate name.

**Data and Calculation:** ‘Exports’ is drawn from the *tradedstat\_foodaid* worksheet. ‘Intensity’ is drawn from *foodaid\_intensity\_n* which takes the figures from *crop\_trade\_yield\_w* as world-average intensities are used for all imports and exports in the cropland section of *NFA 2014*. The ‘EF<sub>E</sub>’ column is calculated by applying **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values.

**Refers to:** *foodaid\_intensity\_n* (L4), *tradedstat\_foodaid* (L5)

**Referenced by:** *ef\_crop* (L2)

#### 4.2.7 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 2014** that are used in calculating the cropland Footprint. It provides a cropland Footprint of imports for 157 categories of livestock and derived livestock products.

**Refers to:** *livestock\_intensity\_w* (L4), *tradedstat\_n* (L5), *cnst\_grazing* (Constants)

**Referenced by:** *ef\_crop* (L2), *ef\_grazing* (L2), *livestock\_intensity\_n\_crop* (L4), *livestock\_intensity\_n\_grazing* (L4), *livestock\_intensity\_n\_fish* (L4), *ef\_fish* (L2)

See section 5.3.2 for full worksheet description.

#### 4.2.8 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 2014** that are used in calculating the cropland Footprint. It provides a cropland Footprint of exports for 157 categories of livestock and derived livestock products.

**Refers to:** *livestock\_intensity\_n\_crop* (L4), *livestock\_intensity\_n\_grazing* (L4), *livestock\_intensity\_n\_fish* (L4), *tradedstat\_n* (L5), *cnst\_grazing* (Constants), *constant\_ag\_extr* (Constants),

**Referenced by:** *ef\_crop* (L2), *ef\_grazing* (L2), *ef\_fish* (L2)

See section 5.3.2 for a full worksheet description.

#### 4.2.9 crop\_unharvest

**Level 4** (6 cropland worksheets at this level)

*Crop\_unharvest* calculates the Footprint of unharvested cropland.

**Layout:** *Crop\_unharvest* begins with two identifying columns, 'Name' and 'Unit,' followed by three columns, 'EF<sub>p</sub>', 'EF<sub>i</sub>' and 'EF<sub>e</sub>' which represent the Footprint of unharvested cropland for production, imports, and exports respectively.

**Data and Calculation:** Values in the columns 'EF<sub>p</sub>' and 'EF<sub>i</sub>' reference the total cropland Footprint calculated in the 'Crop Products', 'Cropland in Livestock' and 'Food Aid' rows in the *ef\_crop* worksheet. A national 'unharvested tax %' is used 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). This is a change from

previous editions. The tax is now no longer reported in *ef\_crop* and added to the other items, but rather embedded into the calculation of the crop YF.

Values in the column 'EF<sub>E</sub>' are calculated in the same way as the preceding two columns, but the 'Unharvested Percentage' is calculated as a weighted average of the 'EF<sub>P</sub>' and 'EF<sub>I</sub>' values.

**Refers to:** *ef\_crop* (L2)

**Referenced by:** *yf\_crop* (Constants), *crop\_yield\_n* (L4), *crop\_yield\_w* (L4)

#### 4.2.10 *foodaid\_intensity\_n*

**Level 4** (6 cropland worksheets at this level)

*Foodaid\_intensity\_n* calculates the weighted Footprint intensity of the 16 product aggregates tracked by FAOSTAT as food aid.

**Layout:** *Foodaid\_intensity\_n* begins with two identifying columns, 'Aggregate Name' and 'FAO Code'. These report the crop aggregate name, and the FAOSTAT aggregate classification code. The next column, 'Exports', shows the total volume exported of 65 agricultural products which the template then aggregates into 16 categories based on aggregation codes from FAOSTAT. The next column, 'EF<sub>E</sub>', reports the Footprint of exports of the aggregated categories. The final two columns, 'Imports Intensity' and 'Exports Intensity' report the weighted Footprint intensities for the aggregated categories' imports and exports.

**Data and Calculation:** Values in the 'Exports' and 'EF<sub>E</sub>' columns are drawn from the *foodaid\_yield\_n* worksheet and are comprised of the sums of the individual elements in each aggregated category. Values in the 'Imports Intensity' and 'Exports Intensity' columns are calculated as the import (or export) Footprint divided by the import (or export) volume.

**Refers to:** *foodaid\_yield\_n* (L4), *crop\_trade\_yield\_w* (L4)

**Referenced by:** *foodaid\_efi* (L3), *foodaid\_efe* (L3)

#### 4.2.11 *foodaid\_yield\_n*

**Level 4** (6 cropland worksheets at this level)

*Foodaid\_yield\_n* calculates the Footprint of imports and exports of the 65 products that comprise the aggregate categories tracked by FAOSTAT as food aid.

**Layout:** *Foodaid\_yield\_n* begins with three identifying columns, 'Name,' 'FAO Code,' and 'Aggregate Code.' These report the name, the FAOSTAT classification code, and the FAOSTAT aggregate classification code. The next two columns, 'Imports' and 'Exports' show the total volume imported and exported of 65 agricultural products. The next column, 'Yield', reports the world-average yield for each product. The final two columns, 'EF<sub>I</sub>' and 'EF<sub>E</sub>' calculate the Footprint of imports and exports respectively.

**Data and Calculation:** Values in the 'Imports' and 'Exports' columns are drawn from the *tradedstat\_n* worksheet. Values in the 'Yield' column are drawn from the *crop\_trade\_yield\_w* worksheet. The values in the 'EF<sub>I</sub>' and 'EF<sub>E</sub>' columns are calculated as in equation 2.3b.

**Refers to:** *crop\_trade\_yield\_w* (L4), *tradedstat\_n* (L5), *eqf* (Constants)

**Referenced by:** *foodaid\_intensity\_n* (L5)

#### 4.2.12 crop\_trade\_yield\_w

**Level 4** (6 cropland worksheets at this level).

*Crop\_trade\_yield\_w* calculates world-average yields for the 413 agricultural products tracked in the trade Footprint calculations.

**Layout:** The first seven columns identify traded goods, as well as any corresponding primary products. The next column, 'Extr,' lists extraction rates for derived products. 'Import' lists the quantity imported in tonnes. Finally, 'Yield' calculates the world-average yield per hectare for each agricultural commodity listed.

**Data and Calculation:** This worksheet uses extraction rates to calculate all yields in units of world average cropland. 'Extr' values are drawn directly from the *constant\_ag\_extr* worksheet.

For derived products, 'Yield' is calculated by multiplying the yield of the appropriate primary product by the derived product's extraction rate (for primary products the extraction rate is set to be 1). The extraction rates used here are the same world averages used in the *crop\_yield\_w* and *crop\_yield\_n* worksheets.

**Refers to:** *crop\_yield\_w* (L4), *constant\_ag\_extr* (L5), *tradedstat\_w* (L5)

**Referenced by:** *crop\_efe* (L3), *crop\_efi* (L3), *foodaid\_yield\_n* (L4), *foodaid\_intensity\_n* (L4), *grass\_supply\_n* (L4), *market\_feed\_supply\_n* (L5)

#### 4.2.13 crop\_yield\_n

**Level 4** (6 cropland worksheets at this level)

*Crop\_yield\_n* calculates the national-average yield of the 164 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:** *Crop\_yield\_n* begins with three identifying columns, 'Name,' 'FAO Code,' and 'HS+ Code.' These report the name, the FAOSTAT classification code, and HS+ classification code. The next two columns, 'Production' and 'Area,' show national production for all 164 agricultural products and the total area devoted to cultivating each, respectively. The final column, 'Yield,' calculates the national-average yield for each product.

**Data and Calculation:** Values in the 'Production' and 'Area' columns are drawn from the *prodstat\_crop\_n* worksheet. Yield is equal to the domestic annual production divided by the harvested area.

**Refers to:** *prodstat\_crop\_n* (L5), *crop\_unharvest* (L4)

**Referenced by:** *yf\_crop* (Constants)

#### 4.2.14 crop\_yield\_w

**Level 4** (6 cropland worksheets at this level)

*Crop\_yield\_w* calculates the world-average yields of the 164 agricultural products that are considered in the calculation of a country's cropland Footprint of production.

**Layout:** *Crop\_yield\_w* begins with three identifying columns, ‘Name,’ ‘FAO Code,’ and ‘HS+ Code.’ These report the name, the FAOSTAT classification code, and HS+ classification code. The next two columns, ‘Production’ and ‘Area,’ show world production for all 164 agricultural products and the total area devoted to cultivating each, respectively. The next 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. Yield is equal to the world annual production divided by the harvested area.

**Refers to:** *prodstat\_crop\_w* (L5), *crop\_unharvest* (L4)

**Referenced by:** *crop\_eff* (L3), *crop\_trade\_yield\_w* (L4), *yf\_crop* (Constants), *feed\_intensity\_w* (L4), *fish\_feed\_group\_yield\_w* (L4)

#### 4.2.15 prodstat\_crop\_n

**Level 5** (5 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:** *Prodstat\_crop\_n* begins with three identifying columns, ‘Name,’ ‘FAO Code,’ and ‘HS+ Code.’ These are the same as the first three columns in the *crop\_eff* worksheet. 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\_n* 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 164 crops products.

The production quantities from this worksheet are also used in two worksheets in the grazing land section of **NFA 2014**. The *grass\_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), *grass\_supply\_n* (L4), *residue\_supply\_n* (L4)

#### 4.2.16 prodstat\_crop\_w

**Level 5** (5 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:** *Prodstat\_crop\_w* begins with three identifying columns, ‘Name,’ ‘FAO Code,’ and ‘HS+ Code.’ These are the same as the first three columns in the *crop\_eff* worksheet. The next columns, ‘Area’ and ‘Production’ report the global area cultivated and the world harvest, respectively, for each agricultural product.



**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* worksheet to calculate world-average yields for various agricultural goods.

**Refers to:** None

**Referenced by:** *crop\_yield\_w* (L4)

#### 4.2.17 tradestat\_n

**Level 5** (5 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 'FAO Code,' identical to those in the *crop\_efi* and *crop\_efe* worksheets. These identifying columns are followed by two columns, 'Imports' and 'Exports' 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 2014*, *tradestat\_n* is used by the *crop\_efi* and *crop\_efe* worksheets to calculate a country's embodied Footprint of trade. The *tradestat\_n* worksheet is also used in calculating the embodied grazing land Footprint in livestock products as explained in section 4.2.11.

**Refers to:** None

**Referenced by:** *crop\_efi* (L3), *crop\_efe* (L3), *foodaid\_yield\_n* (L4), *grass\_supply\_n* (L4), *livestock\_efi* (L3), *livestock\_efe* (L3), *livestock\_foodaid\_intensity\_n* (L4)

#### 4.2.18 tradestat\_w

**Level 5** (5 cropland worksheets at this level)

The *tradestat\_w* worksheet reports the imports and exports of all agricultural products traded from the world overall. 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 'FAO Code,' identical to those in the *crop\_efi* and *crop\_efe* worksheets and another column 'Aggregate Code'. These identifying columns are followed by two columns, 'Imports' and 'Exports' showing the imported and exported quantities for each of the traded products, respectively.

**Data and Calculation:** The *tradestat\_w* 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 2014*, *tradestat\_w* is used by the *crop\_efi* and *crop\_efe* worksheets to calculate a country's embodied Footprint of trade. The *tradestat\_w* worksheet is also used in calculating world-average yields for the agricultural products tracked in the trade Footprint calculations as explained in section 4.2.12.

**Refers to:** None

**Referenced by:** *livestock\_foodaid\_intensity\_n* (L4), *foodaid\_yield\_n* (L4), *crop\_trade\_yield\_w* (L4)

#### 4.2.19 tradestat\_foodaid

**Level 5** (5 cropland worksheets at this level)

*Tradestat\_foodaid* reports the imported and exported volume of agricultural product aggregates traded as food aid.

**Layout:** This worksheet begins with two identifying columns, 'Name' and 'FAO Code,' identical to those in the *crop\_efi* and *crop\_efe* worksheets. These identifying columns are followed by two columns, 'Imports' and 'Exports' showing the imported and exported quantities (as food aid) for each of the traded product aggregates, respectively.

**Data and Calculation:** The *tradestat\_foodaid* 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 2014**, *tradestat\_foodaid* is used by the *foodaid\_efi* and *foodaid\_efe* worksheets to calculate a country's Footprint embodied Footprint of trade in food aid.

**Refers to:** None

**Referenced by:** *foodaid\_efi* (L3), *foodaid\_efe* (L3), *livestock\_foodaid\_efi* (L3), *livestock\_foodaid\_efe* (L3), *fooadaid\_fish* (L3)

#### 4.2.20 constant\_crop\_water

**Constants** (1 cropland worksheets at this level)

*constant\_crop\_water* reports the water content of each of 176 crops.

**Layout:** *constant\_crop\_water* begins with two identifying columns, 'Item' and 'Code'. These report the name and FAOSTAT classification code. The next column, 'Water content', lists the percentage of each product that is water.

**Data and Calculations:** Values for 'Water content' are from Fridolin Krausmann, IFF, Wien, Austria. As this is a constants worksheet, no calculations are performed.

**Refers to:** None

**Referenced by:** *residue\_supply\_n* (L4)

# 5 Grazing Land Footprint

Color: Yellow

## 5.1 Description

### 5.1.1 Overview

The grazing land Footprint assesses demand for grazing land to feed livestock, as well as the embodied demand for grazing land in traded goods. This is the most logically complex section of *NFA 2014*. The calculations estimate 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 2014* relies 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 partially 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 5.2) and Livestock Trade (section 5.3). The first of these describes all worksheets containing calculations or data pertaining solely to the grazing land Footprint. The second describes 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.

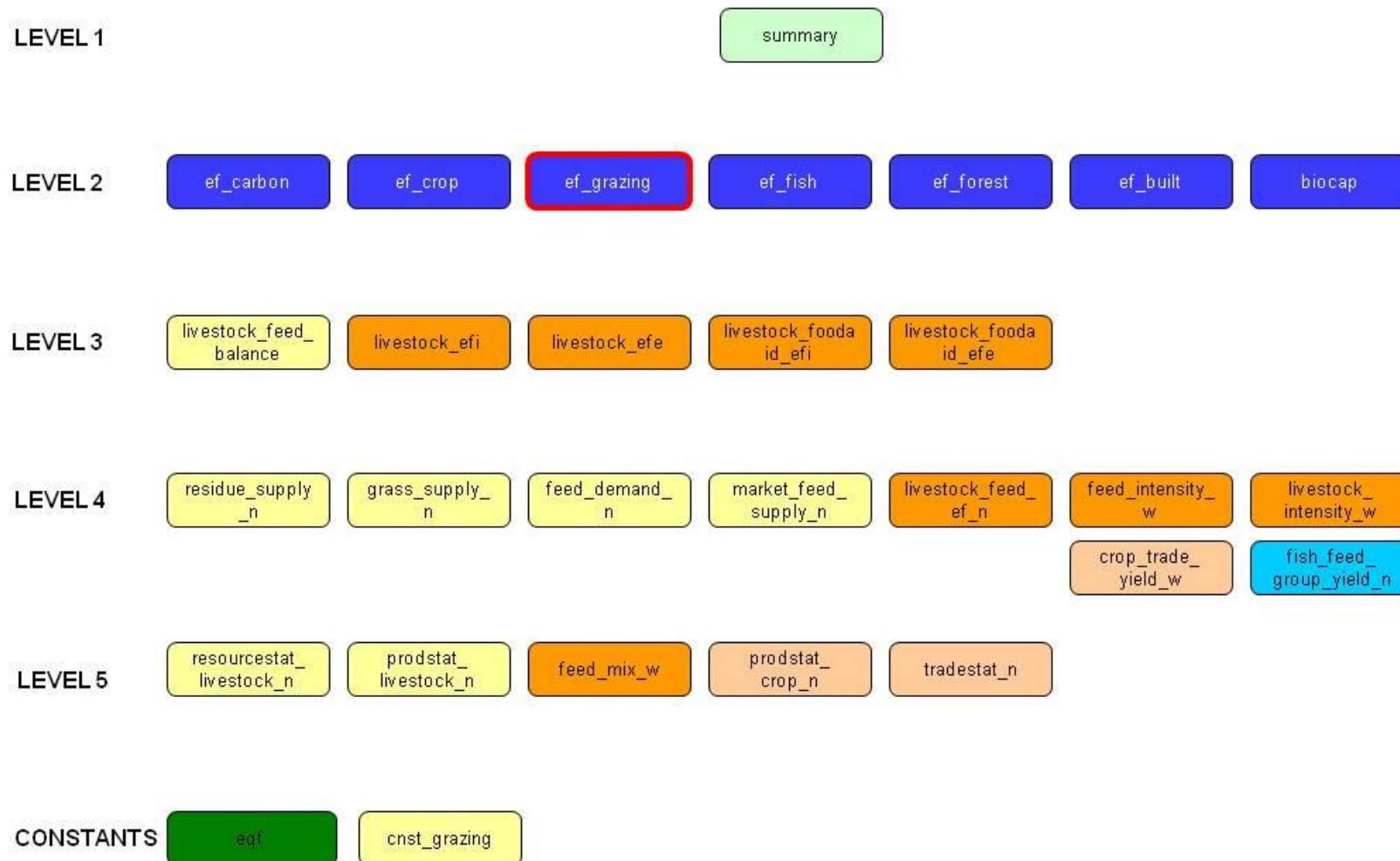
### 5.1.2 Data Sources

Data	Worksheet	Data Source
Production quantities of livestock products, and livestock populations (tonnes year <sup>-1</sup> or heads or 1000 heads)	<i>prodstat_livestock_n</i> uses for the production data. <i>Resourcestat_n</i> uses this to assess stocks of livestock that are supported but not harvested yearly.	FAO ProdSTAT Statistical Database. <a href="http://faostat.fao.org/site/452/default.aspx">http://faostat.fao.org/site/452/default.aspx</a> (accessed 2013).
Imports and exports of livestock (1000 tonnes year <sup>-1</sup> )	<i>tradestat_n</i>	FAO TradeSTAT Statistical Databases. <a href="http://faostat.fao.org/site/406/default.aspx">http://faostat.fao.org/site/406/default.aspx</a> (accessed 2013).
Feed Intake (kg dry matter head <sup>-1</sup> )	<i>feed_demand_n</i>	Haberl, H., K.H. Erb, F. Krausmann, V. Gaube, A. Bondeau, C. Plutzer, S. Gingrich, W. Lucht and M.

day <sup>-1</sup> ) and Feed Demand (tonnes dry matter year <sup>-1</sup> )		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) <sup>-1</sup> )	<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.
Animal weights (tonnes head <sup>-1</sup> )	<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. <a href="http://faostat.fao.org/site/348/default.aspx">http://faostat.fao.org/site/348/default.aspx</a> (accessed 2013).
Imports and exports of livestock as food aid (1000 tonnes year <sup>-1</sup> )	<i>tradedstat_n</i>	FAO TradeSTAT Statistical Databases. <a href="http://faostat.fao.org/site/406/default.aspx">http://faostat.fao.org/site/406/default.aspx</a> (accessed 2013).

### 5.1.3 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. Reflecting this fact, 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 5-1**

*Diagram for Grazing land Footprint calculations.* 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.

## 5.2 Worksheets

**Figure 5-1** 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 2014* workbook contains one Level 2 worksheet, *ef\_grazing*, one Level 3 worksheet, four Level 4 worksheets, two Level 5 worksheets, and one Constants level worksheet. In addition, the grazing land Footprint calculation draws data from three sheets in the cropland section of *NFA 2014*, one at Level 3 and two at Level 5. The grazing land worksheets are colored light yellow in the *NFA 2014* workbook and in the Guidebook. The structure and function of each of these worksheets is described below.

### 5.2.1 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 embodied 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 labelled ‘EF<sub>P</sub>’, ‘EF<sub>I</sub>’, ‘EF<sub>E</sub>’ and ‘EF<sub>C</sub>.’ A reference diagram of data flows and a graphical representation of the resource throughput are also provided.

**Data and Calculation:** The ‘EF<sub>P</sub>’, ‘EF<sub>I</sub>’, and ‘EF<sub>E</sub>’ columns report values directly from the Level 3 worksheets *livestock\_feed\_balance* into ‘Domestic Grazing Land’, *livestock\_efi*, *livestock\_efe*, *livestock\_foodaid\_efi* and *livestock\_foodaid\_efe* into ‘Grazing Land in Livestock.’ The ‘EF<sub>C</sub>’ 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:** *livestock\_feed\_balance* (L3), *livestock\_efi* (L3), *livestock\_efe* (L3), *livestock\_foodaid\_efi* (L3), *livestock\_foodaid\_efe* (L3)

**Referenced by:** *summary* (L1)

### 5.2.2 livestock\_feed\_balance

*Level 3 (Only grazing land worksheet at this level)*

*livestock\_feed\_balance* calculates the total Pasture Grass Demand needed to feed livestock nationally.

**Layout:** *livestock\_feed\_balance* begins with one identifying column, 'Name,' which identifies categories of feed supply and demand. The next column labelled 'Quantity' is the quantity of each category (Market Feed, Residue Feed, Cropped Grass Feed) in tonnes/year. The next three columns contain the footprint in global hectares of the land-use types 'Crop', 'Grazing', and 'Fish', respectively. The two rows below row 'Total' show the grass demanded for feed, and the grass actually used for feed.

**Data and Calculation:** The *NFA 2014* assumes that livestock are fed with available crop-derived feeds and then, if necessary, with grass from grazing lands, calculated with data derived from the *feed\_demand\_n* and *livestock\_feed\_balance\_n* worksheets.

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 – the multiplication of the Footprint intensity of grass from '*feed\_intensity\_w*' with the demand for pasture grass – takes place in the 'EF Grazing' column in the 'Remaining Demand' row cell D12.

This cell compares the available biocapacity and the calculated Ecological Footprint of production for grazing land and returns the minimum of the two. This is done because, as noted earlier, the Footprint of grazing land is not allowed to exceed available biocapacity.

**Refers to:** *residue\_supply\_n* (L4), *grass\_supply\_n* (L4), *feed\_demand\_n* (L4),  
*market\_feed\_supply\_n* (L5), *feed\_intensity\_w* (L4), *biocap* (L2)

**Referenced by:** *livestock\_feed\_ef\_n* (L4), *ef\_grazing* (L2)

### 5.2.3 *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:** *Feed\_demand\_n* begins with three identifying columns, 'Name', 'FAO Code,' and 'HS+ Code'. These represent the names, FAOSTAT, and HS+ codes for each of the 15 types of livestock tracked. The next column, 'Feed Name' represents the aggregate category each type of livestock is in.

The next column, 'Heads,' show the number of livestock produced, while the next two columns, 'Feed Intake' and 'Feed Demand' represent the needs for feed per animal per day, and the total feed needed for each type of livestock respectively. The next six columns: '% Grass Feed', 'Crop and Fish Feed Demand', 'Grass Feed Demand', 'Expected Crop', 'Expected Grass', and 'Expected Fish', represent the quantity of crop, fish, and grass needed for each type of livestock and the expected amount of feed to come from grass, fish and crop products. The final three columns represent the Ecological Footprint necessary to produce each type of livestock, for cropland, fishing grounds, and grazing land respectively.

**Data and Calculation:** Values in 'Heads' are drawn from *resourvestat\_livestock*. Values in 'Feed Intake' come from *constant\_livestock\_demand*. The next column, 'Feed Demand,' calculates the total demand for feed of each considered livestock group by multiplying 'Heads' by 'Feed Intake' and converting from kg/day to tonnes/year. Values in '% Grass



Feed' are drawn from *feed\_mix\_w*, and the values in 'Expected Crop', 'Expected Grass', and 'Expected Fish' are calculated by multiplying 'Feed Demand' by values in '%Crop', '%Grass' and '%Fish' drawn from *feed\_mix\_w* worksheet. The next column, 'Expected Crop EF,' is calculated by multiplying 'Expected Crop' by the weighted average Footprint intensity of the crops consumed by that livestock class (from *livestock\_intensity\_w*), and dividing by the total feed requirement per tonne of live weight for the livestock class (from *feed\_mix\_w*). 'Expected EF Fish' is calculated similarly, but using 'Expected Fish' in place of 'Expected Crop'. 'Expected EF Grazing,' is calculated by multiplying the 'Expected Grass' values by the Footprint intensity of grass production (from *feed\_intensity\_w*).

**Refers to:** *resourcestat\_livestock* (L5), *feed\_mix\_w* (L5), *livestock\_intensity\_w* (L4), *feed\_intensity\_w* (L4), *residue\_supply\_n* (L4), *constant\_livestock\_demand* (Constants)

**Referenced by:** *livestock\_feed\_ef\_n* (L4), *livestock\_feed\_balance* (L3)

### 5.2.4 market\_feed\_supply\_n

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

*Market\_feed\_supply\_n* calculates the Footprint of various domestic crop harvests used as animal feed.

**Layout:** This worksheet begins with two identifying columns, 'Feed Name,' and 'FAO Code,' reporting the ProdSTAT names and codes for each crop product potentially used for feed. The list of products reported in 'Feed Name' excludes products counted in the *grass\_supply\_n* worksheet. The third column, 'Feed Amount,' shows the national production of each crop used as animal feed. This is followed by three 'EF' columns, which report the crop, grazing, and fish Footprints associated with each crop product.

**Data and Calculation:** 'Feed Amount' is drawn from FAOStat 'EF's are calculated as in **Equation 2.3b**, using values from the *crop\_trade\_yield\_w* and *eqf* worksheets

**Refers to:** *crop\_trade\_yield\_w* (L4), *livestock\_intensity\_w* (L4), *iyf* (Constants), *fish\_capture\_yield* (L4), *eqf* (Constants)

**Referenced by:** *livestock\_feed\_balance* (L3)

### 5.2.5 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 three identifying columns, 'Name,' 'FAO Code,' and 'HS+ Code'. These report the ProdSTAT names and codes for each type of grass used for feed. The fourth column, 'Production,' shows the harvested quantities of each of the grass crops, in tonnes of dry matter. The two following columns, 'Imports' and 'Exports,' show the traded quantities of these grass products. The next column, labelled 'Available,' shows the total amount of cropped grass fed to livestock, and the final column, 'EF,' shows the Footprint associated with each type of cropped grass.

**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 *livestock\_feed\_balance\_n* worksheet to determine the amount livestock feed demand that is met with cropped grass.

Domestic cropped grass production is drawn from the *prodstat\_crop\_n* worksheet. 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 similar to **Equation 2-1**. This quantity is then divided by the global average yield for the specific grass type and the equivalence factor for cropland to give the Ecological Footprint associated with each.

**Refers to:** *prodstat\_crop\_n* (L5), *tradedstat\_n* (L5), *crop\_trade\_yield\_w* (L4), *crop\_efp* (L3), *eqf* (Constants)

**Referenced by:** *livestock\_feed\_balance* (L4)

### 5.2.6 residue\_supply\_n

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

The *residue\_supply\_n* worksheet shows the national supply of crop residues used as livestock feed.

**Layout:** This worksheet begins with three identifying columns, ‘Crop Name,’ ‘FAO Code,’ and ‘HS+ Code,’ reporting the ProdSTAT names and codes of each crop producing residues potentially used as feed.

The fourth 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. (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), *constant\_livestock\_residue* (Constants), *constant\_feed\_region* (Constants), *constant\_crop\_water* (Constants)

**Referenced by:** *livestock\_feed\_balance* (L4), *feed\_demand\_n* (L4)

### 5.2.7 prodstat\_livestock\_n

**Level 5** (2 grazing land worksheets at this level)

*Prodstat\_livestock\_n* reports the production numbers and product yield for 41 livestock products.

**Layout:** This worksheet begins with three identifying columns, ‘Name,’ ‘FAO Code,’ and ‘HS+ Code,’ reporting the ProdSTAT names and codes for each livestock based product. The remaining columns report the production weight, number of animals, and the weight of product per animal.

**Data and Calculation:** The data are all drawn from ProdSTAT and are used in the *livestock\_intensity* series of worksheets. No calculations are performed.

**Refers to:** None

**Referenced by:** *livestock\_intensity\_n\_grazing* (L4), *livestock\_intensity\_n\_crop* (L4), *livestock\_intensity\_n\_fish* (L4)

### 5.2.8 *resourcestat\_livestock\_n*

**Level 5** (2 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 three identifying columns, 'Name,' 'FAO Code,' and 'HS+ 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). *resourcestat\_livestock\_n* 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), *livestock\_intensity\_n\_grazing* (L4), *livestock\_intensity\_n\_fish* (L4), *livestock\_intensity\_n\_crop* (L4)

### 5.2.9 *cnst\_grazing*

**Constant** (1 grazing land worksheets at this level)

This worksheet contains constant values for weight per head of various grazing animals.

**Layout:** The first column 'Name' lists the grazing animals grouped first by world average weights, and second grouped by national average weights. The second column, 'Unit', contains the units—tonnes per head—for each value. The third column contains the values for weight per head of each grazing animal. The first row refers to above-ground NPP percent and the second row refers to edible above-ground NPP percent whereas the rows below the third refer to national and world average weight of individual livestock species.

**Data and Calculation:** The worksheet does not perform any calculations. The data for 'Value' come from ProdSTAT.

**Refers to:** None

**Referenced by:** *feed\_intensity\_w* (L4), *livestock\_efi* (L3), *livestock\_efe* (L3), *livestock\_intensity\_n\_fish* (L4), *livestock\_intensity\_n\_crop* (L4), *livestock\_intensity\_n\_grazing* (L4), *livestock\_foodaid\_intensity* (L4)

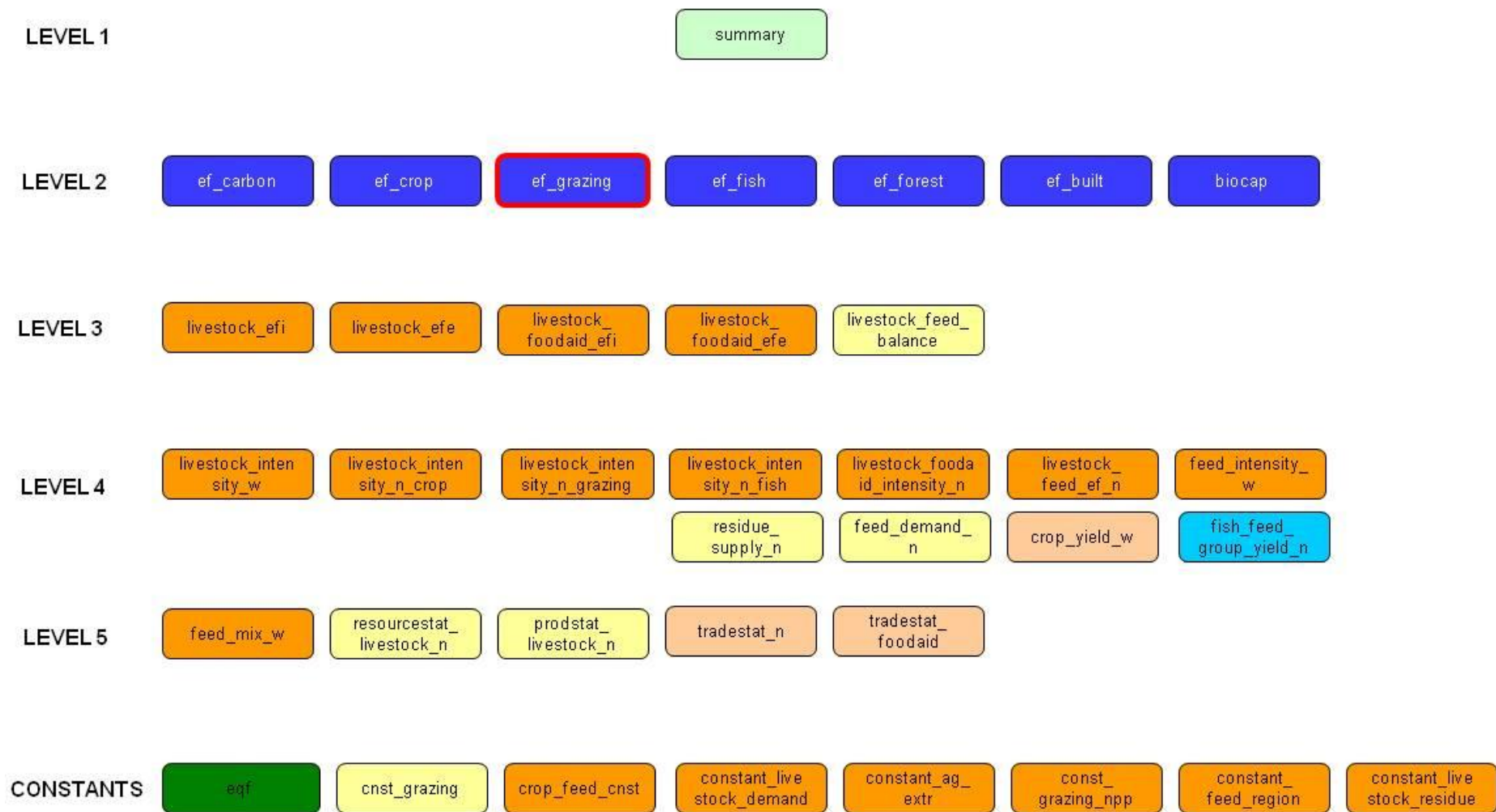
### 5.3 Worksheets: Livestock Trade

Color: Dark Orange

The livestock trade section of **NFA 2014** 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 5.1 for a detailed explanation). The livestock trade section contains four Level 3 worksheets, nine Level 4 worksheets and one Level 5 worksheet.

Figure 5-2 shows all of the worksheets involved in the calculation of the livestock trade section. Two worksheets from the cropland section of **NFA 2014** (*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 2014** workbook and the Guidebook. The structure and function of each of these worksheets is described below.

Data	Worksheet	Data Source
Extraction rates	<i>livestock_intensit_y_w</i> , <i>feed_intensity_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.
World Quantity of Feed Types	<i>crop_feed_cnst</i>	
Technical Conversion Factor	<i>cnst_ag_extr</i>	FAO Technical Conversion Factors documentation. June 2011.
Pasture NPP, Pasture Area	<i>cnst_grazing_npp</i>	Zaks, D. et al 2007. From Miami to Madison: Investigating the relationship between climate and terrestrial net primary production. <i>Global Biogeochem Cycles</i> , 21.
Crop Residue Feed Conversion Ratio, Species-specific daily feed intake	<i>cnst_livestock_residue</i> , <i>cnst_livestock_demand</i>	Haberl et al 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. <i>PNAS</i> , 104:31, 12942-12947.



**Figure 5-2**

*Diagram for Livestock Trade Footprint calculations.* 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.

### 5.3.1 livestock\_efi

**Level 3** (4 livestock trade worksheets at this level)

*livestock\_efi* calculates the Footprints of imports of 157 livestock and animal products.

**Layout:** This worksheet begins with four identifying columns. The ‘Product Name’, ‘FAO Code’, ‘HS+ Code’, and ‘Aggregate Code’ columns report the TradeSTAT names and codes for each of the 157 products. ‘Live Weight’ reports the weight in tonnes per head of each product name by referring to *cnst\_grazing*. The sixth column, ‘Imports’, shows the imported amount of each of the 157 products. This column is followed by a summary column, labelled ‘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 *tradestat\_n* worksheet. For a few products, *tradestat\_n* worksheet provides data in units of heads rather than tonnes. In this case, animal weights in the ‘Live Weight’ column 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 ‘Imports’ column) by the corresponding Footprint intensity value drawn from the *livestock\_intensity\_w* worksheet (see section 5.3.6). ‘Total’ is calculated by summing the Footprints of the various feed sources into one embodied Footprint value.

The embodied Footprint of grass production (Grass column) is added to the total grazing land Footprint. The ‘Fish Meal’ column is used in the calculation of *ef\_fish*, *livestock\_intensity\_n\_grazing*, and *livestock\_intensity\_n\_fish*. The ‘Other Concentrate Feed’ column is not implemented in **NFA 2014**, and contains zeroes for all records.

**Refers to:** *livestock\_intensity\_w* (LA), *tradestat\_n* (L5), *cnst\_grazing* (Constants)

**Referenced by:** *ef\_crop* (L2), *ef\_grazing* (L2), *livestock\_intensity\_n\_crop* (LA), *livestock\_intensity\_n\_grazing* (LA), *livestock\_intensity\_n\_fish* (LA), *ef\_fish* (L2)

### 5.3.2 livestock\_efe

**Level 3** (4 livestock trade worksheets at this level)

*livestock\_efe* calculates the Footprint of exports of 157 livestock and animal products.

**Layout:** This worksheet begins with seven identifying columns. The ‘Product Name’, ‘FAO Code’, ‘HS+ Code’, ‘Aggregate Code’, ‘Primary/Derived’, ‘Parent Product’, and ‘Parent Code’ columns report the TradeSTAT names and codes for each of the 157 products. ‘Live Weight’ reports the weight in tonnes per head of each product name. ‘Extr’ reports the extraction ratio for derived products. The tenth column, ‘Exports,’ shows the exported amount of each of the 157 products. Subsequent columns calculate the Footprint of various feed types contributing to the exported animal products.

**Data and Calculation:** Export quantities are drawn from the *tradestat\_n* worksheet. For a few products, the *tradestat\_n* worksheet provides data in units of heads rather than tonnes. In these cases, animal weights in the ‘Live Weight’ column 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 5.3.6). '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. The 'Fish Meal' column is used in the calculation of *ef\_fish*, *livestock\_intensity\_n\_grazing*, and *livestock\_intensity\_n\_fish*. All other embodied Footprint values are cropland Footprints, since this is the origin of the various feeds listed.

**Refers to:** *tradedstat\_n* (L5), *livestock\_intensity\_n\_crop* (L4), *livestock\_intensity\_n\_grazing* (L4), *livestock\_intensity\_n\_fish* (L4), *constant\_ag\_extr* (Constants), *cnst\_grazing* (Constants)

**Referenced by:** *ef\_crop* (L2), *ef\_grazing* (L2), *ef\_fish* (L2)

### 5.3.3 livestock\_foodaid\_efi

**Level 3** (4 livestock trade worksheets at this level)

**Layout:** The first column is 'Product Name'. The second is 'FAO Code'. The third column, 'Imports', has data from *tradedstat\_foodaid*. The fourth, fifth, and sixth columns are labelled 'Crop Efi', 'Grazing Efi', and 'Fish Efi', respectively.

**Data and Calculation:** The 'Imports' column obtains imported quantities of foodaid from the *tradedstat\_foodaid* worksheet. The last three columns all obtain food intensities for each respective land-type from *livestock\_foodaid\_intensity\_n*. This intensity is multiplied by the imported quantity to calculate the footprint in other worksheets.

**Refers to:** *tradedstat\_foodaid* (L5), *livestock\_foodaid\_intensity\_n* (L4)

**Referenced by:** *ef\_crop* (L2), *ef\_fish* (L2), *ef\_grazing* (L2)

### 5.3.4 livestock\_foodaid\_efe

**Level 3** (4 livestock trade worksheets at this level)

**Layout:** The first column is 'Product Name'. The second is 'FAO Code'. The third column, 'Exports', has data from *tradedstat\_foodaid*. The fourth, fifth, and sixth columns are labelled 'Crop Efe', 'Grazing Efe', and 'Fish Efe', respectively.

**Data and Calculation:** The 'Exports' column obtains exported quantities of foodaid from the *tradedstat\_foodaid* worksheet. The last three columns all obtain food intensities for each respective land-type from *livestock\_foodaid\_intensity\_n*. This intensity is multiplied by the exported quantity to calculate the footprint in other worksheets.

**Refers to:** *tradedstat\_foodaid* (L5), *livestock\_foodaid\_intensity\_n* (L4)

**Referenced by:** *ef\_crop* (L2), *ef\_fish* (L2), *ef\_grazing* (L2)

### 5.3.5 livestock\_foodaid\_intensity\_n

**Level 4** (7 livestock trade worksheets at this level)

**Layout:** The first column is 'Product Name'. The second column is the associated FAO Code' and the third is 'Aggregate Code' (values if applicable). The columns 'World Total Imports' and 'National Exports' list the amount in metric tonnes of Product. The next three columns are 'Crop Intensity', 'Grazing Intensity', and 'Fish Intensity', which calculate the respective land-use intensities of each product.



**Data and Calculation:** The Intensities are calculated by dividing the footprint by the quantity.

**Refers to:** *tradedstat\_n* (L5), *tradedstat\_w* (L5), *livestock\_intensity\_w* (L4), *cnst\_grazing* (Constants)

**Referenced by:** *livestock\_foodaid\_efi* (L3), *livestock\_foodaid\_efe* (L3)

### 5.3.6 *livestock\_intensity\_w*

**Level 4** (7 *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 2014**.

**Layout:** This worksheet begins with six identifying columns. The ‘Product Name’, ‘FAO Code’, and ‘HS+ Code’ columns report the ProdSTAT names and codes for each animal product and ‘Primary/Derived’ indicates whether a record refers to a primary or derived product. The fifth and sixth columns, ‘Parent Product’ and ‘Parent Code,’ show the ProdSTAT name and code of the corresponding product’s parent product. These six identifying columns are followed by a column labelled ‘Extr,’ which shows the extraction rate for each derived product. As elsewhere in **NFA 2014**, extraction rates convert derived 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. ‘Intensity Crop’ and ‘Intensity Grazing’ have this Footprint intensity disaggregated between cropland and grazing land. These columns are 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 5.3.11) with the feed mix values drawn from the *feed\_mix\_n* worksheet (see section 5.3.12).

*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 5.3.1 and 5.3.2). 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\_w* (L5), *constant\_ag\_extr* (Constants)

**Referenced by:** *feed\_demand\_n* (L4), *livestock\_efi* (L3), *livestock\_efe* (L3), *livestock\_intensity\_n\_crop* (L4), *livestock\_intensity\_n\_grazing* (L4), *livestock\_intensity\_n\_fish* (L4), *livestock\_foodaid\_intensity\_n* (L4), *market\_feed\_supply\_n* (L4)

### 5.3.7 *livestock\_intensity\_n\_crop*

**Level 4** (7 *livestock worksheets at this level*)

The *livestock\_intensity\_n\_crop* worksheet calculates the crop-based Footprint intensity of exports for each livestock category.

**Layout:** This worksheet begins with four identifying columns. The ‘Name’, ‘FAO Code’ and ‘HS+ Code’ columns report the ProdSTAT names and codes for each livestock

product category. The ‘Parent Product’ column lists the parent product from which each product is derived. The next two columns, ‘Production / Stock’ and ‘Embodied EF’ report the domestic production quantity of each product and the crop-based Ecological Footprint embodied in the production, respectively. The next two columns, ‘Imports’ and ‘Imports EF’ report the imported quantity of each product and the crop-based Ecological Footprint embodied in these imports, respectively. The final column, ‘Exports Intensity’, calculates the Ecological Footprint embodied in exported livestock products per unit of production.

**Data and Calculation:** The domestic production quantities for live animals are calculated by multiplying the number of each animal produced from the *resourcestat\_livestock\_n* worksheet by the weight per head from the *cnst\_grazing* worksheet, or the values are drawn from the *prodstat\_livestock\_n* worksheet. The ‘Embodied EF’ column is calculated by multiplying the quantity produced by the crop feed intensity from the *livestock\_intensity\_w* worksheet and adjusted by the relative feed intensity from the *livestock\_feed\_ef\_n* worksheet.

The imported quantity of each product is drawn from the *livestock\_efi* worksheet, as is the ‘Imports EF’ column. The ‘Exports Intensity’ column is then calculated by taking the sum of Embodied Footprint and Imports Footprint and dividing by the sum of the domestic production quantity and imports.

**Refers to:** *livestock\_efi* (L3), *livestock\_intensity\_w* (L4), *livestock\_feed\_ef\_n* (L4), *resourcestat\_livestock\_n* (L5), *prodstat\_livestock\_n* (L5), *cnst\_grazing* (Constants)

**Referenced by:** *livestock\_efe* (L3)

### 5.3.8 livestock\_intensity\_n\_grazing

**Level 4** (7 livestock trade worksheets at this level)

The *livestock\_intensity\_n\_grazing* worksheet calculates the grazing-based Footprint intensity of exports for each livestock category.

**Layout:** This worksheet begins with four identifying columns. The ‘Name’, ‘FAO Code’ and ‘HS+ Code’ columns report the ProdSTAT names and codes for each livestock product category. The ‘Parent Product’ column lists the parent product from which each product is derived. The next two columns, ‘Production / Stock’ and ‘Embodied EF’ report the domestic production quantity of each product and the grazing-based Ecological Footprint embodied in the production, respectively. The next two columns, ‘Imports’ and ‘Imports EF’ report the imported quantity of each product and the grazing-based Ecological Footprint embodied in these imports, respectively. The final column, ‘Exports Intensity’, calculates the Ecological Footprint embodied in exported livestock products per unit of production.

**Data and Calculation:** The domestic production quantities for live animals are calculated by multiplying the number of each animal produced from the *resourcestat\_livestock\_n* worksheet by the weight per head from the *cnst\_grazing* worksheet, or the values are drawn from the *prodstat\_livestock\_n* worksheet. The ‘Embodied EF’ column is calculated by multiplying the quantity produced by the grazing intensity from the *livestock\_intensity\_w* worksheet and adjusted by the relative grazing intensity from the *livestock\_feed\_ef\_n* worksheet.

The imported quantity of each product is drawn from the *livestock\_efi* worksheet, and the 'Imports EF' column is calculated by subtracting the crop feed Ecological Footprint from the total embodied Ecological Footprint in imports. The 'Exports Intensity' column is then calculated by taking the sum of Embodied Footprint and Imports Footprint and dividing by the sum of the domestic production quantity and imports.

**Refers to:** *livestock\_efi* (L3), *livestock\_intensity\_w* (L4), *livestock\_feed\_ef\_n* (L4), *resourcestat\_livestock\_n* (L5), *prodstat\_livestock\_n* (L5), *cnst\_grazing* (Constants)

**Referenced by:** *livestock\_efe* (L3)

### 5.3.9 livestock\_intensity\_n\_fish

**Level 4** (7 livestock trade worksheets at this level)

The *livestock\_intensity\_n\_fish* worksheet calculates the fish-based Footprint intensity of exports for each livestock category.

**Layout:** This worksheet begins with four identifying columns. The 'Name', 'FAO Code' and 'HS+ Code' columns report the ProdSTAT names and codes for each livestock product category. The 'Parent Product' column lists the parent product from which each product is derived. The next two columns, 'Production / Stock' and 'Embodied EF' report the domestic production quantity of each product and the fish-based Ecological Footprint embodied in the production, respectively. The next two columns, 'Imports' and 'Imports EF' report the imported quantity of each product and the fish-based Ecological Footprint embodied in these imports, respectively. The final column, 'Exports Intensity', calculates the Ecological Footprint embodied in exported livestock products per unit of production.

**Data and Calculation:** The domestic production quantities for live animals are calculated by multiplying the number of each animal produced from the *resourcestat\_livestock\_n* worksheet by the weight per head from the *cnst\_grazing* worksheet, or the values are drawn from the *prodstat\_livestock\_n* worksheet. The 'Embodied EF' column is calculated by multiplying the quantity produced by the crop feed intensity from the *livestock\_intensity\_w* worksheet and adjusted by the relative feed intensity from the *livestock\_feed\_ef\_n* worksheet.

The imported quantity of each product is drawn from the *livestock\_efi* worksheet, as is the 'Imports EF' column. The 'Exports Intensity' column is then calculated by taking the sum of Embodied Footprint and Imports Footprint and dividing by the sum of the domestic production quantity and imports.

**Refers to:** *livestock\_efi* (L3), *livestock\_intensity\_w* (L4), *livestock\_feed\_ef\_n* (L4), *resourcestat\_livestock\_n* (L5), *prodstat\_livestock\_n* (L5), *cnst\_grazing* (Constants)

**Referenced by:** *livestock\_efe* (L3)

### 5.3.10 livestock\_feed\_ef\_n

**Level 4** (7 livestock trade worksheets at this level)

The *livestock\_feed\_ef\_n* worksheet calculates an adjustment factor to change the observed Ecological Footprint embodied in crop feed and grazing to the actual Ecological Footprint.

**Layout:** This worksheet begins with a single identifying column 'Land Use Type'. The next two columns, 'Expected Feed' and 'Expected EF' list the calculated feed quantity

and embodied Ecological Footprint from each land use type. The ‘Actual EF’ column shows the observed Ecological Footprint for livestock production on each land type, and the ‘Relative Feed Intensity’ column shows the adjustment factor between the observed and actual Ecological Footprint.

**Data and Calculation:** The calculated feed production is drawn from the *feed\_demand\_n* worksheet, as is the calculated Ecological Footprint. The observed Ecological Footprint is drawn from the *livestock\_feed\_balance* worksheet. The relative feed intensity is the ratio of the ‘Actual EF’ column to the ‘Expected EF’ column.

The second table contains the World and National Total Feed Requirements (as tonnes of feed per tonne Live Weight), respectively, for specific categories of livestock. The column ‘Relative Intensity’ is the ratio of National to World Total Feed Requirement.

**Refers to:** *feed\_demand\_n* (L4), *livestock\_feed\_balance* (L4), *feed\_mix\_w* (L5)

**Referenced by:** *livestock\_intensity\_n\_crop* (L4), *livestock\_intensity\_n\_grazing* (L4), *livestock\_intensity\_n\_fish* (L4)

### 5.3.11 feed\_intensity\_w

**Level 4** (7 livestock trade worksheets at this level)

The *feed\_intensity\_w* worksheet calculates the world average Ecological Footprint per unit of production for livestock feed.

**Layout:** This worksheet begins with six identifying columns. The ‘Name’, ‘FAO Code’ and ‘HS+ Code’ columns report the ProdSTAT names and codes for each crop feed product category. The ‘Primary/Derived’ column denotes whether the product is a primary or derived product, and if the product is derived from a parent then the parent’s name and code are shown in the ‘Parent Name’ and ‘Parent Code’ columns.

The next column, ‘Extr’, shows the extraction ratio for each product (set at 1 for primary products), and the ‘Yield’ column shows the tonnes of product that can be produced on a hectare of land at the world average productivity for that land use type. The ‘EQF’ column lists the equivalence factor for the land use type. The ‘YF’ column lists the Intertemporal Yield Factor. The ‘Intensity’ column calculates the Ecological Footprint per unit of production for each feed type.

**Data and Calculation:** The extraction ratio is obtained from the *cnst\_ag\_extr* worksheet. The yield factors are drawn from the *crop\_yield\_w* worksheet and adjusted by the extraction ratio for derived products. The equivalence factors are pulled from the *eqf* worksheet, the intertemporal yield factors are drawn from the *iyf* worksheet, and the intensity is calculated by dividing the equivalence factor by the yield factor.

**Refers to:** *crop\_yield\_w* (L4), *fish\_feed\_group\_yield\_n* (L4), *crop\_feed\_cnst* (Constants), *cnst\_grazing* (Constants), *eqf* (Constants), *cnst\_ag\_extr* (Constants), *iyf* (Constants), *cnst\_grazing\_npp* (Constants)

**Referenced by:** *livestock\_intensity\_w* (L4), *feed\_demand\_n* (L4), *livestock\_feed\_balance* (L4)

### 5.3.12 feed\_mix\_w

**Level 5** (1 livestock trade worksheets at this level)

**Layout:** For the table beginning on Row 5, the first column ‘Name’ lists the name of the grazing animal. The second and third columns list ‘FAO Code’ and ‘HS+ Code’ respectively for each grazing animal. The fourth column ‘Primary/Derived’ contains the Primary ‘P’ or Derived ‘D’ nature of each commodity. The next three columns represent the percentage of Grass, Crop and Fish that comprise the diet of each grazing animal. The next column ‘Crop Total’ is the sum of all crops consumed by each grazing animal plus grass crops and crop residue in tonnes per live weight. The next column ‘TFR’ represents the Total Feed Requirement for each grazing animal. The next 15 columns contain the tonnes per live weight of grains consumed by each grazing animal. The next five columns contain the tonnes per live weight of feed as Fish Meal, Other Concentrate Feed, Grass, Grass Crops, and Crop Residue that is consumed by each grazing animal, respectively.

For the table (“Table 1”) beginning on Row 33, the first column lists the name of each grazing animal, and the second column contains the associated FAO Code of each grazing animal. The next 15 columns contain percentages of every grain consumed by each grazing animal. The column ‘Tot Crop %’ contains the sum of the percentages of the first 15 columns of grain columns. The grey columns ‘Fish Meal’, ‘Other Concentrate Feed’, ‘Grass’, ‘Grass Crop %’, and ‘Crop Residue %’ are percentages of these products that are consumed by each grazing animal, respectively.

For the table (“Table 2”) beginning on Row 60, the first column lists the name of each grazing animal, and the second column contains the associated FAO Code of each grazing animal. The next 15 columns contain percentages of every grain consumed by each grazing animal. These percentages are multiplied by the TFRs (listed in the top table) of every animal.

#### **Data and Calculation:**

**Refers to:** External Data, *crop\_feed\_cnst* (Constants)

**Referenced by:** *livestock\_intensity\_w* (L4), *feed\_demand\_n* (L4), *livestock\_feed\_ef\_n* (L4)

#### **5.3.13 crop\_feed\_cnst**

**Constants** (6 livestock trade worksheets at this level)

The *crop\_feed\_cnst* worksheet contains constants of world averages of quantities for Market, Grass Crops, and Residue Feed.

**Layout:** The first column names the different categories of feed, summed in the last row. The second column contains world quantities of feed categories in tonnes. The third column has a list of percentages of each feed category of the total amount of all feed by weight. The fourth column, ‘Intensity’, lists the impact of each feed in global hectares per tonne.

#### **Data and Calculation:**

**Refers to:** External Data

**Referenced by:** *feed\_intensity\_w* (L4), *feed\_mix\_w* (L5), *crop\_trade\_yield\_w* (L4)

#### **5.3.14 constant\_ag\_extr**

**Constants** (6 livestock trade worksheets at this level)

The *constant\_ag\_extr* worksheet contains constants of quantity, value, price, and extraction rate for 256 food products.

**Layout:** The first column, 'item', contains the item name. 'item codes' lists the FAO code for the item. 'Level' lists the FAO product level (1 – Top Parent, 2 – Parent, or 3 – Sup-group of parent). 'Top Parent', 'Parent', and 'Sub-group of parent' list, if applicable, information on the categorization of each product. 'TCF' lists the FAO Technical Conversion Factor. 'Quantity', 'Value', and 'Price' report FAOSTAT data. 'EXTR' lists the extraction rate.

**Data and Calculation:** The data come from ProdSTAT and TradeSTAT. 'TCF' comes from FAO's Technical Conversion Factors documentation.

**Refers to:** External Data

**Referenced by:** *crop\_trade\_yield\_w* (L4) *livestock\_efe* (L3) *livestock\_intensity\_w* (L4), *feed\_intensity\_w* (L4)

### 5.3.15 const\_grazing\_npp

**Constants**(6 livestock trade worksheets at this level)

The *const\_grazing\_npp* worksheet lists the average net primary production of grazing land in every country.

**Layout:** The first column, 'UN\_country\_Code', lists the United Nations country code for each country. 'Name (GFN)' lists the Global Footprint Network common name for the country. 'Country Name' lists the abbreviated country name. 'Pasture NPP' lists the net primary production of pastureland in that country. 'Pasture Area' lists the surface area of pasture in that country.

**Data and Calculation:** The worksheet does not perform calculations. Data come from Zaks et al (2007).

**Refers to:** External Data

**Referenced by:** *yf* (Constants), *feed\_intensity\_w* (L4)

### 5.3.16 constant\_feed\_region

**Constants**(6 livestock trade worksheets at this level)

The *constant\_feed\_region* worksheet lists the feed region of every country.

**Layout:** The first column, 'UN\_Region', lists the United Nations region number for each country. 'GFN Name' lists the Global Footprint Network common name for the country. 'FAO Code' lists the FAO number of the country. 'Feed Region' lists the feed region of the world the country is found in.

**Data and Calculation:** The worksheet does not perform calculations.

**Refers to:** External Data

**Referenced by:** *residue\_supply\_n* (L4)

### 5.3.17 constant\_livestock\_residue

**Constants**(6 livestock trade worksheets at this level)

The *constant\_livestock\_residue* worksheet lists the crop residue feed conversion ratio for major crop types.

**Layout:** The first column, 'Crops' contains the name of the crop. The next 8 columns contain the regions of the world, which display a) the harvest factor, b) recovery rate, c) share of recovered crop residue used for feed, and d) the crop residue feed conversion ratio for that crop. The final column contains the same information, but for the world (this only applies to the fourth calculation, table d).

**Data and Calculation:** The worksheet does not perform calculations. Data come from Haberl et al 2009. There are four tables of data reported in the worksheet. The first table contains the harvest factors. The next contains the recovery rates. The third contains the share of recovered crop residues used as feed. Finally, the last table reports the crop residue feed conversion ratio.

**Refers to:** External Data

**Referenced by:** *residue\_supply\_n* (LA)

### 5.3.18 constant\_livestock\_demand

**Constants**(6 livestock trade worksheets at this level)

The *constant\_livestock\_demand* worksheet lists the species-specific daily feed intake of livestock in different parts of the world.

**Layout:** The first column lists the name of the species. The rest of the columns list the region of the world, or the world as a whole, that the daily feed intake for the species identified in each row is calculated for.

**Data and Calculation:** The worksheet does not perform calculations. Data come from Haberl et al 2009.

**Refers to:** External Data

**Referenced by:** *feed\_demand\_n* (LA)

# 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 (in *fish\_capture\_yield* using data from *cnst\_fish*). A higher trophic level fish requires more space on the continental shelf than one at a lower trophic level.

**NFA 2014** tracks the production of 1,718 marine and freshwater species, including fish, invertebrates, mammals, and aquatic plants. The Fishing Grounds Footprint includes all wild caught fish and production through aquaculture. The complete list of species corresponds to all species tracked in FishSTAT (FAO FishSTAT Fisheries Statistical Database).



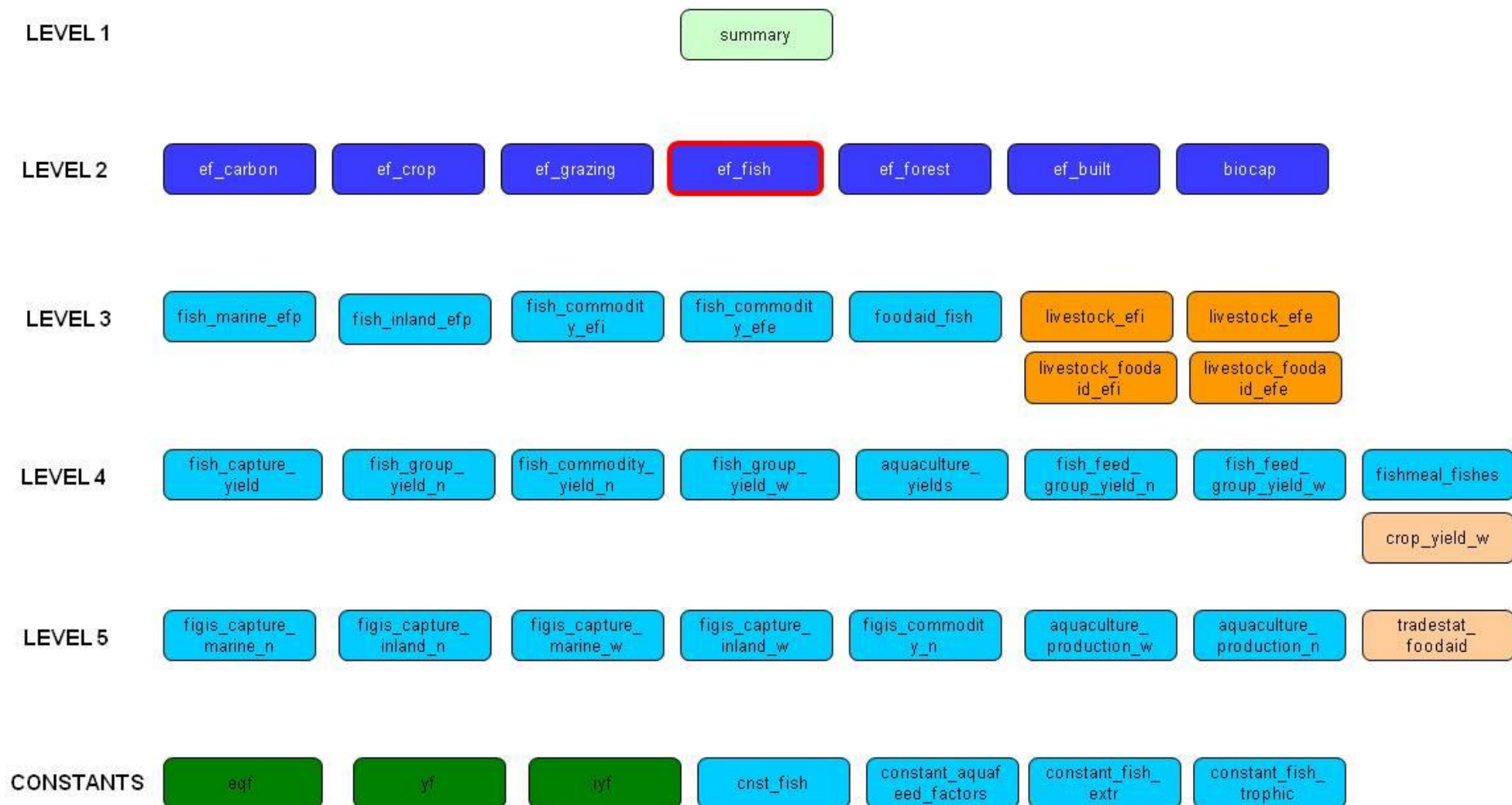
## 6.1.2 Data Sources

Data	Worksheet	Data Source
Production, imports, exports (tons)	<i>figis_capture_marine, figis_capture_inland, aquaculture_production</i>	FAO FishSTAT Fisheries Statistical Database. <a href="http://www.fao.org/fishery/figis">http://www.fao.org/fishery/figis</a> (accessed 2013).
Trophic levels	<i>fish_yield_w</i>	Fishbase Database. Froese, R. and D. Pauly. Editors. 2013. <a href="http://www.fishbase.org">http://www.fishbase.org</a> (accessed 2013).
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. <a href="http://www.searoundus.org/project.htm">http://www.searoundus.org/project.htm</a> (accessed 2013).
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. The Fish Resources of the Ocean. West Byfleet, Surrey, England: Fishing News.
Extraction rate	<i>constant_fish_extr</i>	Extraction Rates. FAO Fisheries Circular 847 revision 1. Commodity and Parent: FISHSTAT Plus 2.3. <a href="http://www.fao.org/fi/website/FIRetrieveAction.do?dom=topic&amp;fid=160">http://www.fao.org/fi/website/FIRetrieveAction.do?dom=topic&amp;fid=160</a>

## 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 (Database), 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 **NFA 2014**.
- The yields for fish catches are calculated by estimating the amount of primary production required, given the trophic level. 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 particular 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 uses data that track 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 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 6-1**

*Fishing grounds Footprint calculations.* The Fishing Grounds section of the *NFA 2014* contains five 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. References are also made to Livestock and Cropland worksheets.

## 6.2 Worksheets

**Figure 6-1** 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 2014* consists of five Level 3 worksheets, eight Level 4 worksheets, seven Level 5 worksheets and four Constants worksheet. All of the fishing grounds worksheets are colored cyan in *NFA 2014*. References are also made to two Livestock and two Cropland worksheets. 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 labelled '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 labelled 'EF<sub>p</sub>,' 'EF<sub>i</sub>,' 'EF<sub>e</sub>' and 'EF<sub>c</sub>,' respectively. Each row in the *ef\_fish* table corresponds to one of the broad 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 five categories totaled in this worksheet: 'Marine capture,' 'Inland capture,' 'Fish in Livestock,' 'Food Aid Fish,' and 'Commodities.' FishSTAT reports both 'capture' groups in terms of the species landed, so for two these categories  $EF_p = EF_c$ . The 'Fish in Livestock' represents fish meal used in livestock feed mixes, and references the livestock worksheets where the calculations for the Footprints of fish meal imported and exported as embodied in trade of livestock products are done. The 'Food Aid Fish' category captures all fish traded for Food Aid. The 'Commodities' category encompasses trade in many derived fish products. Thus, production data are split between the inland and marine catch categories while the 'Fish in Livestock,' 'Food Aid Fish,' 'Commodities' rows report all trade.

**Data and Calculation:** The 'EF<sub>p</sub>,' 'EF<sub>i</sub>,' and 'EF<sub>e</sub>' columns report values directly from the Level 3 worksheets. 'Marine capture' sums the Footprints of all 1,718 species listed in *fish\_marine\_efp*, while 'Inland capture' does the same for the 287 freshwater species in *fish\_inland\_efp*. Since traded quantities of 'Marine capture' and 'Inland capture' are not available by species, the EF<sub>i</sub> and EF<sub>e</sub> are empty and the Footprint of consumption is equal to the Footprint of production.

Imports and exports for the 'Fish in Livestock' category are drawn from *livestock\_efi*, *livestock\_foodaid\_efi*, *livestock\_efe*, and *livestock\_foodaid\_efe*; for the 'Food Aid Fish' category from *foodaid\_fish* (as reported in TradeSTAT in the cropland section of the workbook); and for the 'Commodities' category from *fish\_commodity\_efi*, and *fish\_commodity\_efe*. 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<sub>p</sub>, EF<sub>i</sub>, and EF<sub>e</sub>.

**Refers to:** *fish\_marine\_efp* (L3), *fish\_inland\_efp* (L3), *fish\_commodity\_efi* (L3), *fish\_commodity\_efe* (L3), *livestock\_efi* (L3), *livestock\_foodaid\_efi* (L3), *livestock\_efe* (L3), *livestock\_foodaid\_efe* (L3), *foodaid\_fish* (L3),  
**Referenced by:** *summary* (L1)

### 6.2.2 fish\_marine\_efp

**Level 3** (5 fishing grounds worksheets at this level)

The *fish\_marine\_efp* worksheet calculates the Footprint of production of 1,718 fish species that are landed in the country. Catch data does not include information on the geographic 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 'Unit,' which report the names and units of measurement for each of the 1,718 marine species. The next column lists the trophic level of each species and a 'Production' column giving landed catch in tonnes follows this. The next four columns list estimated yield, the equivalence factor for marine fishing grounds, the intertemporal yield factor, and the footprint of production for each of the 1,718 species. Following the convention used throughout *NFA 2014*, these are labelled 'Yield,' 'EQF,' 'TYF' and 'EF<sub>p</sub>,' respectively.

**Data and Calculation** When available, individual species' average trophic levels are obtained from Fishbase (Database). If a trophic level estimate is not available, average values for the species' group is used. The trophic levels listed here are used only in the named range, '*fish\_yield\_w*', to calculate the weighted average trophic level of a country's catch. 'Production' is drawn from *figis\_capture\_marine\_n*. The named range 'Yield' is drawn from *fish\_yield\_w*. 'EQF' is drawn from *eqf*. 'TYF' comes from *iyf*. The 'EF<sub>p</sub>' 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\_n* (L5), *fish\_capture\_yield* (L4), *eqf* (Constants), *iyf* (Constants), *constant\_fish\_trophic* (Constants)  
**Referenced by:** *ef\_fish* (L2)

### 6.2.3 fish\_inland\_efp

**Level 3** (5 fishing grounds worksheets at this level)

*Fish\_inland\_efp* calculates the Footprint of production of 287 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 'unit', which report the names and units of measurement for each of 287 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 260 species. Following the convention used throughout *NFA 2014*, these are labelled 'Yield,' 'EQF,' 'TYF', and 'EF<sub>p</sub>,' respectively.

**Data and Calculation** When available, individual species' average trophic levels are obtained from Fishbase (Database). If a trophic level estimate is not available, average

values for the species' group is 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\_inland\_n*. 'Yield' is drawn from *fish\_yield\_w*. 'EQF' is drawn from *eqf*. 'TYF' comes from *iyf*. The 'EF<sub>p</sub>' 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\_n* (L4), *fish\_capture\_yield* (L4), *eqf* (Constants), *iyf* (Constants), *constant\_fish\_trophic* (Constants)

**Referenced by:** *ef\_fish* (L2)

#### 6.2.4 fish\_commodity\_efi

**Level 3** (5 fishing grounds worksheets at this level)

*Fish\_commodity\_efi* calculates the Footprint of imported fish for each of the 127 fish commodities reported.

**Layout:** *Fish\_commodity\_efi* begins with two identifying columns, 'Commodity' and 'HS Code', which report the commodity name and the 2002 Harmonized Standard name of the traded products. The next column, 'Imports', 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, the intertemporal yield factor, the Footprint of imports for each product, and the Embodied Crop Footprint. These last five columns are labelled 'Yield', 'EQF', 'TYF', 'EF<sub>I</sub>', and 'Embodied Crop Footprint', respectively.

**Data and Calculation:** 'Imports' is drawn from *figis\_commodity\_n*, which reports raw trade data. 'Yield' is drawn from *fish\_commodity\_yield\_n*, applying worldwide average yields to all imported products. 'EQF' is drawn from the *eqf* worksheet. 'TYF' comes from *iyf*. The 'EF<sub>I</sub>' column calculates the Footprint of production of imported fish according to **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values. 'Embodied Crop Footprint' calculates the embodied cropland Footprint in fish imports, drawing from *fish\_commodity\_yield\_n*.

**Refers to:** *figis\_commodity\_n* (L5), *fish\_commodity\_yield\_n* (L4), *eqf* (Constants), *iyf* (Constants)

**Referenced by:** *ef\_fish* (L2), *ef\_crop* (L2), *foodaid\_fish* (L3)

#### 6.2.5 fish\_commodity\_efe

**Level 3** (5 fishing grounds worksheets at this level)

*fish\_commodity\_efe* calculates the Footprint of exported fish for each of the 127 fish commodities reported.

**Layout:** *fish\_commodity\_efe* begins with two identifying columns, 'Commodity' and 'HS Code,' which report the commodity name and the 2002 Harmonized Standard name of the traded products. The next column, 'Exports,' shows the tonnes of each product exported. This is followed by columns listing the world-average yield for each traded product, the equivalence factor for fishing grounds, the intertemporal yield factor, the Footprint of exports for each product, and the Embodied Crop Footprint. These last five columns are labelled 'Yield', 'EQF', 'TYF', 'EF<sub>E</sub>', and 'Embodied Crop Footprint'.

**Data and Calculation:** ‘Export’ is drawn from *figis\_commodity\_n*, which reports raw trade data. ‘Yield’ is drawn from *fish\_commodity\_yield\_n*. 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 6.2.7). ‘EQF’ is drawn from the *eqf* worksheet. ‘TYF’ comes from *iyf*. The ‘EF<sub>E</sub>’ column calculates the Footprint of exported fish according to **Equation 2-3b**. This column also checks for errors, returning zeroes instead of any error values. ‘Embodied Crop Footprint’ calculates the embodied cropland Footprint in fish exports, drawing from *fish\_commodity\_yield\_n*.

**Refers to:** *figis\_commodity\_n* (L4), *fish\_commodity\_yield\_n* (L4), *eqf* (Constants), *iyf* (Constants)

**Referenced by:** *ef\_fish* (L2), *ef\_crop* (L2), *foodaid\_fish* (L3)

### 6.2.6 foodaid\_fish

**Level 3** (5 fishing grounds worksheets at this level)

*foodaid\_fish* calculates the Footprints of imports and exports of the ‘Fish & Products +’ category in the TradeSTAT database.

**Layout:** *foodaid\_fish* is a small table with four columns for ‘Flow’, ‘Qty’, ‘Intensity’, and ‘EF’, as well as two rows, one for imports and one for exports. The ‘Flow’ column is short for trade flow (i.e. import or export). The ‘Qty’ column is for the quantity of imports or exports, in tonnes. ‘Intensity’ is a calculation of yield based on the commodities imported and exported. ‘EF’ denotes the Ecological Footprint of imports and exports in food aid.

**Data and Calculation:** ‘Qty’ is drawn from ‘*tradedstat\_foodaid*’ in the cropland section of the workbook. It is the quantity of ‘Fish & Products +’ imported and exported. ‘Intensity’ is calculated as the sum of the Footprint of all traded commodities divided by the sum of the weights of all traded commodities. The Footprint of imports and exports in foodaid is a product of the quantity and the intensity.

**Refers to:** *tradedstat\_foodaid* (L5), *fish\_commodity\_efi* (L3), *fish\_commodity\_efe* (L3)

**Referenced by:** *ef\_fish* (L2)

### 6.2.7 fish\_commodity\_yield\_n

**Level 4** (8 fishing grounds worksheets at this level)

*Fish\_commodity\_yield\_n* calculates the import and export yields for derived products.

**Layout:** *Fish\_commodity\_yield\_n* begins with three identifying columns, ‘Commodity’, ‘HS Code’, and ‘Parent’, which report the commodity name, the 2002 Harmonized Standard name of the traded products, and the parent product from which the commodity is derived. The next columns, ‘Feed Group’ and ‘Extr,’ show which feed group the fish of the parent product belongs to and the extraction ratio for each derived product, respectively. This is followed by columns listing the average yield for each traded product for imports and exports, and the total quantity of imports for each product. Following these are columns for ‘Crop Import Intensity’ and ‘Crop Export Intensity’, which calculate the Footprint of embodied cropland products from aquaculture feed mixes in imported and exported commodities.



**Data and Calculation:** ‘Extr’ are extraction rates drawn from FishSTAT. ‘Imports Yield’ and ‘Exports Yield’ are calculated by multiplying the extraction ratio by the group yield for imports and exports from *fish\_group\_yield\_n*. ‘Imports Primary EQ’ is calculated by dividing the total quantity of imports for each product from *figis\_commodity\_n* by the extraction ratio. ‘Crop Import Intensity’ and ‘Crop Export Intensity’ for aquaculture species are calculated by the extraction ratio multiplied by the ‘Crop Intensity’ that is calculated in *fish\_group\_yield\_w*.

**Refers to:** *figis\_commodity\_n* (L5), *fish\_group\_yield\_n* (L4) *fish\_group\_yield\_w* (L4), *constant\_fish\_extr* (Constants)

**Referenced by:** *fish\_commodity\_efe* (L3), *fish\_commodity\_efi* (L3), *fish\_feed\_group\_yield\_n* (L4), *fish\_group\_yield\_n* (L4)

### 6.2.8 fish\_group\_yield\_n

**Level 4** (8 fishing grounds worksheets at this level)

*Fish\_group\_yield\_n* calculates the catch, trophic level, PPR, yield, import quantity and yield, and exports yield for each of the 39 major fish commodity groups.

**Layout:** *Fish\_group\_yield\_n* begins with a single identifying column, ‘Commodity Group,’ which lists the name for the commodity group. This is followed by the ‘Catch’ column, which shows the capture weight of each commodity group. The next column, ‘Effective Trophic Level,’ presents the fractional average trophic level for each group and the following column, labelled ‘PPR,’ calculates the average primary production required to support a tonne of each group. The PPR is used to calculate ‘Yield’ in the next column. The ‘Imports’ column shows the weight of each commodity group imported, and the ‘Imports Yield’ shows the world-average yield for each commodity group. ‘Aquaculture Production’ and ‘Aquaculture Yield N’ are shown next, and these along with imports and catch are used to determine the ‘Effective Yield N’. The final column, ‘Crop Intensity,’ calculates the rate of crop land in feed mixes required by a combination of catch, imports, and aquaculture production.

**Data and Calculation:** ‘Catch’ sums the catch quantities of all individual species in each commodity group from the *fish\_capture\_yield* worksheet. ‘Effective Trophic Level’ is calculated by rearranging **Equation 6.1** (below) and summing the national production and PPR values for all of the individual species in each commodity group from *fish\_capture\_yield*. ‘PPR’ is calculated according to **Equation 6.1**. ‘Yield’ is calculated from the PPR value using **Equation 6.2**.

‘Imports’ quantities are the results of summing the imports of each individual species in the commodity group referring to *fish\_commodity\_yield\_n*. The ‘Imports Yield’ is then calculated by the weighted average of world marine catch and world aquaculture production as calculated in *fish\_group\_yield\_w*.

‘Aquaculture Production N’ shows the national production for the species and their commodity group produced through aquaculture, referencing *aquaculture\_production\_n*. ‘Aquaculture Yield N’ is calculated in *aquaculture\_yields*, which is used with ‘Aquaculture Production N’ to calculate the ‘Effective Yield N’ in the next column. ‘Effective Yield N’ is the weighted average yield of catch, aquaculture production, and imports.

‘Crop Intensity’ is calculated from the ‘Crop Intensity’ for aquaculture (as calculated in *aquaculture\_yields*) multiplied by national aquaculture production, which is divided by imports, aquaculture production and total national capture.

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 is available from the Fishbase (Database) (Froese and Pauly 2008).

**Refers to:** *fish\_commodity\_yield\_n* (L4), *cnst\_fish* (Constants), *fish\_capture\_yield* (L4), *fish\_group\_yield\_w* (L4), *aquaculture\_production\_n* (L5), *aquaculture\_yields* (L4)

**Referenced by:** *fish\_commodity\_yield\_n* (L4), *fishmeal\_fishes* (L4)

### 6.2.9 fish\_group\_yield\_w

**Level 4** (8 fishing grounds worksheets at this level)

*fish\_group\_yield\_w* calculates the world-average yields of 39 major fish commodity groups.

**Layout:** *fish\_group\_yield\_w* is similar to *fish\_group\_yield\_n*, except it contains world data, not national data. It begins with a single identifying column for ‘Commodity Group’ that is followed by the ‘Catch’ column, which shows the world total capture weight of each commodity group. The next column, ‘Effective Trophic Level,’ presents the fractional world average trophic level for each group. The following column, labelled ‘PPR,’ calculates the average primary production required to support a tonne of each group. The PPR is used to calculate ‘Catch Yield’ in the next column. ‘Aquaculture Production W’ and ‘Aquaculture Yield W’ are shown next, and these along with world catch are used to determine the ‘Effective Yield W’.

The final column, ‘Crop Intensity,’ calculates the rate of crop land in feed mixes required by a combination of catch, imports, and aquaculture production.

**Data and Calculation:** ‘Catch’ sums the world wide quantities for all individual species in each commodity group from the *fish\_capture\_yield* worksheet. ‘Effective Trophic Level’ is calculated by rearranging **Equation 6.1**, summing the world production and PPR values for all of the individual species in each commodity group from *fish\_capture\_yield*, and ‘PPR’ is the calculated as by **Equation 6.1**. ‘Catch Yield’ is calculated from the PPR value using **Equation 6.2**.

‘Aquaculture Production W’ shows world total production for the species and their commodity group produced through aquaculture, referencing *aquaculture\_production\_w*. ‘Aquaculture Yield W’ is calculated in *aquaculture\_yields*, which is used with ‘Aquaculture Production W’ to calculate the ‘Effective Yield W’ in the next column. ‘Effective Yield W’ is the weighted average yield of catch and aquaculture production.

‘Crop Intensity’ is calculated from the ‘Crop Intensity’ for aquaculture (as calculated in *aquaculture\_yields*) multiplied by world total aquaculture production, which is divided by total world capture and aquaculture production.

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 is available from the Fishbase (Database) (Froese and Pauly 2008).

**Refers to:** *fish\_capture\_yield* (L4), *aquaculture\_production\_w* (L5), *aquaculture\_yields* (L4), *cnst\_fish* (Constants)

**Referenced by:** *fish\_commodity\_yield\_n* (L4), *fish\_group\_yield\_n* (L4)

### 6.2.10 aquaculture\_yields

**Level 4** (8 fishing grounds worksheets at this level)

*Aquaculture\_yields* calculates the yield factors for aquaculture production, both national and world.

**Layout:** *aquaculture\_yields* begins with a single identifying column for ‘Commodity Group’. ‘Meal Intensity’, ‘Oil Intensity’, and ‘Crop Intensity’ are the relative portions of these in fish feed mixes for each commodity. The next two columns, ‘Fish Intensity N’ and ‘Fish Intensity W’ add together the ‘Meal Intensity’ and ‘Oil Intensity’ (fish products) portions of feed mixes for both domestic production and world average Fish intensity. ‘Yield N’ and ‘Yield W’ are the national and world average yield factors, and ‘Crop Intensity N’ and ‘Crop Intensity W’ are the intensity of cropland footprint in aquaculture fish feed mixes, though ‘Crop Intensity N’ currently contains no data or calculations.

**Data and Calculation:** ‘Meal Intensity’, ‘Oil Intensity’, and ‘Crop Intensity’ reference feed constants. ‘Fish Intensity N’ and ‘Fish Intensity W’ calculates the intensity of Meal and Oil used in aquaculture production based on the relative proportion of these and the feed rate per ton of fish referenced to *fish\_feed\_group\_yield\_n* and *fish\_feed\_group\_yield\_w*, respectively. The yield factors in the ‘Yield N’ and ‘Yield W’ columns are calculated using the intensities and the equivalence factors for Inland Water in *eqf*. ‘Crop Intensity W’ is calculated from the crop portion of the fish feed mix and the feed rate per ton of fish.

The row for Seaweeds (first product row) has no calculations. Seaweeds is included for consistency in the listing of Commodity Group products, but the calculations on this sheet are not relevant for its production.

**Refers to:** *fish\_feed\_group\_yield\_n* (L4), *fish\_feed\_group\_yield\_w* (L4), *eqf* (Constants), *constant\_aquafeed\_factors* (Constants)

**Referenced by:** *fish\_group\_yield\_w* (L4), *fish\_group\_yield\_n* (L4)

### 6.2.11 fish\_feed\_group\_yield\_n

**Level 4** (8 fishing grounds worksheets at this level)

*fish\_feed\_group\_yield\_n* calculates the intensity of fish meal that is fed to livestock and aquaculture fish within a nation.

**Layout:** *fish\_feed\_group\_yield\_n* has three tables. The first table is used to determine the fish feed intensity for livestock exports. It starts with an ‘FAO Category’ corresponding to the data, which is followed by ‘Feed Category’ corresponding to the livestock feed mix. The ‘Catch’ column is for fish caught and allocated to livestock feed. The ‘Effective Trophic Level’ and ‘PPR’ columns correspond to the fish in the ‘Feed Category’. ‘Yield’ is calculated for domestic catch. These columns are followed by columns for ‘Imports’ and ‘Imports Yield’. The final column is ‘Export Yield’.

The second table is used to determine the intensities for the fish species used in fish meal. The first column is for 'Fish Group Name' for the fish that are used in aquaculture fish feed. The next column, 'Imports Intensity' is for the world average production intensity, this is followed by a column for 'Import Quantity' for each fish in the 'Fish Group'. 'Production Intensity N' is the intensity for domestic catch, and 'Production N' is the tonnage of fish caught and allocated for fish feed. The next column uses the preceding columns to calculate 'Export Intensity', followed by 'Imports + Production'.

The third table calculates the Intensity of Fishmeal and Fish Oil used in *aquaculture\_yields*. There are three columns, with two sets of headings in each column to separate fish meal and fish oil. In the first column is 'Intensity of Fishmeal Fish' followed by the calculation for Fishmeal, and then the second heading after that is 'Intensity of Fish oil Fish' followed by the calculation for fish oil. The second column is for 'Extraction Rate of Fishmeal' and 'Extraction Rate of Fish oil', and indicates the relative amounts of these products in the fish feed. In the third column is 'Intensity of Fishmeal' and 'Intensity of Fish oil', which refers to the intensity of the fishmeal and fish oil that are fed to fish.

**Data and Calculation:** In the first table, production is referenced in *fish\_capture\_yield* for 'Catch', where the catch for all of the species in each 'Feed Category' are summed. 'Effective Trophic Level' and 'PPR' are calculated by **Equation 6.1**. 'PPR' is used with 'Available PP' from *cnst\_fish* to determine the 'Yield'. The 'Imports' column references the 'Feed Group' column of *fish\_commodity\_yield\_n*, and sums the corresponding 'Imports Primary EQ' (or imported quantity of fish in the commodities) for all species within each 'Feed Category'. 'Imports Yield' references world average import from *fish\_feed\_group\_yield\_w*. 'Exports Yield' is the weighted average yield of production (catch) and imports.

In the second table, 'Imports Intensity' references world average 'Production Intensity W' from *fish\_feed\_group\_yield\_w*. 'Import Quantity' references the 'Fish Feed Group' in *fishmeal\_fishes*. In 'Production Intensity N', the EQF factor for Marine (referenced in *eqf*) is divided by 'Effective PPR W' calculated in *fishmeal\_fishes*. 'Production N' references the catch of the 'Fish Group Name' in *fishmeal\_fishes*. In the next column, 'Exports Intensity', the weighted average intensity of production and imports is calculated. 'Imports + Production' is simply the weight of imports plus the weight of production.

In the third table, the 'Intensity of Fishmeal Fish' and 'Intensity of Fish oil Fish' are the same, and are calculated by adding together the 'Exports Intensity' (the weighted average of production and imports) and the 'Imports + Production' in the second table, then dividing this sum by 'Imports + Production'. This is the total intensity of fish used in fishmeal. The extraction rates are extraction rates drawn from FishSTAT. The 'Intensity of Fishmeal' and 'Intensity of Fish oil' are multiplied by the extraction rates to determine the 'Intensity of Fishmeal'. The value for 'Intensity of Fishmeal' is referenced by a livestock worksheet, *feed\_intensity\_w*. The value for 'Intensity of Fish oil' is referenced by *aquaculture\_yields* in its calculation.

**Refers to:** *fish\_capture\_yield* (L4), *cnst\_fish* (Constants), *fish\_commodity\_yield\_n* (L4), *fish\_feed\_group\_yield\_w* (L4), *fishmeal\_fishes* (L4), *eqf* (Constants), *constant\_fish\_extr* (Constants)

**Referenced by:** *aquaculture\_yields* (L4), *feed\_intensity\_w* (L4)

## 6.2.12 fish\_feed\_group\_yield\_w

**Level 4** (8 fishing grounds worksheets at this level)

*fish\_feed\_group\_yield\_w* is used to calculate the intensity of fishmeal that is fed to imports of livestock and aquaculture commodities, in addition to the crop intensity of fish meal for imported aquaculture commodities.

**Layout:** *fish\_feed\_group\_yield\_w* has five small tables. The first table is used to determine the fish feed intensity for livestock imports. It starts with an 'FAO Category' corresponding to the data, which is followed by 'Feed Category' corresponding to the livestock feed mix. The 'Catch' column is for fish caught and allocated to livestock feed. The 'Effective Trophic Level' and 'PPR' columns correspond to the fish in the 'Feed Category'. These columns are followed by a column for 'Yield'.

The second table is used to determine the intensities for the fish species used in fish meal. The first column is for 'Fish Group Name' for the fish that are used in aquaculture fish feed. The next column, 'Production Intensity W' is for the world average production intensity, this is followed by a column for 'Production W' which is total world catch for each fish in the 'Fish Group'.

The third table calculates the Intensity of Fishmeal and Fish Oil used in *aquaculture\_yields*. There are three columns, with two sets of headings in each column to separate fish meal and fish oil. In the first column is 'Intensity of Fishmeal Fish' followed by the calculation for Fishmeal, and then the second heading after that is 'Intensity of Fish oil Fish' followed by the calculation for fish oil. The second column is for 'Extraction rate of Fishmeal' and 'Extraction rate of Fish oil', and indicates the relative amounts of these products in the fish feed. In the third column is 'Intensity of Fishmeal' and 'Intensity of Fish oil', which refer to the intensity of the fishmeal and fish oil that are fed to fish. These are global averages used to determine the 'Intensity of Fishmeal' in imported commodities.

The fourth table is for the world average yield for crop products that are used in fishmeal for imported aquaculture commodities. There are two columns. The first column is for 'Crops used in aquafeed' and it contains the list of crops used in fishmeal, and the second column is for 'Yield W'.

There are also only two columns in the fifth table, which is where the 'Average Crop Yield W' and 'Crop Intensity' are calculated. This 'Crop Intensity' value is referenced by *aquaculture\_yields* to determine the cropland footprint in aquaculture commodities.

**Data and Calculation:** In the first table, global production is referenced from *fish\_capture\_yield* for 'Catch' where the catch for all of the species in each 'Feed Category' are summed. 'Effective Trophic Level' and 'PPR' are calculated by **Equation 6.1**. 'Available PP' from *cnst\_fish* is divided by 'PPR' to determine the 'Yield'.

In the second table, 'Production Intensity W', the EQF factor for Marine (referenced in *eqf*) is divided by 'Effective PPR W' which is calculated in *fishmeal\_fishes*. 'Production W' reports the world total catch of each 'Fish Group Name', referenced from *fishmeal\_fishes*.

In the third table, the 'Intensity of Fishmeal Fish' and 'Intensity of Fish oil Fish' are the same, and are calculated by adding together the 'Production Intensity' and the 'Production' in the second, then dividing this sum by 'Production'. This is the total

intensity of fish used in fishmeal. The extraction rates are taken from FishSTAT. The ‘Intensity of Fishmeal Fish’ and ‘Intensity of Fish oil Fish’ are multiplied by the extraction rates to determine the ‘Intensity of Fishmeal’ and the ‘Intensity of Fish oil’.

In the fourth table, the ‘Yield W’ references yields calculated in one of the cropland worksheets, *crop\_yield\_w* for each of the crops in the ‘Crops used in aquafeed’ column. The ‘Yield W’ values are used in the next (fifth) table to determine ‘Average Crop Yield W’. This average is multiplied by the EQF factor for cropland in *eqf* to determine the ‘Crop Intensity W’ of this average yield.

**Refers to:** *fish\_capture\_yield* (LA), *cnst\_fish* (Constants), *eqf* (Constants), *fishmeal\_fishes* (LA), *crop\_yield\_w* (LA), *constant\_fish\_extr* (Constants)  
**Referenced by:** *fish\_feed\_group\_yield\_n* (LA), *aquaculture\_yields* (LA)

### 6.2.13 fishmeal\_fishes

**Level 4** (8 fishing grounds worksheets at this level)

*fishmeal\_fishes* is where the trophic level and PPR for all of the fish used in fishmeal are calculated.

**Layout:** *fishmeal\_fishes* has two tables. The top table starts with three identifying columns for ‘Common Name’, ‘Scientific Name’, and ‘Commodity Group’. These are followed by two columns of data for fish production allocated to fishmeal called ‘Production N’ for national catch and ‘Production W’ for total world catch. Next are columns for ‘Trophic Level’ and ‘PPR’ for each of the fish species, followed by ‘Yield’. The last two columns are for the primary production equivalents, labelled ‘PPE N’ and ‘PPE W’ for the nation and the world respectively.

The bottom table summarizes the values in the top table into ‘Commodity Group’, which is referenced by *fish\_feed\_group\_n* and *fish\_feed\_group\_w*. It has columns for ‘Production N’, ‘Production W’, ‘Import Quantity’, ‘Effective PPR N’, ‘Effective PPR W’, ‘Yield N’, and ‘Yield W’.

**Data and Calculation:** in the top table ‘Production N’ and ‘Production W’ reference *fish\_capture\_yield* for national and world catch data. The ‘Trophic level’, ‘PPR’, and ‘Yield’ columns also reference *fish\_capture\_yield* for the world average trophic level, primary production required and world average yield. National catch data from ‘Production N’ are multiplied by the ‘PPR’ to determine the ‘PPE N’, and ‘Production W’ is multiplied by the ‘PPR’ to determine ‘PPE W’. These primary production equivalents (PPE) are the amount of carbon in the fish caught. Production is converted to PPEs so that the individual species can be aggregated into Commodity Groups of many species in the next table.

In the bottom table, all of the ‘Commodity Group’ fish that are used in fishmeal are listed. In the ‘Production N’ and ‘Production W’ columns, the catch for all of the species within each commodity group are added together. The ‘Import Quantity’ column references the import quantity of the ‘Commodity Group’ in *fish\_group\_yield\_n*. ‘Effective PPR N’ is calculated by dividing the sum of production for all species in each Commodity Group by the sum of the associated ‘PPE N’ for all species in each Commodity Group. A similar calculation is done in ‘PPE W’ using world production data and ‘PPE W’. ‘Yield N’ and ‘Yield W’ reference the ‘Available PP’ value in *cnst\_fish*

and divides it by ‘Effective PPR N’ and ‘Effective PPR W’ respectively. The last row in this table is for the ‘Total’ of each of these columns.

**Refers to:** *fish\_capture\_yield* (LA), *fish\_group\_yield\_n* (LA), *cnst\_fish* (Constants)

**Referenced by:** *fish\_feed\_group\_yield\_n* (LA), *fish\_feed\_group\_yield\_w* (LA)

### 6.2.14 fish\_capture\_yield

**Level 4** (8 fishing grounds worksheets at this level)

*fish\_capture\_yield* is used to calculate the yield factors for all fish caught and landed by a nation, and for total world catch.

**Layout:** *fish\_capture\_yield* begins with four identifying columns for ‘Common Name’, ‘Scientific Name’, ‘Commodity Group’, and ‘FAO Group’. The columns are followed by a column for ‘Unit’. Then there are data columns for ‘Production N’ or national catch data, and ‘Production W’ for total world catch. Next are ‘Trophic Level’ and ‘PPR’, which are used to calculate ‘Yield’.

**Data and Calculation:** The ‘Production N’ and ‘Production W’ columns add together the marine catch (referencing *figis\_capture\_marine\_n* and *figis\_capture\_marine\_w* respectively) and inland catch (referencing *figis\_capture\_inland\_n* and *figis\_capture\_inland\_w* respectively). The ‘Trophic Level’ column is for world average trophic levels obtained from Fishbase (Database). The ‘PPR’ column calculates the primary production requirement: the ratio of the mass of primary producers which are 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 Pauly and Christensen 1995).

#### Equation 6-1

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)<sup>-1</sup>
- TE = Transfer efficiency of aquatic ecosystems, t feed (t product)<sup>-1</sup>  
= 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 very limited 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** as bycatch data become

more available. *NFA 2014* uses primary production figures in tonnes of carbon per hectare. Both discard rate and transfer efficiency are stored in *cnst\_fish*.

‘Yield’ is calculated from the PPR value using **Equation 6.2**.

<p><b>Equation 6-2</b> Yield for Aquatic Species</p> $\text{Yield} = \frac{1}{\text{PPR}} * \text{APP}$
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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).

**Refers to:** *figis\_capture\_marine\_n* (L5), *figis\_capture\_inland\_n* (L5), *figis\_capture\_marine\_w* (L5), *figis\_capture\_inland\_w* (L5), *cnst\_fish* (Constants), *constant\_fish\_trophic* (Constants)

**Referenced by:** *fish\_marine\_eff* (L3), *fish\_inland\_eff* (L3), *fish\_group\_yield\_n* (L4), *fish\_group\_yield\_w* (L4), *fish\_feed\_group\_yield\_n* (L4), *fish\_feed\_group\_yield\_w* (L4), *fishmeal\_fishes* (L4), *market\_feed\_supply\_n* (L4)

### 6.2.15 aquaculture\_production\_n

**Level 5** (7 fishing grounds worksheets at this level)

*aquaculture\_production\_n* is the source data for all fish production from aquaculture operations for a nation.

**Layout:** There are two identifying columns, one for ‘Species’ and one for ‘Commodity Group’. These are followed by a column for ‘Unit’ and a column for ‘Production’.

**Data and Calculation:** There are no calculations in this worksheet as this reports only raw data from the FishSTAT (FAO FishSTAT Statistical Database).

**Refers to:** External

**Referenced by:** *fish\_group\_yield\_n* (L4)

### 6.2.16 aquaculture\_production\_w

**Level 5** (7 fishing grounds worksheets at this level)

*aquaculture\_production\_w* is the source data for all fish production from aquaculture operations.

**Layout:** There are two identifying columns, one for ‘Species’ and one for ‘Commodity Group’. These are followed by a column for ‘Unit’ and a column for ‘Production’.



**Data and Calculation:** There are no calculations in this worksheet as this reports only raw data from the FishSTAT (FAO FishSTAT Statistical Database).

**Refers to:** External

**Referenced by:** *fish\_group\_yield\_w* (L4)

### 6.2.17 *figis\_capture\_marine\_n*

**Level 5** (7 fishing grounds worksheets at this level)

*figis\_capture\_marine\_n* reports the tonnes of marine fish landed within the country for each of the 1,718 species reported.

**Layout:** *figis\_capture\_marine\_n* begins with two identifying columns, 'Common Name' and 'Scientific Name', reporting the names for each of the 1,718 marine species. The next column is for 'Unit' and 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).

**Refers to:** External

**Referenced by:** *fish\_marine\_efp* (L3), *fish\_capture\_yield* (L4)

### 6.2.18 *figis\_capture\_inland\_n*

**Level 5** (7 fishing grounds worksheets at this level)

*figis\_capture\_inland\_n* reports the tonnes of inland fish landed within the country for each of the 287 inland fish species reported.

**Layout:** *figis\_capture\_inland* begins with two identifying columns, 'Common Name' and 'Scientific Name', reporting the names for each of the 287 inland species. The next column is for 'Unit' and 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).

**Refers to:** External

**Referenced by:** *fish\_inland\_efp* (L3), *fish\_capture\_yield* (L4)

### 6.2.19 *figis\_capture\_marine\_w*

**Level 5** (7 fishing grounds worksheets at this level)

*Figis\_capture\_marine\_w* reports the total tonnes of marine fish landed world-wide for each of the 1,718 species reported.

**Layout:** *figis\_capture\_marine\_w* begins with two identifying columns, 'Common Name' and 'Scientific Name', reporting the names for each of the 1,718 marine species. The next column is for 'Unit' and 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).

**Refers to:** External

**Referenced by:** *fish\_capture\_yield* (L4)

### 6.2.20 *figis\_capture\_inland\_w*

**Level 5** (7 fishing grounds worksheets at this level)

*figis\_capture\_inland\_w* reports the tonnes of inland fish landed within the country for each of the 287 inland fish species reported.

**Layout:** *figis\_capture\_inland\_w* begins with two identifying columns, ‘Common Name’ and ‘Scientific Name’, reporting the names for each of the 287 inland species. The next column is for ‘Unit’, and 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).

**Refers to:** None

**Referenced by:** *fish\_capture\_yield* (L4)

### 6.2.21 *figis\_commodity\_n*

**Level 5** (7 fishing grounds worksheets at this level)

*figis\_commodity\_n* reports the imports and exports for each of the 127 fish commodities reported from 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.

**Data and Calculation:** There are no calculations in this worksheet as this reports only raw data from FishSTAT (FAO FishSTAT Statistical Database).

**Refers to:** External

**Referenced by:** *fish\_commodity\_efe* (L3), *fish\_commodity\_efi* (L3), *fish\_commodity\_yield\_n* (L4)

### 6.2.22 *cnst\_fish*

**Constants** (4 fishing grounds worksheet at this level)

*cnst\_fish* provides three constant values that 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 are provided in the 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.

‘Discard Factor’ indicates the proportion 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. It is assumed that the same discard factor applies to all species world-wide.

‘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 lower trophic level.

**Refers to:** None

**Referenced by:** *fish\_capture\_yield* (LA), *fish\_group\_yield\_n* (LA), *fish\_group\_yield\_w* (LA), *fish\_feed\_group\_yield\_n* (LA), *fish\_feed\_group\_yield\_w* (LA), *fishmeal\_fishes* (LA)

### 6.2.23 constant\_aquafeed\_factors

**Constants** (4 fishing grounds worksheets at this level)

*constant\_aquafeed\_factors* reports the intensity of fish meal, fish oil, and other feed feed to aquaculture species.

**Layout:** *constant\_aquafeed\_factors* starts with 3 identifying columns, ‘Species’, reporting the 2002 Harmonized Standard name; ‘Aquaculture Group’, reporting the species grouping; and ‘Commodity Group’, reporting the aggregated grouping. The next three columns, ‘Fish Meal Intensity’, ‘Fish Oil Intensity’, and ‘Remaining Feed Intensity’, report the relative intensities of each of these inputs to aquaculture for growing each species listed.

**Data and Calculation:** There are no calculations in this worksheet, as this reports only raw data from FishSTAT.

**Refers to:** External

**Referenced by:** *aquaculture\_yields* (LA)

### 6.2.24 constant\_fish\_extr

**Constants** (4 fishing grounds worksheets at this level)

*constant\_fish\_extr* reports the extraction rates of 127 aquatic commodities.

**Layout:** *constant\_fish\_extr* contains 1 identifying column, ‘Commodity’, reporting the commodity name. The last column, ‘Extr’, reports the extraction rate for each commodity.

**Data and Calculation:** There are no calculations in this worksheet, as this reports only raw data from FishSTAT.

**Refers to:** External

**Referenced by:** *fish\_commodity\_yield\_n* (LA), *fish\_feed\_group\_yield\_w* (LA), *fish\_feed\_group\_yield\_n* (LA)

### 6.2.25 constant\_fish\_trophic

**Constants** (4 fishing grounds worksheets at this level)

*constant\_fish\_trophic* reports the trophic level of 1713 aquatic species.

**Layout:** *constant\_fish\_trophic* contains 2 identifying columns, ‘Scientific Name’, reporting the genus and species names; and ‘ISSCAAP’, which reports the International Standard

Statistical Classification of Aquatic Animals and Plants. The last column, “Trophic Level”, reports the species trophic level.

**Data and Calculation:** There are generally no calculations in this worksheet, as this reports only raw data from FishSTAT. Where species data are not directly available, the level is a weighted average based on the 2004 world capture production (FISHSTAT) for ISSCAAP group. All are world average trophic levels except “Selachimorpha (Pleurotremata)”, which is set equal to “Dogfish sharks nei”.

**Refers to:** External

**Referenced by:** *fish\_inland\_eff* (L3), *fish\_marine\_eff* (L3), *fish\_capture\_yield* (L4)

# 7 Forest Products Footprint

*Color: Light Green*

## 7.1 Description

### 7.1.1 Overview

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

The forest products Footprint represents the area of world average forest land needed to supply wood for fuel, construction, and paper. To calculate the 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 does have an indirect relationship to forest yield, the carbon and forest Footprints are treated entirely separately in the **NFA 2014** workbook. The calculation of the carbon Footprint is described in Chapter 3.

The **NFA 2014** workbook tracks the production of 13 categories of primary forest products and 20 products derived from them. The complete list of products has been generated from a list of all forest products included in the UN's FAOSTAT ForeSTAT database as of December 2007 (FAO ForeSTAT Statistical Database). The product names and codes correspond to those used in this database.

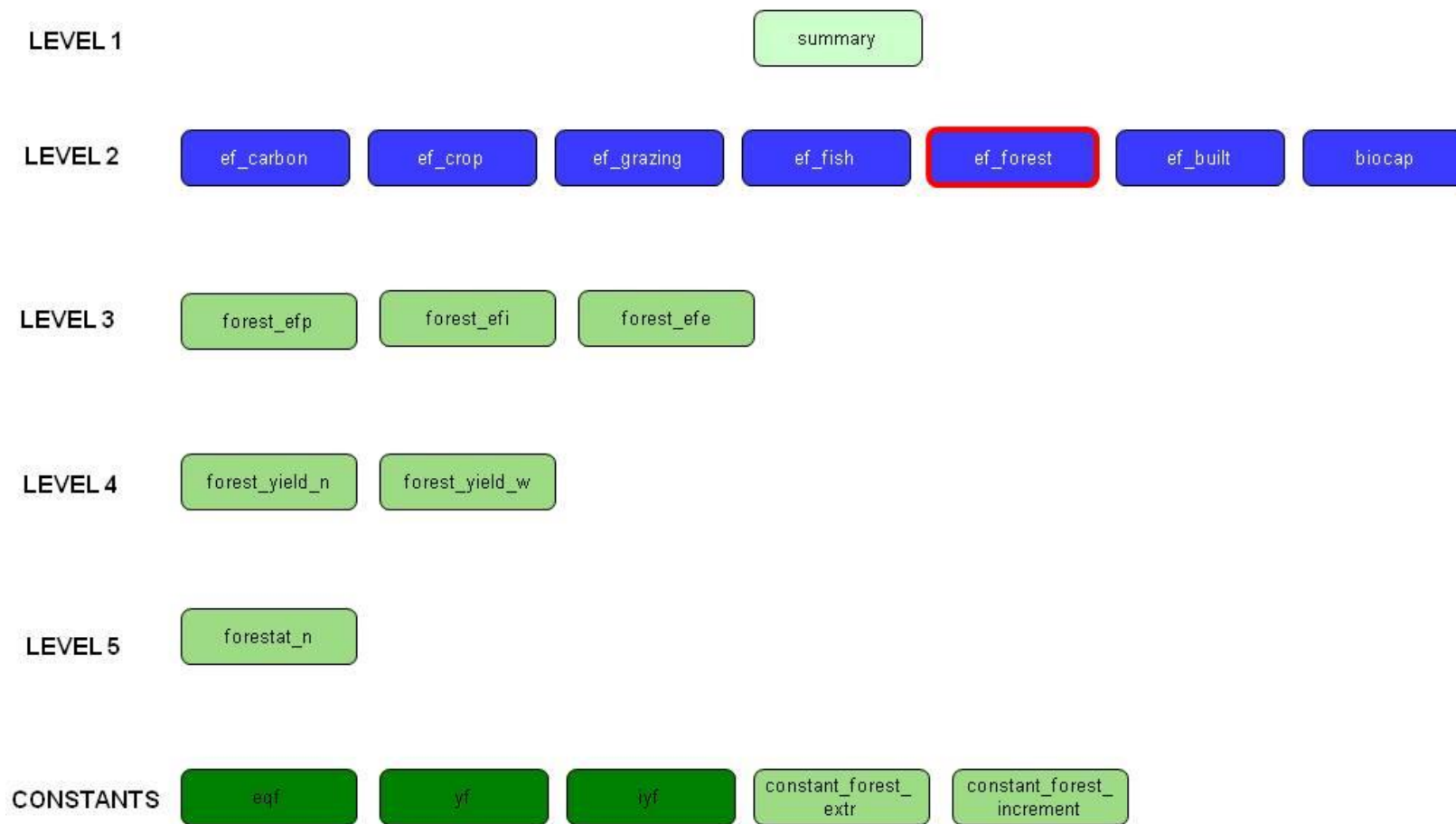
## 7.1.2 Data Sources

Data	Worksheet	Data Source
Production, imports, exports (tonnes, m <sup>3</sup> or m <sup>3</sup> roundwood equivalent)	<i>forestat_n</i>	FAO ForeSTAT Statistical Database. <a href="http://faostat.fao.org/site/626/default.aspx#ancor">http://faostat.fao.org/site/626/default.aspx#ancor</a> (accessed 2013).
Derived product extraction rates (unit primary product / unit derived product)	<i>forest_yield_w</i> <i>forest_yield_n</i>	UNECE and FAO. 2005. <i>European Forest Sector Outlook Study</i> . <a href="http://www.unece.org/timber/docs/sp/sp-20.pdf">http://www.unece.org/timber/docs/sp/sp-20.pdf</a> (accessed October 2008)
Net annual increment (m <sup>3</sup> ha <sup>-1</sup> yr <sup>-1</sup> )	<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> . <a href="ftp://ftp.fao.org/docrep/fao/006/X0105E/X0105E.pdf">ftp://ftp.fao.org/docrep/fao/006/X0105E/X0105E.pdf</a> (accessed October 2008).  IPCC. 2006. <i>2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture Forestry and Other Land Use</i> . <a href="http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html">http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html</a> (accessed September 2008).

## 7.1.3 Notes

- All primary forest products are reported in units of m<sup>3</sup> 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 derived product. However, the *NFA 2014* workbook treats paper as a derived 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 derived products, but they are assigned an extraction rate greater than 1 to convert yield values for merchantable timber into equivalent fuelwood yields. Fuel wood has no primary product counted in another category however, so including fuel wood in the final EF<sub>p</sub> does not lead to double counting.
- Derived forest products are reported either in units of cubic meters (m<sup>3</sup>) 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 *NFA 2014* 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 7-1**

*Forest Footprint.* This flow diagram illustrates the calculation of the Forest land Footprint in *NFA 2014*. 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.

## 7.2 Worksheets

**Figure 7-1** 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 2014* 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 are described below.

### 7.2.1 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 fuel wood products.

**Layout:** This worksheet begins with an identifying column, labelled ‘Name,’ which identifies the broadest categories of timber products. This is followed by four columns labelled ‘EF<sub>p</sub>,’ ‘EF<sub>i</sub>,’ ‘EF<sub>e</sub>’ and ‘EF<sub>c</sub>.’ 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<sub>p</sub>,’ ‘EF<sub>i</sub>,’ and ‘EF<sub>e</sub>’ columns report values directly from the Level 3 worksheets *forest\_efp*, *forest\_efi*, and *forest\_efe*, respectively. The ‘EF<sub>c</sub>’ 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 derived products contribute only to the Footprint embodied in 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)

### 7.2.2 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, ‘FAO Code’ gives the code used in ForeSTAT to identify the product category, ‘Unit’ indicates the unit of each product (m<sup>3</sup>

rwe, m<sup>3</sup>, or t) and ‘Primary/Derived’ contains either a ‘P’ to indicate a primary product or a ‘D’ to indicate a derived product.

The next column is labelled ‘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 derived products. The next column, ‘EQF,’ provides the equivalence factor for forest land. ‘YF’ contains the intertemporal yield factors. This is followed by a column labelled ‘EF<sub>p</sub>’ which calculates the forest land Footprint of production for each of the 33 listed products.

**Data and Calculation:** ‘Production’ is drawn from the *foreststat\_n* worksheet. ‘Yield’ is drawn from *forest\_yield\_n* worksheet. ‘EQF’ is drawn from the *eqf* worksheet. ‘YF’ comes from the *iyf* worksheet.

The ‘EF<sub>p</sub>’ 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 fuelwood and timber products marked as primary (“P”) are included in a country’s total forest Footprint of production.

**Refers to:** *foreststat\_n* (L5), *eqf* (Constants), *forest\_yield\_n* (L4), *iyf* (Constants)

**Referenced by:** *ef\_forest* (L2), *forest\_efe* (L3)

### 7.2.3 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, ‘Imports,’ 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. ‘YF’ reports the Intertemporal Yield Factor. The last column, labelled ‘EF<sub>i</sub>,’ calculates the Footprint of imports for each of the 33 products tracked in the forest land section of **NFA 2014**.

**Data and Calculation:** ‘Imports’ is directly drawn from the *foreststat\_n* worksheet. Because the **NFA 2014** 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. ‘YF’ comes from the *iyf* worksheet.

The ‘EF<sub>i</sub>’ column is calculated according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values.

**Refers to:** *foreststat\_n* (L5), *forest\_yield\_w* (L4), *eqf* (Constants), *iyf* (Constants)

**Referenced by:** *ef\_forest* (L2), *forest\_efe* (L3)

### 7.2.4 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:** *forest\_efe* begins with four identifying columns, identical to those in the *forest\_efp* and *forest\_efi* worksheets.

The next column, ‘Exports,’ shows the exported product quantities. This is followed by ‘Yield’ and ‘EQF’ columns which report yields for exported products, and the equivalence factor for forest land, respectively. ‘YF’ reports the Intertemporal Yield Factor. The last column, labelled ‘EF<sub>E</sub>,’ calculates the Footprint of exports for each of the 33 products tracked in the forest land section of **NFA 2014**.

**Data and Calculation:** ‘Exports’ is directly drawn from *foreststat\_n* worksheet. ‘Yield’ is calculated using production and import values from *forest\_efp* and *forest\_efi* or it is drawn from *forest\_yield\_w*, as world average extraction rates are assumed for derived forest products. ‘EQF’ is drawn from the *eqf* worksheet. ‘YF’ comes from the *iyf* worksheet.

The ‘EF<sub>E</sub>’ column is calculated according to **Equation 2-3**. This column also checks for errors, returning zeroes instead of any error values.

**Refers to:** *foreststat\_n* (L5), *forest\_efp* (L3), *forest\_efi* (L3) *eqf* (Constants), *iyf* (Constants)

**Referenced by:** *ef\_forest* (L2)

### 7.2.5 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 2014**.

**Layout:** This worksheet begins with four identifying columns identical to those in the Level 3 worksheets. The next column is labelled ‘Extr’ and gives the extraction rates for derived products, while primary products are set equal to 1. The final column, labelled ‘Yield,’ lists the world-average yield for each product.

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

In **NFA 2014**, derived, processed wood products are assigned to the primary product ‘Sawnlogs+Veneer Logs (C).’ Derived pulp and paper products are assigned to the primary product ‘Pulpwood, Round&Split (C).’ Because all primary products in **NFA 2014** are assigned the same yield, the choice of which of these to associate with each derived product has no impact on that derived 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:** External, *constant\_forest\_extr* (Constants), *constant\_forest\_increment* (Constants)

**Referenced by:** *forest\_efi* (L3)

### 7.2.6 forest\_yield\_n

**Level 4** (2 Forest worksheets at this level)

The *forest\_yield\_n* worksheet calculates a country's domestic yield for the 33 tracked categories of primary forest products. This worksheet is used in calculating a country's forest biocapacity.

**Layout:** The columns of this worksheet are identical to those of the *forest\_yield\_w* worksheet. It calculates the yield of 33 forest products as the derived product yields are used to calculate the Footprints of production and export.

**Data and Calculation:** The extraction rates for wood fuel are 1.84 while for all other forest products it is 1. For both categories, 'Yield' is the national average net annual increment for all forests.

**Refers to:** External, *constant\_forest\_extr* (Constants), *constant\_forest\_increment* (Constants)

**Referenced by:** *forest\_eff* (L3)

### 7.2.7 forestat\_n

**Level 5** (1 Forest worksheets at this level)

The *forestat\_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 2014**.

**Layout:** The *forestat\_n* worksheet begins with two identifying columns, 'Name' and 'FAO Code,' which report the names and ForeSTAT codes for each forest product.

The next columns report production quantities, imports, and exports for each forest product. These are labelled 'Production,' 'Imports' and 'Exports,' and their values are used in the *forest\_eff*, *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 ForeSTAT (FAO ForeSTAT Statistical Database). Units are also reported in all the Level 3 worksheets involved in calculating the forest Footprint.

**Data and Calculation:** No calculations are made on this worksheet. These data are drawn from ForeSTAT (FAO ForeSTAT Statistical Database).

**Refers to:** External

**Referenced by:** *forest\_eff* (L3), *forest\_efi* (L3), *forest\_efe* (L3)

### 7.2.8 constant\_forest\_extr

**Constants** (2 forests worksheets at this level)

*constant\_forest\_extr* reports the extraction rates of 52 forest products.

**Layout:** *constant\_forest\_extr* contains 2 identifying columns, 'Name', reporting the name of the product; and 'Code', which contains FAO Codes. The column 'Unit' reports the units in which the product is measured while column 'P/S' reports whether the product is a primary or a secondary product. The remaining columns 'TCF' and 'World' report the extraction rates for the forest products. The extraction rate is 1 for all primary products.

**Data and Calculation:** There are no calculations in this worksheet, as this reports only raw data from ForeSTAT database.

**Refers to:** External

Referenced by: *forest\_yield\_n*(L4), *forest\_yield\_w*(L4)

### 7.2.9 constant\_forest\_increment

**Constants** (2 forests worksheets at this level)

*constant\_forest\_increment* reports for each nation the net annual increment, which is the average growth of timber measured as cubic meters under-bark per hectare per year.

**Layout:** *constant\_forest\_increment* contains 2 identifying columns, 'UN\_Country\_Code', and 'Country/area' followed by 'Net Annual Increment [2008]' column, and an 'Estimated' column which denotes whether the NAI value is a national value or a regional estimate.

**Data and Calculation:** There are no calculations in this worksheet, only raw data from Forest Resources Assessment 2008.

**Refers to:** External

**Referenced by:** *forest\_yield\_w* (L4), *forest\_yield\_n* (L4), *yf* (Constants)

## 8 Built-up Land Footprint

*Color: Red*

### 8.1 Description

#### 8.1.1 Overview

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

The **NFA 2014** 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.

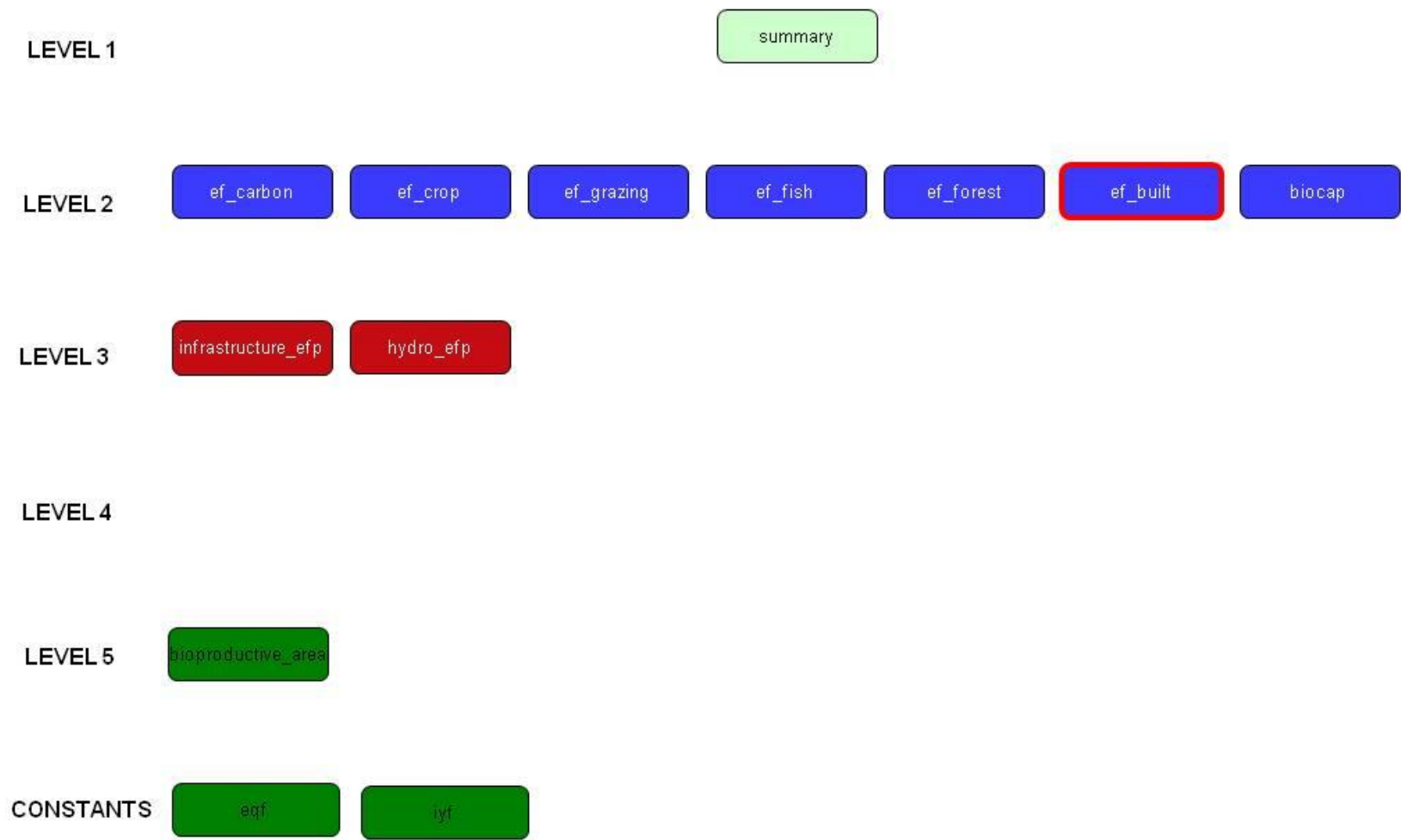
Data from 20 dams, for which both hydroelectric output and inundated area were calculated, are used to estimate the area intensity of hydroelectric generation.

#### 8.1.2 Data Sources

Data	Worksheet	Data Source
Infrastructure area (ha)	<i>infrastructure_efp</i>	World Resources Institute Global Land Cover Classification Database. <a href="http://earthtrends.wri.org">http://earthtrends.wri.org</a> (accessed March 2013).
Hydroelectricity Production (MWh)	<i>hydro_efp</i>	British Petroleum. 2013. Statistical Review of World Energy. <a href="http://www.bp.com/productlanding.do?categoryId=6929&amp;contentId=7044622">http://www.bp.com/productlanding.do?categoryId=6929&amp;contentId=7044622</a> (accessed 2013).
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

### 8.1.3 Notes

- Based on the fact that human settlements historically developed and congregated on the most agriculturally fertile land, 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 20 dams for which both hydroelectric output and inundated area were collected are used to estimate the area occupied 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. Again, since the Footprint and biocapacity of built-up land are equal, any inaccuracies in this assumption will equally affect both.
- The *NFA 2014* workbook does not track imports and exports of built-up land, although built-up land is embodied in goods that 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. *NFA 2014* assumes that there is no trade in hydroelectricity. Because *NFA 2014* 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 2014* workbook likely underestimate the actual extent of impermeable surfaces overlaying productive land.





**Figure 8-1**

*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 2014*. The *hydro\_efp* worksheet contains all data necessary to calculate the Footprint of hydroelectricity.

## 8.2 Worksheets

The built-up land section of the **NFA 2014** 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 red in **NFA 2014** and the Guidebook. The calculation of built-up land biocapacity is treated separately in Chapter 10.

### 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'. 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 because there are no Footprints of Imports or Exports of these areas.

**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, labelled 'Name'. This is followed by a column reporting the area covered by infrastructure, labelled 'Area'. The next two columns provide the yield factor and equivalence factor for cropland, and are labelled 'Yield Factor' and 'EQF,' respectively. Next, 'YF' reports the Intertemporal Yield Factor. The final column, 'EF<sub>p</sub>,' calculates the Footprint.

**Data and Calculation:** Infrastructure areas ('Area') are drawn from the *bioproductive\_area* 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 *yf* and *eqf* worksheets, respectively. 'Yield' and 'EQF' values for cropland are used to calculate the Footprint of infrastructure, following **Equation 2-3**. 'YF' comes from the *yf* worksheet.

**Refers to:** *yf* (Constants), *eqf* (Constants), *bioproductive\_area* (Constants), *iyf* (Constants)  
**Referenced by:** *ef\_built* (L2), *biocap* (L2)

### 8.2.3 hydro\_efp

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

The *hydro\_efp* worksheet calculates the built-up land Footprint of production associated with hydroelectric generation within a country.

**Layout:** *hydro\_efp* begins with an identifying column labelled '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 labelled 'Yield' and 'EQF,' respectively. 'YF' reports the Intertemporal Yield Factor. The final column, 'EF<sub>p</sub>,' 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 a study of 20 large dams (Goodland 1997). The fourth column, 'EQF,' reports the equivalence factor drawn from the *eqf* worksheets. **NFA 2014** assigns an equivalence factor of 1 to hydroelectric area, reflecting the assumption that world average land is inundated by hydroelectric reservoirs. 'YF' comes from *iyf*. The last column shows the Footprint of production, 'EF<sub>p</sub>,' calculated according to **Equation 2-3b**.

**Refers to:** *eqf* (Constants),  
**Referenced by:** *ef\_built* (L2), *biocap* (L2)

# 9 Biocapacity

*Color: Green*

## **9.1 Description**

### **9.1.1 Overview**

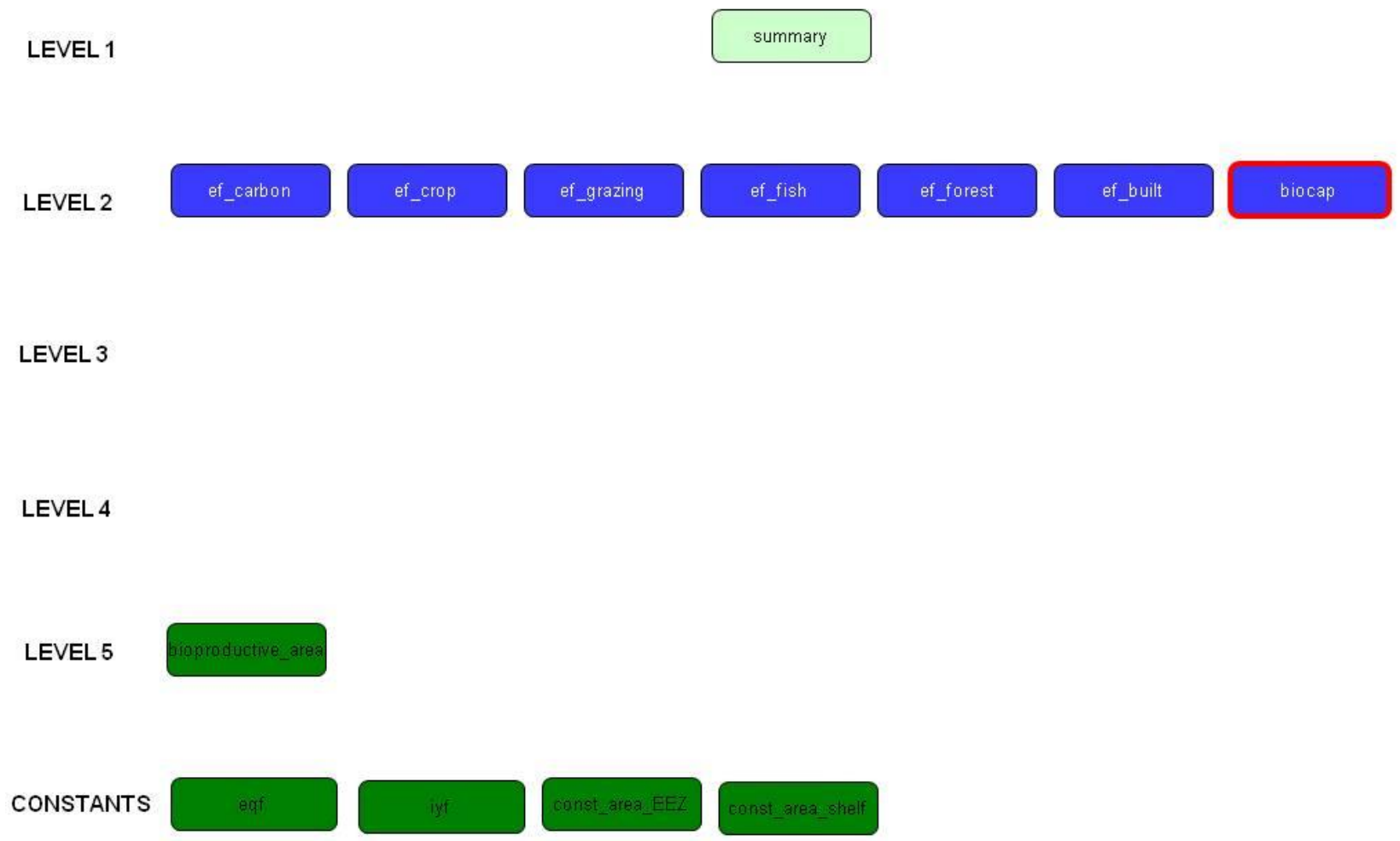
Biocapacity refers to the amount of biologically productive land and water areas available within the boundaries of a given country. Biocapacity is calculated for each of the five major land use types: cropland, grazing land, fishing grounds (marine and inland waters), forest, and built-up land (infrastructure and hydro). Built-up land biocapacity is included here because, though built-up land does not generate resources, buildings and infrastructure occupy the biocapacity of the land they cover. The carbon Footprint does not have corresponding biocapacity because **NFA 2014** assumes all carbon uptake as a demand on forest land biocapacity. Therefore, including carbon dioxide biocapacity in addition to forest land biocapacity would lead to double counting.

### 9.1.2 Data Sources

Data	Worksheet	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>bioproductive_area</i> (CORINE2000)	Corine Land Cover 2000. European Topic Centre on Land Use and Spatial Information, 2000. Barcelona: EIONET. <a href="http://terrestrial.eionet.europa.eu/CLC2000/">http://terrestrial.eionet.europa.eu/CLC2000/</a> (accessed October 2013).
Second source for data on cropland, grazing land, other wooded land, inland waters.	<i>bioproductive_area</i> (FAOSTAT)	FAO ResourceSTAT Statistical Database. <a href="http://faostat.fao.org/site/348/default.aspx">http://faostat.fao.org/site/348/default.aspx</a> (accessed January 2013).
Second source for built-up land areas.	<i>bioproductive_area</i> (GAEZ)	Global Agro-Ecological Zones. FAO and International Institute for Applied Systems Analysis 2000. <a href="http://www.fao.org/ag/agl/agll/gaez/index.htm">http://www.fao.org/ag/agl/agll/gaez/index.htm</a> . (accessed October 2013).
Third source for built-up land areas.	<i>bioproductive_area</i> (GLC)	Global Land Cover 2000. Institute for Environment and Sustainability, Joint Research Center and European Commission. Italy: IES. <a href="http://www.tem.jrc.it/glc2000/">http://www.tem.jrc.it/glc2000/</a> (accessed October 2013).
Fourth source for built-up land areas.	<i>bioproductive_area</i> (SAGE)	Global Land Use Database. Center for Sustainability and the Global Environment, University of Wisconsin-Madison. 1992. <a href="http://www.sage.wisc.edu:16080/iamdata/">http://www.sage.wisc.edu:16080/iamdata/</a> (accessed January 2007).
Only source for area of marine continental shelf.	<i>cnst_area_shelf</i> (WRI)	WRI Global Land Cover Classification Database. <a href="http://earthtrends.wri.org">http://earthtrends.wri.org</a> (accessed July 2011).
Area of marine EEZ. Not currently used in biocapacity calculation	<i>cnst_area_EEZ</i> (SeaAroundUs)	Sea Around Us Project. Fisheries Centre, Pew Charitable Trusts and the University of British Columbia. 2008. <a href="http://www.seaaroundus.org/project.htm">http://www.seaaroundus.org/project.htm</a> (accessed October 2008).

### 9.1.3 Notes

- There is no biocapacity figure for carbon uptake. All other land use types have a corresponding biocapacity calculation.
- Biocapacity for cropland is equal to the cropland Footprint of production because the yields are defined by human use.



**Figure 9-1**

*Worksheets used to calculate biocapacity.* The *biocap* worksheet performs all biocapacity calculations. The only lower level worksheet in the biocapacity section of *NFA 2014* is the *bioproductive\_area* worksheet.

## 9.2 Worksheets

The biocapacity section of the *NFA 2014* workbook consists of one Level 5 worksheet, *bioproductive\_area*, which provides data directly to the Level 2 *biocap* worksheet. Like the other Level 2 worksheets in the *NFA 2014* workbook, *biocap* is colored blue and *bioproductive\_area* is colored green.

### 9.2.1 biocap

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

*biocap* calculates the biocapacity for all bioproductive land use types in the *NFA 2014* workbook.

**Layout:** The only identifying column, ‘Land Use Type’, lists each of the land use type names. The following column, ‘Area’, reports a country’s area in hectares of each land use type. The next three columns list the yield factor, intertemporal yield factor, and equivalence factor for each land use type. The final column, ‘Biocapacity’, lists the biocapacity of each land type.

**Data and Calculation:** Area data are drawn from the *bioproductive\_area* worksheet. For each land or land use type, except marine fishing grounds, more than one data source is available. For EU member countries included in the database, Corine Land Cover 2000 (CLC2000) 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. ‘YF’ is 1 in all years for all land types except cropland, and is also indexed to 1 for cropland in the most recent year of data for each country.

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.

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* (Constants), *eqf* (Constants), *bioproductive\_area* (L5), *infrastructure\_efp* (L3), *hydro\_efp* (L3), *iyf* (Constants)

**Referenced by:** *summary* (L1)

### 9.2.2 bioproductive\_area

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

*bioproductive\_area* contains the source data on the areas devoted to each land use type. This worksheet often contains multiple possible sources for a single value, allowing the use of the most robust dataset from which data are available.

**Layout:** The *bioproductive\_area* worksheet begins with three identifying columns. The first, ‘Source’, lists the data source. The second column, ‘Land Use Type’, states the land use type which the data applies to. The third column, ‘Description,’ identifies the data point as it is described in the source. “Infrastructure” is used as the area for built-up land. For fishing grounds, the *bioproductive\_area* 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. **NFA 2014** prioritises the most reliable data sources.

**Refers to:** External, *const\_area\_EEZ* (Constants)

**Referenced by:** *biocap* (L2), *infrastructure\_efp* (L2)

### 9.2.3 const\_area\_EEZ

**Constants**

*const\_area\_EEZ* reports the Exclusive Economic Zone area and average primary production rate for all countries.

**Layout:** The worksheet begins with the identifying columns ‘UN\_Country\_Code’ and ‘GFN\_Name’, reporting the official United Nations country code (if there is one), and

the Global Footprint Network internal name for each country, country grouping, or part of a country. ‘EEZArea main land’ reports the EEZ area around the main portion of the country. ‘AvgPPRate main land’ lists the average primary production rate for the same water. ‘EEZArea all land’ lists the water area of EEZ around all portions of the country’s land. ‘AVGPPRate all land’ lists the average primary production rate for this same water. Below this are several groups of results that report data for multiple countries that previously constituted parts of one country.

**Data and Calculation:** The only calculations in this worksheet are determining the fraction of area of EEZ occupied by each country within a multi-country group, such as Belgium & Luxembourg. Otherwise, the table reports data from SeaAroundUS (2008).

**Refers to:** External

**Referenced by:** *yf* (Constants), *bioproductive\_area* (Constants)

#### 9.2.4 const\_area\_shelf

##### **Constants**

*const\_area\_shelf* reports the area of continental shelf that is a part of each country’s landmass.

**Layout:** The worksheet begins with the identifying columns ‘UN\_Country\_Code’, ‘GFN\_Name’, ‘Country’, and ‘’, reporting, respectively, the official United Nations country code (if there is one), the Global Footprint Network internal name for each country, country grouping, or part of a country, the name of a country if it represents the entire country’s land area (or else it is blank), and the 3-letter abbreviation for the country, if there is one. ‘Country’ may contain a note, in curly brackets, indicating a dispute over the territorial size of some countries. These notes are explained at the bottom of the worksheet. ‘km2’ reports the area, in square kilometres, of the continental shelf. Similar to *const\_area\_EEZ*, some countries are also grouped together in a separate table in the worksheet, where in a period of time covered by the National Footprint Accounts the countries constituted portions of a single country.

**Data and Calculation:** The only calculation in this worksheet is a total of all continental shelf area (“According to the UN Convention of the Law of the Sea, the Continental Shelf is the area of the seabed and subsoil which extends beyond the territorial sea to a distance of 200 nautical miles from the territorial sea baseline and beyond that distance to the outer edge of the continental margin. Areas of continental shelf that are disputed by overlapping claims by one or more nations have been excluded from this table. Areas that are of cooperative joint development between two or more nations have also been excluded”). Otherwise, the table reports data from WRI (2011).

**Refers to:** External

**Referenced by:** *bioproductive\_area* (Constants)

# 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 use type. Yield factors are used in biocapacity calculations when biocapacity is reported in global hectares. For land use types for which there are data on the average growth for primary production, 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 use type, wha nha<sup>-1</sup>.
- $Y_N^L$  = Yield for a given country and land use type, t nha<sup>-1</sup>.
- $Y_W^L$  = World-average yield for a given land use type, t wha<sup>-1</sup>.

Cropland produces more than one primary product. For this land use type, **Equation 100-2** is used.

### Equation 100-2

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 use type, wha nha<sup>-1</sup>.
- $A_N$  = Area harvested for a given quantity of product in a given country, nha<sup>-1</sup>.
- $A_W$  = Area that would be required to produce a given quantity of product using world average land, wha<sup>-1</sup>.
- $P_N$  = Amount of given product extracted or waste generated in a country, t yr<sup>-1</sup>.
- $Y_N$  = National yield for product extraction, t nha<sup>-1</sup> yr<sup>-1</sup>.
- $Y_W$  = World-average yield for product extraction, t wha<sup>-1</sup> yr<sup>-1</sup>.

## 10.2 Worksheets

The main yield factor calculations for each land use type are done 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 use types in the *NFA 2014* workbook except for cropland, which is calculated in the *yf\_crop* worksheet.

**Layout:** The only identifying column, 'Land Use Type', lists all of the land use types with the exception of carbon Footprint. Next, the 'National Yield' column reports the national yield for a land use type, 'World Yield' reports the world-average yield for a land use type, and 'Yield Factor' reports the yield factor for that land use 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:** *constant\_forest\_increment* (Constants), *const\_area\_EEZ* (Constants), *const\_grazing\_npp* (Constants), *yf\_crop* (Constants)

**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 three identifying columns: 'Name,' 'FAO Code,' and 'HS+ Code'. These report the product name codes for each product. Only primary products are included in this list. The 'Area<sub>N</sub>' column shows the actual area harvested for the domestic production of each crop. The 'Area<sub>W</sub>' 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 'Yield Factor' column shows the calculated yield factor for each individual crop

**Data and Calculation:** The national area values are drawn from the *crop\_yield\_n* worksheet. The calculation of ‘Area<sub>w</sub>’ is shown in **Equation 100-2**. The ‘Yield Factor’ column shows the yield factor for each individual agricultural product, calculated as ‘Area<sub>w</sub>’ divided by ‘Area<sub>N</sub>.’

**Refers to:** *crop\_yield\_n* (L4), *crop\_yield\_w* (L4), *crop\_eff* (L3), *crop\_unharvest* (L4)

**Referenced by:** *yf* (Constants)

### 10.2.3 iyf

#### **Constants**

New for *NFA 2014*, the *iyf* worksheet reports the intertemporal yield factor for each land use type. It attempts to address the number of global hectares of biocapacity available on the planet in any given year reflecting only the total physical bioproductive area of the planet, but being insensitive to changes in yields. This can cause difficulties of interpretation when comparing changes in biocapacity and Ecological Footprint over time, as it is hard to represent actual variations in demand and supply of regenerative capacity.

**Layout:** This worksheet begins with one identifying column, ‘Land use type’, reporting each land type, except for Carbon. The final column, ‘Inter-temporal yield factor’, reports the value of the factor for the given land use type.

**Data and Calculation:** Data come from internal Global Footprint Network calculations as entered in **Equation 100-3: Intertemporal Yield Factor**. The values for all land use types except for Cropland are set to 1, because time series yield data are currently available for crop-based products only. Additionally, the value for Inland Water is always set equal to Marine, similar to values for these two land use types in other constants worksheets.

In general, though, and as implemented for cropland, for any given land type producing products *i* in a given year *j*, with a selected base year *b*, a world-average Intertemporal Yield Factor (IYF<sub>w</sub>) is thus calculated as:

<p><b>Equation 100-3</b> Intertemporal Yield Factor Calculation</p> $\text{IYF}_{w,j} = \frac{\sum_i \frac{P_{w,i,j}}{Y_{w,i,b}}}{\sum_i \frac{P_{w,i,j}}{Y_{w,i,j}}}$
--

where P is the amount of a product harvested (or CO<sub>2</sub> emitted), Y is the product specific yield and the subscript W denotes world values. The selected base year is always the most recent year in the period of years analysed (e.g. 2006 for the National Footprint Accounts 2006 Edition).

**Refers to:** External

**Referenced by:** *biocap* (L2), *infrastructure\_eff* (L3), *market\_feed\_supply\_n* (L4), *fossil\_eff* (L3), *crop\_eff* (L3), *crop\_eff* (L3), *crop\_efe* (L3), *feed\_intensity\_w* (L4), *fish\_marine\_eff* (L3),

*fish\_inland\_eff* (L3), *fish\_commodity\_efi* (L3), *fish\_commodity\_efe* (L3), *forest\_eff* (L3), *forest\_efi* (L3), *forest\_efe* (L3)

# 11 Equivalence Factors

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## 11.1 Description

Equivalence factors reflect the relative productivity of world average hectares of different land use 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 2014*. 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 use type divided by the average suitability index for all land use 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.

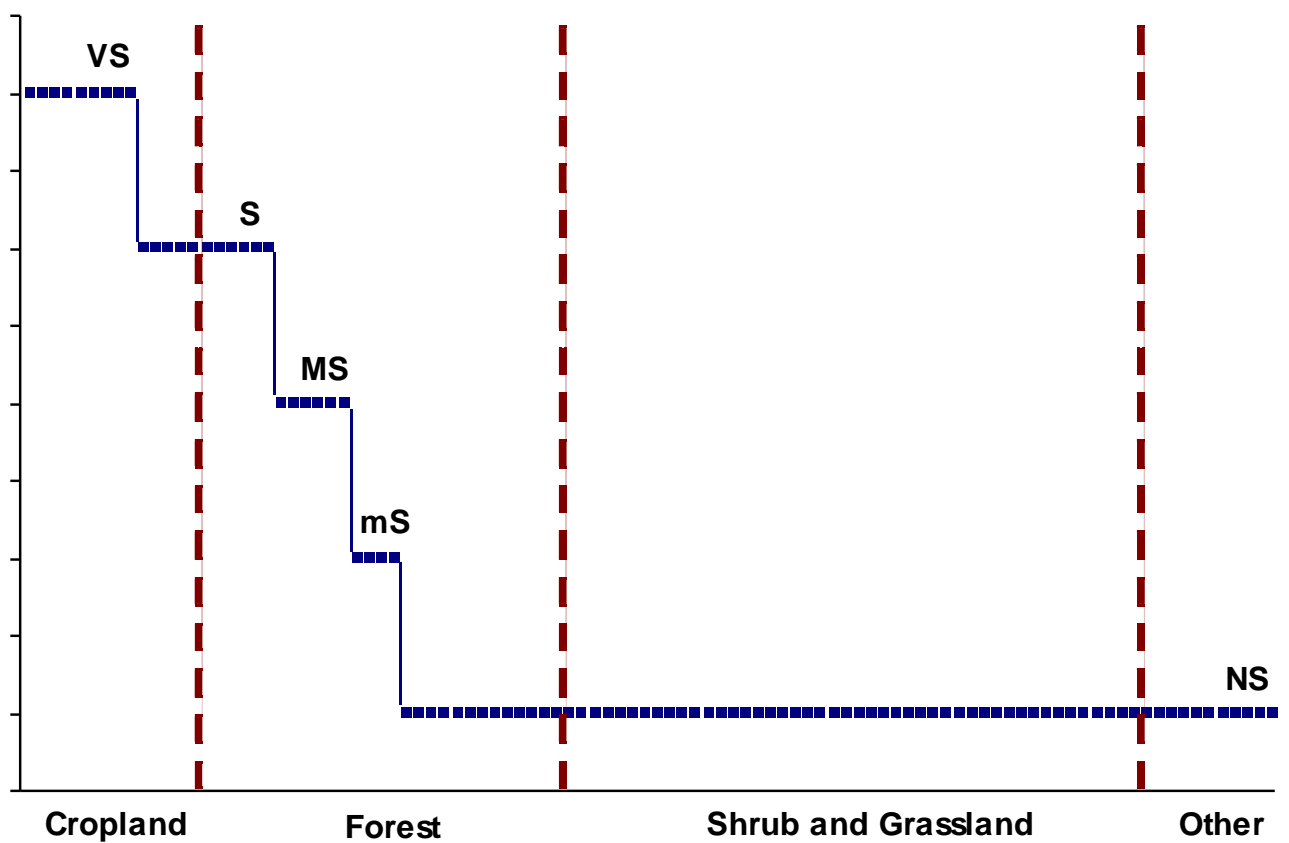
**Layout:** This worksheet begins with one identifying column: 'Land use type', which lists the land use types, breaking fishing grounds in to 'Marine' and 'Inland Water' and dividing built-up land into 'Infrastructure' and 'Hydro.' The next column, 'Equivalence Factor', lists the equivalence factors 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:** External

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





**Figure 11-1**

A schematic diagram representing the relation of suitability scores (GAEZ) to the Land Types in the National Footprint Accounts. This relation is used for the Equivalence Factor calculation which happens outside of the National Footprint Accounts workbook.

## 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 ~12 billion hectares of [biologically productive land and water](#) on this planet in 2008. Dividing by the number of people alive in that year (6.7 billion) gives 1.79 [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 2008 was approximately 12 billion hectares.

**Carbon Footprint:** When used in Ecological Footprint studies, this term is synonymous with demand on [CO<sub>2</sub> 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 unit of currency, rather than the demand on bioproductive area. The Ecological Footprint encompasses the carbon Footprint, and also captures the extent to which measures for reducing the carbon Footprint lead to changes in other Footprint components.

**CO<sub>2</sub> area (or CO<sub>2</sub> land):** The demand on biocapacity required to sequester (through photosynthesis) the carbon dioxide (CO<sub>2</sub>) 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 CO<sub>2</sub> 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 CO<sub>2</sub> which is not absorbed by the ocean.

**Consumption:** Use of goods or of services. The term consumption has different meanings, depending on the 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 analysis 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 either the food, goods, or shelter component, but only in one.

**Consumption Footprint:** The most commonly reported type of [Ecological Footprint](#), it is defined as 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 associated with that consumption. 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 the column headings in the table below, 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 that sub-national region.

Consumption Land Use Matrix

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

**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](#).

**Derived product:** The product resulting from the processing of a [primary product](#). For example wood pulp, a secondary product, is a derived product of roundwood. Similarly, paper is a derived product of wood pulp.

**Double counting:** In order not to exaggerate human demand on nature, Footprint Accounting avoids double counting, or counting the Footprint of the same product or waste emissions 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 2008, 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 to the national scale, the global ecological deficit cannot be compensated for through trade, and is therefore [overshoot](#) by definition.

**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](http://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 [CO<sub>2</sub> 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 2.51. Grazing lands, which have lower productivity than cropland, have an equivalence factor of 0.46 (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 [primary product](#) to the quantity of the resulting [derived product](#). When a primary 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 to 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 (e.g. 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 (CO<sub>2</sub>). 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, respectively, 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:** 10,000 square meters, 1/100th of a square kilometre, 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).

**Intertemporal Yield Factor:** A scaling factor that accounts for changes in the world-average [yield](#) of the same [land use type](#) over time.

**Land type:** The Earth's approximately 12 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 assesses 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 80+ [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* biological capital, or ecological capital for short. This capital is defined as the stock of living ecological assets that yield biological productivity-based goods and services on a continuous basis. Main functions include resource production (such as fish, timber or cereals), waste assimilation (such as CO<sub>2</sub> 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 effectively no net-import of resources to the planet. Local overshoot occurs when a local ecosystem is exploited more rapidly than it can renew itself.

**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 the 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](#) (1.78 gha in 2008). In 2008, the world average Ecological Footprint of 2.7 gha equals 1.48 Planet equivalents.

**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 types of 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 forest [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 cotton 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.

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

**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 weights the different [productivities](#) of different [land types](#) within a given country. Each country and each year has yield factors for cropland, grazing land, forest, and fisheries. For example, in 2008, German cropland was 2.21 times more productive than world average cropland. (The German cropland yield factor of 2.21, multiplied by the cropland [equivalence factor](#) of 2.51,

converts German cropland hectares into [global hectares](#): one hectare of German cropland is equal to 5.6 gha).

Note: 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 2014** workbook, tables are often assigned a named range. The named ranges are given the same name as the worksheet on which they appear, with some exceptions. 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 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 2014** workbook, conditional formatting has been used to hide Excel formatting error codes 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<sub>p</sub> 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 2014** 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 2-1

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 2-2

Calculation of biocapacity for Single Land Type

$$BC = A * YF * IYF * EQF$$

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<sup>-1</sup>

IYF = Intertemporal Yield factor of a given land use type for that year, (unitless)

EQF = equivalence factor for given land type, gha wha<sup>-1</sup>.

### (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 2-3

Ecological Footprint of Yearly Product Extraction or Waste Generation

$$EF = \frac{P}{Y_N} * YF * EQF * IYF$$

Where:

- EF = Ecological Footprint associated with product or waste, gha
- P = amount of product extracted or waste generated, t yr<sup>-1</sup>
- Y<sub>N</sub> = national-average yield for product extraction or waste absorption, t nha<sup>-1</sup> yr<sup>-1</sup>
- YF = Yield factor of a given land type within a country, wha nha<sup>-1</sup>
- EQF = equivalence factor for given land type, gha wha<sup>-1</sup>.
- IYF = Intertemporal Yield factor of a given land use type within a given year, (unitless)

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)

$$EF = \frac{P}{Y_w} * EQF * IYF$$

Where:

- Y<sub>w</sub> = world-average yield for product extraction or waste absorption, t wha<sup>-1</sup> yr<sup>-1</sup>

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 Derived Products (section 2.2.4)**

World average extraction rates are currently used throughout *NFA 2014* 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 derived product. Yields of derived products are calculated using **Equation 2-4**.

**Equation 2-4**  
Calculation for Yield of Derived Products

$$Y^D = Y^P * EXTR$$

Where:

- Y<sup>D</sup> = Yield of derived product, (t derived) ha<sup>-1</sup> yr<sup>-1</sup>
- Y<sup>P</sup> = Yield of parent product, (t primary) ha<sup>-1</sup> yr<sup>-1</sup>
- EXTR = Extraction rate, (t derived) (t primary)<sup>-1</sup>

**(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 6-1**  
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)<sup>-1</sup>  
 TE = Transfer efficiency of aquatic ecosystems, t feed (t product)<sup>-1</sup>  
 = 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 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<sup>-1</sup>.  
 $Y_N^L$  = Yield for a given country and land type, t nha<sup>-1</sup>  
 $Y_W^L$  = World-average yield for a given land type, t wha<sup>-1</sup>

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

Equation 100-2 is used for cropland, which produces more than one primary product.

$$\text{Equation 10-2}$$

Yield Factors Extended Calculation

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

Where:

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

**(9) Equation 10-3: Intertemporal Yield Factor**

$$\text{Equation 00-3}$$

Intertemporal Yield Factor Calculation

$$IYF_{w,j} = \frac{\sum_i \frac{P_{w,i,j}}{Y_{w,i,b}}}{\sum_i \frac{P_{w,i,j}}{Y_{w,i,j}}}$$

Where:

- w = world values
- i = product
- j = year
- b = base year
- $IYF_{w,j}$  = world-average Intertemporal Yield Factor in year j
- $P_{w,i,j}$  = world amount of product harvested (or  $\text{CO}_2$  emitted) for product i in year j
- $Y_{w,i,b}$  = world product-specific yield for product i in the base year
- $Y_{w,i,j}$  = world product-specific yield for product i in year j

## 13 References

- Borucke, M., D. Moore, G. Cranston, K. Gracey, K. Iha, J. Larson, E. Lazarus, M. Wackernagel, and A. Galli, 2012. Calculation Methodology for the National Footprint Accounts, 2011 Edition. Oakland: Global Footprint Network.
- British Petroleum. 2013. Statistical Review of World Energy. [http://www.bp.com/content/dam/bp/excel/Energy-Economics/statistical\\_review\\_of\\_world\\_energy\\_2013\\_workbook.xlsx](http://www.bp.com/content/dam/bp/excel/Energy-Economics/statistical_review_of_world_energy_2013_workbook.xlsx) (accessed January 2014).
- Corine Land Cover 2000. European Topic Centre on Land Use and Spatial Information, 2000. Barcelona: EIONET. <http://www.eea.europa.eu/data-and-maps/data/data-viewers/land-accounts> (accessed October 2013).
- Ewing B, A. Reed, S. Rizk, A. Galli, M. Wackernagel, J. Kitzes. 2008. *Calculation Methodology for the National Footprint Accounts, 2008 Edition*. Oakland: Global Footprint Network.
- Fishbase Database. Froese, R. and D. Pauly (Eds.) 2008. <http://www.fishbase.org> (accessed June 2008).
- Food and Agriculture Organization of the United Nations FAOSTAT Statistical Databases. <http://faostat.fao.org/site/291/default.aspx> (accessed 2006-2008).
- FAO ForeSTAT Statistical Database. <http://faostat.fao.org/site/626/default.aspx> (accessed October 2013).
- FAO PopSTAT Statistical Database. <http://faostat.fao.org/site/452/default.aspx> (accessed October 2013).
- FAO ProdSTAT Statistical Database. <http://faostat.fao.org/site/526/default.aspx> (accessed October 2013).
- FAO ResourceSTAT Statistical Database. <http://faostat.fao.org/site/377/default.aspx#anchor> (accessed August 2007, January 2013).
- FAO TradeSTAT Statistical Databases. <http://faostat.fao.org/site/406/default.aspx> (accessed October 2013).
- FAO FishSTAT Fisheries Statistical Database. <http://www.fao.org/fishery/figis> (accessed October 2013).
- FAO Supply Utilization Accounts Statistical Database. 2003. <http://faostat.fao.org/site/355/default.aspx#anchor> (Archived from prior FAOSTAT)
- FAO. 1998. *Global Fiber Supply Model*. <ftp://ftp.fao.org/docrep/fao/006/X0105E/X0105E.pdf> (accessed October 2008).
- FAO. 2000. *Technical Conversion Factors for Agricultural Commodities*. <http://www.fao.org/es/ess/tcf.asp>. (accessed October 2008)
- Galli, A., J. Kitzes, P. Wermer, M. Wackernagel, V. Niccolucci, and E. Tiezzi, 2007. An Exploration of the Mathematics behind the Ecological Footprint. *International Journal of Ecodynamics* 2(4): 250-257.
- Global Agro-Ecological Zones. FAO and International Institute for Applied Systems Analysis 2000. <http://webarchive.iiasa.ac.at/Research/LUC/GAEZ/index.htm>. (accessed October 2013).
- Global Footprint Network and World Wildlife Fund for Nature. 2012. Living Planet Report 2012. Switzerland: WWF.
- 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, no longer available from that link. GIS data is available at <http://bioval.jrc.ec.europa.eu/products/glc2000/products.php>).

- Global Land Use Database. Center for Sustainability and the Global Environment, University of Wisconsin-Madison. 1992. <http://www.sage.wisc.edu/iamdata/units.php/> (accessed January 2013).
- 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.
- Gulland, J.A. 1971. The Fish Resources of the Ocean. West Byfleet, Surrey, England: Fishing News.
- Hammond, G.P. and C.I. Jones, 2008, 'Embodied energy and carbon in construction materials', *Proc. Instn Civil. Engrs: Energy*, in press.
- Interfacultaire Vakgroep Energie en Milieukunde Energy Analysis Program, Research Report no. 98, Groningen, 1999.
- Intergovernmental Panel on Climate Change. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture Forestry and Other Land Use*. <http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html> (accessed September 2008).
- IPCC. 2001. *Climate Change 2001: The Scientific Basis*. Cambridge, UK: Cambridge University Press, 2001.
- International Energy Agency. CO<sub>2</sub> Emissions from Fuel Combustion Database. 2013. <http://wds.iea.org/wds/> (accessed October 2013).
- . Hydropower FAQ. <http://www.ieahydro.org/faq.htm> (accessed October 2008).
- . 2011. Key World Energy Statistics. Paris:International Energy Agency.
- Kitzes, J., A. Peller, S. Goldfinger and M. Wackernagel. 2006. Calculating the 2006 Edition of the National Footprint Accounts. Oakland: Global Footprint Network.
- Kitzes, J., A. Galli, M. Bagliani, J. Barrett, G. Dige, S. Ede, K. Erb, S. Giljum, H. Haberl, C. Hails, S. Jungwirth, M. Lenzen, K. Lewis, J. Loh, N. Marchettini, H. Messinger, K. Milne, R. Moles, C. Monfreda, D. Moran, K. Nakano, A. Pyhälä, W. Rees, C. Simmons, M. Wackernagel, Y. Wada, C. Walsh and T. Wiedmann. A Research Agenda for Improving National Ecological Footprint Accounts. 2007. Oakland: Global Footprint Network.
- Krausmann, Fridolin. IFF. Wien, Austria. personal communication.
- Marland, G., T.A. Boden, and R. J. Andres. 2007. Global, Regional, and National Fossil Fuel CO<sub>2</sub> Emissions. In *Trends: A Compendium of Data on Global Change*. Oak Ridge, TN: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory and U.S. Department of Energy.
- Pauly D. and V. Christensen. 1995. Primary production required to sustain global fisheries. *Nature*. 374: 255-257.
- Sea Around Us Project. Fisheries Centre, Pew Charitable Trusts and the University of British Columbia. 2008. <http://www.seaaroundus.org/project.htm> (accessed October 2008).
- Thormark, C. (2002), "A low energy building in a life cycle-its embodied energy, energy need for operation and recycling potential", *Building and Environment* 37, pg. 429-435.
- United Nations Commodity Trade Statistics Database. 2013. <http://comtrade.un.org/> (accessed June 2013).
- UN Economic Commission for Europe and Food and Agriculture Organization of the United Nations. 2005. *European Forest Sector Outlook Study*. <http://www.unece.org/timber/docs/sp/sp-20.pdf> (accessed October 2008).
- UNECE and FAO. 2000. *Temperate and Boreal Forest Resource Assessment*. Geneva: UNECE, FAO.
- Vaclav Smil. 2000. *Feeding the World: A Challenge for the Twenty-First Century*. Cambridge: MIT Press.
- Wackernagel, M., C. Monfreda, D. Moran, P. Wermer, S. Goldfinger, D. Eumling and M. Murray. National Footprint and Biocapacity Accounts 2005: the underlying calculation method. 2005. Oakland: Global Footprint Network.
- World Resources Institute Global Land Cover Classification Database. <http://earthtrends.wri.org> (accessed March 2008), no longer available from that link.