

Guidebook to the National Footprint and Biocapacity Accounts



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Advancing the Science of Sustainability



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Guidebook Authors:

David Lin
Laurel Hanscom
Jon Martindill
Michael Borucke
Lea Cohen
Alessandro Galli
Elias Lazarus
Golnar Zokai
Katsunori Iha
Mathis Wackernagel
Chaya Kapoor

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For further information, please contact:

Global Footprint Network
1528 Webster Street
Oakland, CA 94612 USA
Phone: +1.510.839.8879
E-mail: data@footprintnetwork.org
Main website: <http://www.footprintnetwork.org/>
Open data website: <http://data.footprintnetwork.org/>
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Abbreviations

BC	Biocapacity
Constants	Constants Worksheet
EF	Ecological Footprint
EF _E	Ecological Footprint of Exports
EF _I	Ecological Footprint of Imports
EF _P	Ecological Footprint of Production
EQF	Equivalence factor
gha	Global hectares
IYF	Intertemporal Yield Factor
m ³	Cubic meters
m ³ rwe	Cubic meters roundwood equivalent
NFA	National Footprint and Biocapacity Accounts
nha	National-average hectares (for a given land use type)
NPP	Net Primary Production
PPR	Primary Production Requirement (for fish species)
t	Metric tonnes
wha	World average hectares (for a given land use type)
YF	Yield Factor
IEA	International Energy Agency
UN Comtrade	United Nations Commodity Trade Statistics Database
UN FAO	United Nations Food and Agricultural Organization

A Note on Excel Tables

Comments are included as explanatory notes within tables where appropriate and are indicated by a small red triangle in the upper right corner of a cell.

Throughout the **NFA 2021** workbook, tables are often assigned a named range. The named ranges are usually given the same name as the worksheet on which they appear.

Throughout the **NFA 2021** 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.

1 Introduction

1.1 About the NFA 2021

This Guidebook accompanies the National Footprint and Biocapacity Accounts 2021 Edition (hereafter **NFA 2021**). **NFA 2021** covers 234 countries and territories and the world, for all years between 1961 and 2017.

1.1.1 Licensing

Global Footprint Network licenses **NFA 2021** results under a Creative Commons Attribution-ShareAlike 4.0 International License ([CC-BY-SA 4.0](https://creativecommons.org/licenses/by-sa/4.0/)). These data are available for download on the Ecological Footprint Explorer – <http://data.footprintnetwork.org>.

[Free NFA calculation workbooks](#) are available for Hungary and the World. Research and project licenses are available for approximately 150 countries for 1961 to 2017.

Detailed information on licensing options, including the link to download a free Academic Edition, is available on [Global Footprint Network's website](#) or may be obtained by contacting Global Footprint Network directly (data@footprintnetwork.org or +1.510.839.8879).

1.1.2 Additional Information

Users interested in the full methodology of the **NFA 2021** should consult the National Footprint and Biocapacity 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).

2 Structure of the NFA 2021

2.1 Overview

The NFA 2021 shows all steps of a national Ecological Footprint and biocapacity calculation, from raw data to aggregate Footprint and biocapacity. Figure 1-1 shows an overview of the components and calculations that comprise the National Footprint and Biocapacity Accounts.

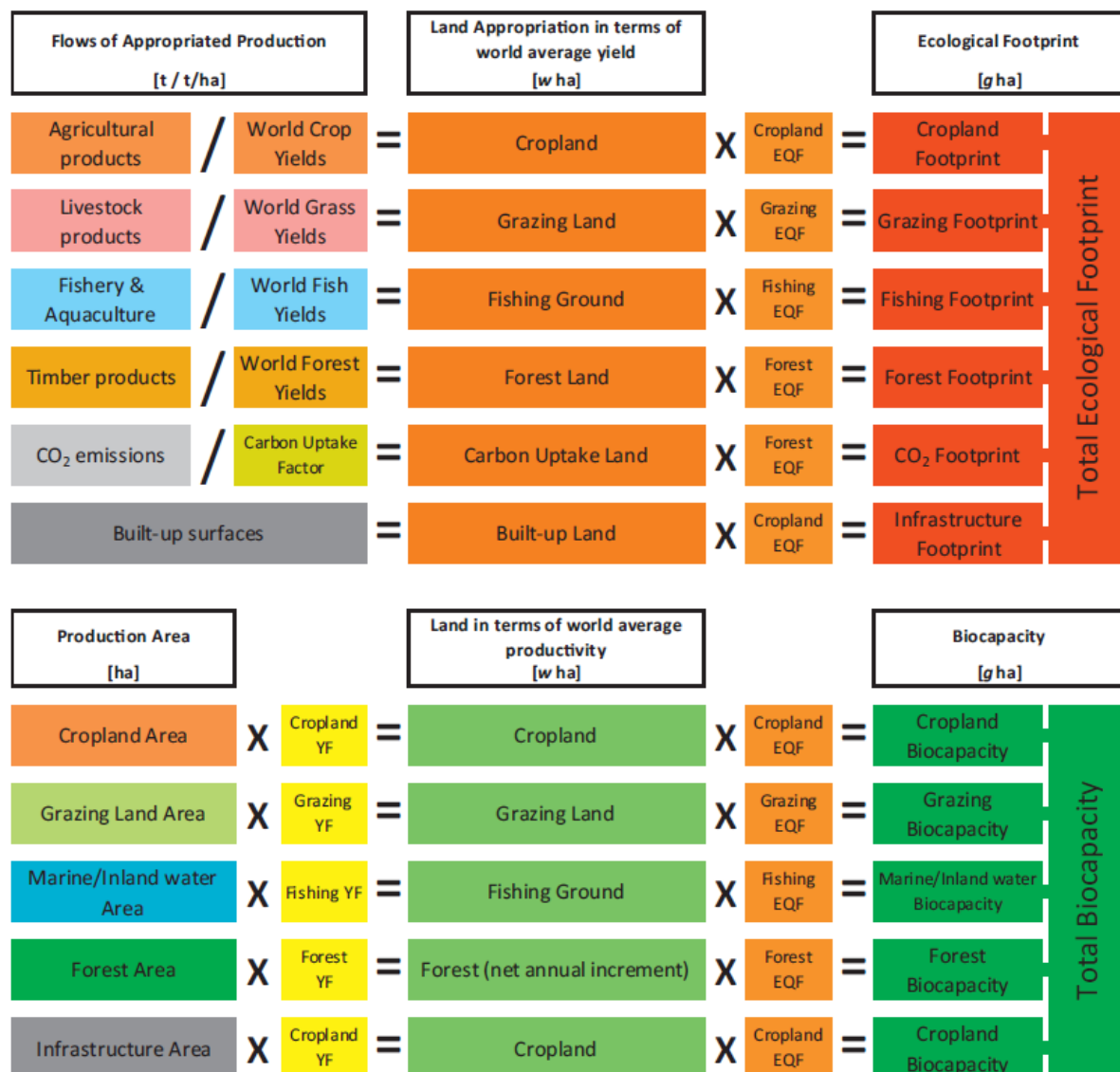


Figure 1-1 The framework of the National Footprint and Biocapacity Accounts.

2.2 Worksheets in NFA 2021

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**.

2.2.1 Summary Worksheet

Hungary					
Ecological Footprint and Biocapacity Totals					
Demand Type [-]	EF _{Production} [gha]	EF _{Imports} [gha]	EF _{Exports} [gha]	EF _{Consumption} [gha]	Biocapacity [gha]
Crop	18,539,259	2,587,871	9,652,599	11,474,532	18,539,259
Grazing	236,673	701,216	324,112	613,776	732,926
Forest Products	2,891,020	3,336,679	1,581,903	4,645,796	6,668,513
Fish	21,457	172,762	28,371	165,847	61,156
Built-up	1,864,292	-	-	1,864,292	1,864,292
Carbon	13,581,789	14,055,787	11,816,940	15,820,636	-
TOTAL	37,134,489	20,854,314	23,403,925	34,584,878	27,866,146
Ecological Footprint and Biocapacity Per Capita					
Demand Type [-]	EF _{Production} [gha person ⁻¹]	EF _{Imports} [gha person ⁻¹]	EF _{Exports} [gha person ⁻¹]	EF _{Consumption} [gha person ⁻¹]	Biocapacity [gha person ⁻¹]
Crop	1.85	0.26	0.96	1.14	1.85
Grazing	0.02	0.07	0.03	0.06	0.07
Forest Products	0.29	0.33	0.16	0.46	0.66
Fish	0.00	0.02	0.00	0.02	0.01
Built-up	0.19	0.00	0.00	0.19	0.19
Carbon	1.35	1.40	1.18	1.57	0.00
TOTAL	3.70	2.08	2.33	3.44	2.77

Figure 2-2-1 The summary worksheet combines the calculated Ecological Footprint and biocapacity for all land use types for the given country and year.

Explanation and Notes:

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, and 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 person.

The third table 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 (net trade for World is always zero), and the fourth row summarizes the Footprint of consumption. The row labelled BC - EF_P shows the biocapacity minus the Ecological Footprint of production, which represents the unused domestic biocapacity. The final row, BC - EF_C, 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 indicate a deficit.

		Total		Per Capita	
		Hungary	World	Hungary	World
Available Biocapacity	[gha]	21,665,692	12,044,043,506	2.17	1.70
Footprint of Production	[gha]	33,484,872	18,584,284,482	3.36	2.62
Net Imports	[gha]	-4,358,523		-0.44	
Footprint of Consumption	[gha]	29,126,349		2.92	
(BC - EF _P)	[gha]	-11,819,180	-6,540,240,976	-1.18	-0.92
(BC - EF _C)	[gha]	-7,460,657		-0.75	

Figure 2-2-2 Comparison summary between nation and World values

To the right of this table is the number of planets required if everyone lived like the people 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.

The topmost table draws Footprints of domestic production, imports, exports and final consumption from 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 [Chapter 8](#) 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.

2.2.2 Ecological Footprint of by Land Use Type Worksheets

These worksheets summarize the Footprints of Production (EF_P), Imports (EF_I), Exports (EF_E) and Consumption (EF_C). 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](#)).

ef_carbon summarizes the carbon Footprint of fossil fuel combustion and electricity trade.

ef_crop summarizes the Footprint of cropland embodied in crop products and in feed products for livestock and fish (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.

ef_forest summarizes the forest products Footprint embodied in primary and secondary forest products.

ef_built summarizes the Footprint associated with infrastructure.

biocap reports a country's bioproductive area and biocapacity in each of the six land use types.

Each worksheet reports the Footprint of production, imports, exports, and consumption for the different components that make up each land use type. The final row in each table sums the Footprints of all components to calculate a total Footprint for that land use type. These totals are used in the *summary* worksheet.

These 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**.

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 a product or waste

EF_p = Footprint of production associated with product or waste

EF_I = Footprint of imports associated with product or waste

EF_E = Footprint of exports associated with product or waste

The 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 factor (YF), intertemporal yield factor (IYF), and equivalence factor (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⁻¹

IYF = Intertemporal Yield factor of a given land use type for that year, *no units*

EQF = Equivalence factor for given land use type, gha wha⁻¹

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

2.2.3 Other Worksheets

The remaining worksheets convert tonnes of a product into the number of global hectares necessary to provide that product. These worksheets include calculations, raw data (in grey cells), and constants (in blue cells). 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.

In calculating Footprints of production, imports, and exports, the basic Ecological Footprint formula is used:

Equation 2-3

Ecological Footprint of Yearly Product Extraction or Waste Generation

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

Where:

EF_P = Ecological Footprint associated with a product or waste, gha

P = Amount of product extracted or waste generated, t yr⁻¹

Y_N = National-average yield for product extraction or waste absorption, t nha⁻¹ yr⁻¹

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

EQF = Equivalence factor for given land use type, gha wha⁻¹

IYF = Intertemporal Yield factor of a given land use type, *no units*

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_W = World-average yield for product extraction or waste absorption (t wha⁻¹ yr⁻¹)

Equation 2-3b reflects the actual implementation of Ecological Footprint calculations in **NFA 2021**. Modifications to this standard formula are noted in the chapters on specific land use types below.

Worksheets that contain intermediate calculations necessary between the raw data and the calculation of the Ecological Footprint, such as yield calculations (e.g., aquaculture_production_n), are often named with the suffix 'n' or 'w' to denote national- or world-level rates.

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, Mancini et al. 2015, SeaAroundUs, FRA 2010). 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 2021** 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) $ha^{-1} yr^{-1}$
 Y^P = Yield of primary product, (t primary) $ha^{-1} yr^{-1}$
EXTR = Extraction rate, (t derived) (t primary) $^{-1}$

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 2021** 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. Consequently, 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).

3 Carbon Footprint

3.1 Description

3.1.1 Overview

The carbon Footprint represents the area of forest land required to sequester anthropogenic carbon dioxide emissions. The **NFA 2021** 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** based on the Footprint intensity of carbon. This conversion factor is derived from the following:

- the yield of the productive land that is required to absorb the carbon dioxide emissions
- the amount of carbon absorbed by oceans
- an equivalence factor for carbon as a **land type**
- an adjustment factor for temporal changes in yield from the forest

The International Energy Agency (IEA) tracks carbon dioxide emissions from fossil fuel combustion across 45 different economic sectors. These data are used in **NFA 2021** 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 is used (Bogen et al. 2013). 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 "international transport emissions." These emissions are allocated to countries according to their respective domestic fossil fuel combustion by the proportion of national to world imports. Emissions from cement are attributed to the producing country; those from gas flaring emissions are distributed based on a country's percentage of World fossil fuel consumption.

3.1.2 Notes

Unlike elsewhere in **NFA 2021**, the carbon Footprint section lists traded commodities by their SITC revision 1 codes, because the longest historical time series are 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 value for each commodity category represents the sum of all energy used for production and waste disposal of a unit weight of that commodity. Like the carbon intensity of energy use, the embodied emissions values 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 International Transport Emissions data (which is 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 2021 includes a category of carbon dioxide emissions from sources other than fossil fuels and allocates emissions from oil and gas flaring (fugitive emissions), cement production, and other industrial processes.

3.2 Worksheets [\(Data Sources\)](#)

3.2.1 ef_carbon

Name [-]	EF _P [gha]	EF _I [gha]	EF _E [gha]	EF _C [gha]
Fossil Fuel Emissions	13,581,789	11,895,508	10,990,203	14,487,093
Other Sources	-	-	-	-
Traded Electricity	-	1,167,614	826,737	340,877
International Transport	-	992,665	-	992,665
TOTAL	13,581,789	14,055,787	11,816,940	15,820,636

Figure 3-2: ef_carbon summarizes the carbon Footprints of production, imports, and exports for anthropogenic carbon emissions.

Explanation and Notes:

For the 'Fossil Fuel Emissions' category, the 'EF_P,' 'EF_I,' and 'EF_E' columns report values aggregated from the worksheets fossil_efp and carbon_efi_efe. The 'EF_C' column for this category is calculated according to [Equation 2-1](#). 'Other Sources' do not involve traded commodities so 'EF_C' is equal to 'EF_P' for each. The 'Traded Electricity' category contains only 'EF_I,' and 'EF_E,' 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_P' value from 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 'Traded Electricity' category draws its 'EF_I' and 'EF_E' values from electricity_trade, accounting for the emissions embodied in traded electricity.

3.2.2 fossil_efp

<div>summary</div> <div>ef_carbon</div>		Refers to: cnst_carbon Referenced by: ef_carbon	iyf carbon_intensity_n	eqf
-----------------------------------------	--	------------------------------------------------------------------------------------	-----------------------------------------------------------	---------------------

Name	Production	Yield	IYF	EQF	EF _p
[-]	[Mt CO ₂ yr ⁻¹]	[t CO ₂ wha _r ⁻¹ yr ⁻¹]	[-]	[gha wha _r ⁻¹]	[gha]
CO2 Fuel Combustion	40.00	2.68	1.00	1.29	13,520,906
Main Activity Electricity and Heat Production	11.10	2.68	1.00	1.29	3,752,051
Main Activity Electricity Plants	6.80	2.68	1.00	1.29	2,298,554
Main Activity CHP Plants	2.70	2.68	1.00	1.29	912,661
Main Activity Heat Plants	1.60	2.68	1.00	1.29	540,836
Own Use in Electricity, CHP and heat plants	0.00	2.68	1.00	1.29	0
Unallocated Autoproducers	0.20	2.68	1.00	1.29	67,605
Autoproducer Electricity Plants	0.00	2.68	1.00	1.29	0

Figure 3-2-2: fossil_efp calculates the carbon Footprint of fossil fuel combustion emissions in a country.

Explanation and Notes:

The fossil_efp worksheet calculates the carbon Footprint of production of different economic sectors, which are identified in the first column, 'Name.'

'Production' and 'Yield' show emissions and world average carbon uptake per hectare, respectively. 'EQF' contains the equivalence factor for forest land, and 'IYF' lists the intertemporal yield factor which is given the value of 1 for all commodities. 'EF_p' calculates the carbon Footprint of emissions from each of the sectors and sector summaries.

'Yield' is drawn from cnst_carbon, and returns the carbon sequestration factor divided by the ratio of carbon to carbon dioxide. Yield represents the annual carbon uptake of a hectare of world average forest. 'EQF' is the equivalence factor for forest land, drawn from eqf. The 'IYF' column provides the intertemporal yield factors. The 'EF_p' column is calculated according to [Equation 2-3](#).

Total CO₂ production (emissions) is reported in the first row, 'CO₂ Sectoral Approach'. This is used to calculate the fossil fuel Footprint of production, which is then used in ef_carbon.

3.2.3 other_CO2_efp

<div>summary</div> <div>ef_carbon</div>		Refers to: cnst_carbon Referenced by: ef_carbon
-----------------------------------------	--	------------------------------------------------------------------------------------

Name	Unit	Value
CO2 - Fugitive	[Mt CO ₂ yr ⁻¹]	7406.77
CO2 - Industrial processes	[Mt CO ₂ yr ⁻¹]	
Footprint intensity of carbon	[gha (t CO ₂) ⁻¹ yr ⁻¹]	0.34
Footprint of non-fossil fuel carbon emissions	[gha]	2,534,394,689

Figure 3-2-3: other_co2_efp calculates the Footprint of carbon dioxide emissions from sources other than fossil fuels.

Explanation and Notes:

This section includes carbon dioxide emissions from sources other than fossil fuels and allocates emissions from oil and gas flaring (fugitive emissions), cement production, and other industrial processes.

3.2.4 carbon_efi_efe

summary

ef_carbon

Refers to:

cnst_carbon

carbon_intensity_n

Referenced by:

ef_carbon

carbon_intensity_n

Name	SITC-1 Code	Imports	Exports	EmbEn	Energy _i	Energy _E	ImportsCO ₂	ExportsCO ₂	EF _i	EF _E
[-]	[-]	[kg yr ⁻¹]	[kg yr ⁻¹]	[Gj t ⁻¹]	[Gj yr ⁻¹]	[Gj yr ⁻¹]	[Mt CO ₂ yr ⁻¹]	[Mt CO ₂ yr ⁻¹]	[gha]	[gha]
Bovine cattle including buffaloes	0011	6,964,500	31,656,300	53	369,119	1,677,784	0.021150	0.086965	5419	22,282
Sheep,lambs and goats	0012	1,788,400	14,659,600	31	55,941	458,552	0.003205	0.023768	821	6,090
Swine	0013	32,747,900	32,481,100	36	1,192,024	1,182,312	0.068300	0.061283	17499	15,701
Poultry,live	0014	256,781	1,875,171	28	7,241	52,880	0.000415	0.002741	106	702

Figure 3-2-4: carbon_efi_efe calculates the embodied Footprint of imports and exports of 625 traded goods.

Explanation and Notes:

‘Name’ and ‘SITC-1 Code’ provide a descriptive name and the United Nations SITC revision 1 code for identifying commodities, respectively, for each product category. ‘Imports’ and ‘Exports’ give the total imported and exported 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. ‘Energy_i’ and ‘Energy_e’ calculate the total embodied energy of the goods by multiplying ‘Imports’ or ‘Exports’ by ‘EmbEn’ for each good. ‘ImportsCO₂’ and ‘ExportsCO₂’ then converts this energy amount into equivalent carbon dioxide emissions. The final columns, ‘EF_i’ and ‘EF_e,’ calculate the embodied Footprint of imports and exports for each of the 625 categories of traded goods.

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_i’ by a constant drawn from cnst_carbon: ‘World Primary Energy Carbon Intensity.’ ‘EF_i’ is then calculated by multiplying ‘ImportsCO₂’ by the Footprint intensity of carbon, drawn from cnst_carbon. The last row in carbon_efi_efe sums the Footprint values for all imported and exported goods. This total is used as the Footprint of imports and exports in ef_carbon.

3.2.5 Int_transport

summary		ef_carbon		Refers to: cnst_carbon
				Referenced by: ef_carbon
Name	Unit	Value		
International Transport Emissions (Mt CO ₂)	[Mt CO ₂]	3.87		
International Transport EF	[gha]	992,665		

Figure 3-2-5: Int_transport calculates the Footprint of International Transport.

Explanation and Notes:

‘International Transport EF’ is derived by multiplying ‘International Transport Emissions’ by the Footprint intensity of carbon (from cnst_carbon) and converting to gha units.

3.2.6 electricity_trade

<div>summary</div> <div>ef_carbon</div>		Refers to: cnst_carbon		
		Referenced by: ef_carbon		
Electricity [-]	Energy [GWh]	CO2 Energy Intensity [Mt GWh ⁻¹]	Emissions [Mt CO ₂ yr ⁻¹]	Footprint [gha]
Imports	12,774	3.57E-04	4.6	1,167,614
Exports	8,871	3.64E-04	3.2	826,737
Production	40,025	3.66E-04	14.6	

Figure 3-2-6: electricity_trade calculates the Footprint of Imported and Exported Electricity.

Explanation and Notes:

The Footprint for Electricity Exports and Imports is calculated as the product of Emissions and the Footprint intensity of carbon converted to appropriate units. Emissions for Electricity Imports is calculated as the product of the 'Energy' column and a Regional Electricity Carbon Intensity factor obtained from [cnst_carbon](#). 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 in Mt CO₂/GWh.

3.2.7 carbon_intensity_n

<div>summary</div> <div>ef_carbon</div>		Refers to: carbon_trade fossil_efp cnst_carbon		
		Referenced by:		
Name	Energy [GJ]	Carbon Intensity [Mt CO ₂ / GJ]	Total Emissions Total CO ₂ (Mt / yr)	
Imports	810,304,816	5.72975E-08	46	
Domestic TPES	1,108,120,356	4.78378E-08	53	
Exports	827,555,726	5.18334E-08		

Figure 3-2-7: carbon_intensity_n calculates carbon intensity at the national level.

Explanation and Notes:

'Carbon Intensity' is the amount in tonnes of CO₂ per gigajoule of energy produced and 'Total Emissions' reflects the total amount of CO₂ emitted per year. Domestic TPES represents Domestic Total Primary Energy Supply.

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 [carbon_efi_efe](#). The 'Energy' column of Domestic TPES is reported as the total primary energy supply for a nation, or if that is not reported, it is calculated as the ratio between Total Emissions and CO₂ 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 'CO₂ Sectoral Approach'.

3.2.8 cnst_carbon

<div>summary</div> <div>ef_carbon</div>		Refers to: eqf Referenced by: fossil_efp other_co2_efp carbon_trade carbon_intensity_n electricity_trade Int_transport_efp
Name	Unit	Value
C to CO ₂ Ratio	[t C (t CO ₂) ⁻¹]	0.27
Carbon Sequestration Factor	[t C wha ⁻¹ yr ⁻¹]	0.97
Ocean Uptake Fraction	[-]	0.281
National Electricity Carbon Intensity	[Mt CO ₂ (GWh) ⁻¹]	3.66E-04
Regional Electricity Carbon Intensity	[Mt CO ₂ (GWh) ⁻¹]	3.57E-04
World Primary Energy Carbon Intensity	[t CO ₂ GJ ⁻¹]	5.73E-02
Total Primary Energy Supply	[PJ]	1108.120
Footprint Intensity of Carbon	[gha (t CO ₂ (yr ⁻¹)) ⁻¹]	0.256

Figure 3.2.8: cnst_carbon displays constants specific to the carbon Footprint calculation.

Explanation and Notes:

This worksheet provides constants for use in the rest of the carbon Footprint calculations. The first record, 'C to CO₂ 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, FRA 2010, Mancini et al. 2015).

'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 2006) 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 CO₂ Emissions from Fuel Combustion Database 2020).

'Footprint Intensity of Carbon' gives the Footprint per ton of carbon dioxide emitted. It is calculated by dividing the equivalence factor for forest land (drawn from eqf) by the 'Carbon Sequestration Factor', 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.

4 Cropland Footprint

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 2021** workbook tracks the production of 177 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 2015 (FAO ProdSTAT Statistical Database).

4.1.2 Notes

FAOSTAT codes in the cropland section of **NFA 2021** 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 and crops used for animal feed (e.g., alfalfa), fibres (e.g., cotton), and other uses (e.g., tobacco and rubber).

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 2021** includes a subsection on livestock trade, which accounts for the embodied cropland and grazing land Footprints in traded livestock products.

4.2 Worksheets [\(Data Sources\)](#)

4.2.1 ef_crop

Name [-]	EF _P [gha]	EF _I [gha]	EF _E [gha]	EF _C [gha]
Crop Products	10,986,746	1,803,009	5,668,912	7,120,843
Crop in Domestic Livestock	7,552,513	174,895	2,589,806	5,137,603
Crop in Traded Livestock		609,412	1,393,552	(784,140)
Crop in Fish	-	555	329	226
TOTAL	18,539,259	2,587,871	9,652,599	11,474,532

Figure 4-2-1: Ef_crop summarizes the cropland Footprints of production, imports, exports, and consumption.

Explanation and Notes:

For the 'Crop Products' group, the 'EF_P,' 'EF_I,' and 'EF_E' columns report values directly from the *crop_efp* and *crop_efi_efe*. For each record, the value in the 'EF_C' column is calculated using

[Equation 2-1](#). The final row in the ef_crop table shows totals for the Footprints of production, imports, exports, and consumption. To avoid double counting, the total Footprint of production for the 'Crop Products' group is calculated by summing only the Footprints of production of the 164 primary products. The final cropland Footprint of consumption is calculated by applying Equation 2-1 to the column totals.

4.2.2 crop_efp

<div>summary</div>		<div>ef_crop</div>		Refers to: crop_intensity Referenced by: ef_crop				constant_crop_factor grass_supply_n		eqf yf_crop		iyf	
Name	FAO Code	HS+ Code	Production _N	Yield _W	IYF	EQF	EF _P						
[-]	[-]	[-]	[t yr ⁻¹]	[t wha ⁻¹ yr ⁻¹]	[-]	[gha wha ⁻¹]	[gha]						
Agave Fibres Nes	800	5304_c		0.77	0.99	2.56	-						
Alfalfa for forage and silage	641	1214.90_c	3,462,590	34.59	0.99	2.56	253,957						
Almonds, with shell	221	0802.11_a	161	1.47	0.99	2.56	278						
Anise, badian, fennel, corian.	711	0909.00	2,396	0.71	0.99	2.56	8,613						
Apples	515	0808.10_a	568,600	14.15	0.99	2.56	101,958						
Apricots	526	0809.10_a	26,761	7.27	0.99	2.56	9,334						

Figure 4-2-2: crop_efp calculates the Footprint of production of 164 crop products.

Explanation and Notes:

'Production' and 'Yield' show the production quantities and yields for domestically produced goods. The 'EQF' column provides the equivalence factor for cropland. The 'IYF' column provides the intertemporal yield factors. 'EF_P' uses the values in the preceding four columns to calculate the Footprint of productions for each crop included in this worksheet, as per [Equation 2-3b](#).

4.2.3 crop_efi_efe

<div>summary</div> <div>ef_crop</div>		Refers to:	crop_efp constant_ag_extr eqf iyf						
		Referenced by:	ef_crop						
Name	FAO Code	HS+ Code	Imports _N	Exports _N	Yield	IYF	EQF	EF _I	EF _E
(-)	(-)	(-)	[t yr ⁻¹]	[t yr ⁻¹]	[t wha ⁻¹ yr ⁻¹]	(-)	[gha wha ⁻¹]	[gha]	[gha]
Wheat		15 1001_a	22,005	2,112,600	2.51	0.99	2.56	22,219	2,133,158
Flour, wheat		16 1101.00	31,285	128,055	2.27	0.99	2.56	34,891	142,813
Bran, wheat		17 2302.30	0	70,126	4.85	0.99	2.56	-	36,700
Macaroni		18 1902_a	10,273	873	2.27	0.99	2.56	11,457	974
Germ of Wheat		19 1104.30_a			1.47	0.99	2.56	-	-
Bread		20 1905_a	6,826	134	2.62	0.99	2.56	6,620	130
Bulaur		21 1904_b			2.39	0.99	2.56	-	-

Figure 4.2.3: crop_efi_efe calculates the Footprint of imports and exports for 413 agricultural products.

Explanation and Notes:

'Imports,' 'Exports' and 'Yield' show import quantities and world-average yields for traded products. 'EQF' gives the equivalence factor for cropland and 'IYF' gives the intertemporal yield factor. 'EF_I' and 'EF_E' use the values in the preceding columns to calculate the Footprint of imports or exports for each product, as per [Equation 2-3b](#).

4.2.4 crop_intensity

<div>summary</div> <div>ef_crop</div>		Refers to:	ef_crop	crop_efp	bioproductive_area
		Referenced by:	yf_crop	crop_efp	
Name	Unit	EF _P	EF _I	EF _E	
Crop Products + Crop in Livestock	[gha]	18,539,259	2,587,871		9,652,599
Crop Area Intensity	[-]	120%	106%		18%
Crop Area Intensity Tax/Premium	[gha]	3,706,550	144,610		1,759,524

Figure 4-2-4: crop_intensity calculates the intensity of national and global cropland.

Explanation and Notes:

‘Crop Products + Crop in Livestock’ refers to the national cropland Footprint. ‘Crop Area Intensity’ is the ratio of area harvested over bioproductive area. Since farmers can grow multiple crops throughout the year, a country can harvest more hectares of cropland than is nationally available. Countries that harvest more cropland than is available have a high intensity (>100%), while countries that leave some cropland area unharvested have a low intensity (<100%). This crop area intensity is also calculated for the world. National and World yields are then scaled using this intensity factor. For example, if a country averages two crops per hectare, that country’s crop area intensity will be 50%. That country’s national yield will then be halved, resulting in a lower Footprint per tonne of production. ‘Crop Area Intensity Tax/Premium’ is the change in Footprint caused by the Cropland Area Intensity adjustment.

4.2.5 constant_crop_factor

<div>summary</div> <div>ef_crop</div>		Refers to:	crop_efp	residue_supply_n	grass_supply_n
		Referenced by:	market_feed_supply_n		
Item	Code	Water Content	Nutrition Index		
Wheat	15	14%	1.038		
Bran, wheat	17	12%	1		
Beverages, fermented wheat	26	90%	1		
Rice, Paddy	27	14%	1		
Rice – total (Rice milled equivalent)	30	12%	1		
Bran, rice	35	10%	1		
Cake, rice bran	37	10%	1		
Barley	44	14%	0.998		
Maize	56	14%	1		

Figure 4-2-5: constant_crop_factor contains data on the water content and nutrition index of crops.

Explanation and Notes:

‘Water Content’ refers to the average % content of water in each agricultural product. ‘Nutrition Index’ is a measurement of nutritional value by weight compared to products in the same aggregate groups. The nutrition index is used to weight different products in the same group when summing their production to calculate an average yield. Currently, only the items in the “Cereals” aggregate group have a calculated Nutrition Index.

5 Grazing Land Footprint

5.1 Description

5.1.1 Overview

The grazing land Footprint assesses demand for grazing land to feed livestock and the embodied demand for grazing land in traded goods. This is the most logically complex section of **NFA 2021**. 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 2021** relies on the methodology and data proposed by Haberl et al. (2008) for calculating human appropriation of net primary production (NPP). 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.

Section 5.2 describes all worksheets containing calculations or data pertaining solely to the grazing land Footprint. Livestock Trade (section 5.3) 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 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, so the grazing land Footprint of production is not allowed to exceed available biocapacity.

5.2 Worksheets: Grazing Land [\(Data Sources\)](#)

5.2.1 ef_grazing

Name [-]	EF _P [gha]	EF _I [gha]	EF _E [gha]	EF _C [gha]
Domestic Grazing	236,673	-	-	236,673
Grazing in Livestock	32,745	701,216	324,112	409,848
TOTAL	236,673	701,216	324,112	613,776

Figure 5-2-1: ef_grazing summarizes the grazing land Footprints of production, imports, exports, and consumption.

Explanation and Notes:

‘Domestic Grazing Land’ contains the Footprint of production and ‘Grazing in Livestock’ reports the embodied Footprint of imports and exports. The ‘EF_C’ column is calculated using Equation 2-1.

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

5.2.2 grazing_efp

summary	ef_grazing	Refers to: <code>residue_supply_n</code> <code>grass_supply_n</code> <code>feed_demand_n</code> <code>market_feed_supply_n</code> <code>feed_intensity_w</code> <code>biocap</code>
		Referenced by: <code>livestock_feed_ef_n</code> <code>ef_grazing</code>

Feed Types	Quantity [t dm yr ⁻¹]	EF Crop [gha]	EF Grazing [gha]	EF Fish [gha]
Market Feed	5,707,707	4,859,750	32,745	37,881
Residue Feed	1,160,084	-		
Cropped Grass Feed	1,663,126	277,853		
Total Non-Pasture Feed	8,530,917	3,340,105	269,418	37,881
(Crop) Feed Requirement	5,546,197			
Remaining Demand	710,655		236,673	

Figure 5-2-2: `grazing_efp` calculates the total Pasture Grass Demand needed to feed livestock nationally.

Explanation and Notes:

The **NFA 2021** assumes that livestock are fed with available crop-derived feeds and then, if necessary, with grass from grazing lands.

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 because the Footprint of grazing land is not allowed to exceed available biocapacity. The two rows below row ‘Total’ show the grass demanded for feed, and the grass actually used for feed.

5.2.3 feed_demand_n

summary	ef_grazing	Refers to: <code>feed_mix_w</code> <code>livestock_intensity_w</code> <code>feed_intensity_w</code> <code>resourcestat_livestock_n</code> <code>residue_supply_n</code> <code>constant_livestock_demand</code>
		Referenced by: <code>livestock_feed_ef_n</code> <code>livestock_feed_balance</code>

Name [-]	FAO Code [-]	HS+ Code [-]	Feed Name [-]	Feed Code [-]	Heads [head]	Feed Intake [kg dm head ⁻¹ day ⁻¹]	Feed Demand [t dm yr ⁻¹]
Asses		1107 0101.20_a	Asses	1107	2,200	6.0	4,818
Buffaloes		946 0102_b	Cattle and buffaloes	866	-	9.2	-
Camels		1126 0106.1_a	Camels	1126	-	10.0	-
Cattle		866 0102_a	Cattle and buffaloes	866	705,000	9.2	2,367,390
Chickens		1057 0105_a	Poultry	1057	29,866,000	0.1	872,087
Ducks		1068 0105ca	Poultry	1057	2,230,000	0.1	65,116
Geese and guinea fowls		1072 0105cb	Poultry	1057	1,817,000	0.1	53,056
Goats		1016 0104.20	Sheep and goats	976	67,000	1.5	36,683
Horses		1096 0101_a	Horses	1096	60,000	10.0	219,000

Figure 5-2-3: `feed_demand_n` calculates the total amount of feed needed to produce the stock of livestock of a country.

Explanation and Notes:

`Feed_demand_n` displays the names, FAOSTAT, and HS+ codes for each of the 15 types of livestock tracked. ‘Feed Name’ represents the aggregate category each type of livestock is in.

‘Heads’ shows the number of livestock produced, and ‘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.

‘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`. 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`).

5.2.4 market_feed_supply_n

summary		ef_grazing		Refers to: <code>eqf</code> <code>lyf</code> <code>crop_trade_yield_w</code> <code>fish_capture_yield</code> <code>livestock_intensity_w</code> <code>constant_crop_factor</code> Referenced by: <code>livestock_feed_balance</code>						
Feed Name	FAO Code	Primary Code	Production	Imports	Exports	Feed Amount	Dry Feed Amount	EF _p crops	EF _i crops	EF _e crops
[t]	[t]	[t]	[t yr ⁻¹]	[t yr ⁻¹]	[t yr ⁻¹]	[t yr ⁻¹]	[t dm yr ⁻¹]	[gha]	[gha]	[gha]
Wheat and products	2511	15	5,630,830	167,040	2,320,650	995,616	856,230	1,627,938	48,293	670,927
Barley and Products	2513	44	1,467,060	67,861	548,492	619,211	532,521	929,879	43,013	347,655
Maize and products	2514	56	8,897,140	47,409	3,422,280	2,959,330	2,545,024	2,501,726	13,331	962,288
Rye and products	2515	71	112,493	7,865	16,105	59,274	50,976	64,581	4,515	9,246
Oats	2516	75	181,792	1,934	5,874	126,685	108,949	130,752	1,391	4,225
Millet and products	2517	79	9,925	419	0	10,161	8,942	9,844	416	-
Sorghum and products	2518	83	13,558	388	2,612	7,964	7,088	9,619	275	1,853
Cereals, Other	2520	108	517,871	778	33,913	349,886	300,902	377,441	567	24,717
Potatoes and products	2531	116	683,935	102,293	8,478	18,500	4,070	2,400	359	30

Figure 5-2-4: `market_feed_supply_n` calculates the Footprint of various domestic crop harvests used as animal feed.

Explanation and Notes:

The list of products reported in ‘Feed Name’ excludes products counted in `grass_supply_n`. The three ‘EF’ columns report the crop, grazing, and fish Footprints associated with each crop product (as per [Equation 2-3b](#)), and ‘Feed Amount’ shows the national production of each crop used as animal feed.

5.2.5 grass_supply_n

summary		ef_grazing		Refers to: <code>prodstat_crop_n</code> <code>tradedstat_n</code> <code>eqf</code> <code>crop_trade_yield_w</code> <code>crop_efp</code> <code>constant_crop_factor</code> Referenced by: <code>livestock_feed_balance</code>					
Name	FAO Code	HS+ Code	Production	Imports	Exports	Available	Available Dry Matter	IYF	EQF
[t]	[t]	[t]	[t yr ⁻¹]	[t yr ⁻¹]	[t yr ⁻¹]	[t yr ⁻¹]	[t dm yr ⁻¹]	[t]	[gha wha-1]
Potato offals	120		-	-	-	-	-	0.99	2.56
Beet pulp	169		-	6,163	-	6,163	5,362	0.99	2.56
Straw husks	635		-	-	5,064	-	-	0.99	2.56
Maize for forage and silage	636	1214.90_a	2,776,620	-	-	2,776,620	555,324	0.99	2.56
Sorghum for forage and silage	637	1214.90_d	83,387	-	-	83,387	16,677	0.99	2.56
Rye grass for forage & silage	638	1214.90_e	-	-	-	-	-	0.99	2.56
Grasses nes for forage and silage	639	1214.90_s	315,000	-	-	315,000	63,000	0.99	2.56

Figure 5-2-5: `grass_supply_n` shows the amount of cropped feed grass available nationally.

Explanation and Notes:

‘Production’ shows the harvested quantities of each of the grass crops, in tonnes of dry matter, and ‘Imports’ and ‘Exports’ show the traded quantities of these grass products. ‘Available,’ shows the total amount of cropped grass fed to livestock, and ‘EF’ shows the Footprint associated with each type of cropped grass. This worksheet only accounts for grass specifically produced for the purpose of being

fed to livestock. This worksheet is used by `livestock_feed_balance_n` to determine the amount livestock feed demand that is met with cropped grass.

5.2.6 residue_supply_n

summary	ef_grazing	Refers to:	<code>prodstat_crop_n</code>	<code>constant_livestock_residue</code>	<code>constant_feed_region</code>	<code>constant_crop_factor</code>
		Referenced by:	<code>livestock_feed_balance</code>	<code>feed_demand_n</code>		
Crop Name	FAO Code	HS+ Code	Production	Residue Feed Ratio	Residue Feed	Dry Residue Feed
			[t yr ⁻¹]	[t residue feed (t crop dm) ⁻¹]	[t residue feed yr ⁻¹]	[t dm residue feed yr ⁻¹]
Groundnuts in shell	242	1202.10_a	10	0.05	1	1
Maize	56	1005_a	8,897,140	0.09	760,705	654,207
Millet	79	1008.20_a	9,286	0.09	794	683
Oil palm fruit	254	1207.10ab	-	0.10	-	-

Figure 5-2-6: `residue_supply_n` shows the national supply of crop residues used as livestock feed.

Explanation and Notes:

This worksheet lists each crop producing residues potentially used as livestock feed. 'Production' shows the amounts of various crops grown within a country. 'Dry Matter %' shows the percentage of dry matter in each product. 'Residue Feed Ratio' shows the amount of crop residues used as feed, as a percentage of the dry mass of usable crop material harvested, and 'Residue Feed' calculates the amount of feed derived from each type of crop residue produced within a country by multiplying 'Production,' 'Dry Matter %,' and 'Residue Feed Ratio'.

5.2.7 prodstat_livestock_n

Figure 5-2-7: `Prodstat_livestock_n` reports the national production numbers and product yield for 41 livestock products.

Explanation and Notes:

This worksheet reports the production weight, number of animals, and the weight of product per animal for 41 livestock products within the given country.

5.2.8 resourcestat_livestock_n

summary	ef_grazing	Refers to:	[External]
		Referenced by:	<code>feed_demand_n</code> <code>livestock_intensity_n_grazing</code> <code>livestock_intensity_n_fish</code> <code>livestock_intensity_n_crop</code>
Name	FAO Code	HS+ Code	Stocks
			[head]
Asses	1107	0101.20_a	2,200
Beehives	1181	0106.90_a	553,000
Buffaloes	946	0102_b	
Camels	1126	0106.1_a	
Cattle	866	0102_a	705,000
Chickens	1057	0105_a	29,866,000

Figure 5-2-8: `resourcestat_livestock` reports stocks of live animals.

Explanation and Notes:

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.

5.2.9 cnst_grazing

summary	ef_grazing	Refers to:	[External]
		Referenced by:	feed_intensity_w livestock_efi livestock_efe livestock_intensity
Name	Unit	Value	
Above-ground NPP %	[-]	70%	
Edible % of above-ground NPP	[-]	30%	

Name	Unit	Stock Code	Product Code	Slaughter Weight (World Average)	Slaughter Weight (National Average)	Import Weight	Export Weight
Asses	[t head ⁻¹]	1107	1108	0.079		0.246	0.255
Buffaloes	[t head ⁻¹]	946	947	0.144		0.252	0.190
Camels	[t head ⁻¹]	1126	1127	0.210			

Figure 5-2-9: cnst_grazing contains constant values for weight per head of various grazing animals.

Explanation and Notes:

cnst_grazing includes two tables. In the first table, 'Value' refers to above-ground NPP percent and the second row refers to edible above-ground NPP percent. The second table gives world average weights and national average weights for 16 categories of grazing animals. 'Import Weight' and 'Export Weight' contain the average weight per head of each category of grazing animal.

5.3 Worksheets: Livestock Trade [\(Data Sources\)](#)

The livestock trade section of NFA 2021 acts as a bridge between the grazing land and the cropland Footprint sections, as livestock are fed from both grazing land and cropland.

5.3.1 livestock_efi_efe

<div>summary</div> <div>ef_grazing</div>		Refers to: <div>cnst_grazing</div> <div>constant_ag_extr</div> Referenced by: <div>ef_crop</div> <div>ef_grazing</div> <div>ef_fish</div> <div>livestock_intensity</div>							
Product Name	FAO Code	HS+ Code	Imports _N	Exports _N	Imports _N	Exports _N	Intensity Crop	Crop Feed EF _i	Crop Feed EF _e
			[t or head]	[t or head]	[t]	[t]	[gha (t dt) ⁻¹]	[gha]	[gha]
Lactose	173	1702.1_a	1,984	162	1,984	162	0.66	1,303	153.87
Pet food	843		44,982	417,932	44,982	417,932	#N/A	-	-
Cattle	866	0102_a	51,231	101,268	17,872	27,605	3.91	69,818	90,416.03
Meat, cattle	867	0201.10_a	1,600	12,840	1,600	12,840	6.71	10,735	72,227.25
Offals, edible, cattle	868	0206aa	3,815	6,075	3,815	6,075	4.11	15,668	20,918.53

Figure 5-3-1: livestock_efi_efe calculates the Footprints of imports and exports of 166 livestock/animal products.

Explanation and Notes:

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 livestock_intensity. 'Total' is calculated by summing the Footprints of the various feed sources into one embodied Footprint value.

5.3.2 livestock_intensity

summary	ef_grazing	Refers to:	livestock_efi	livestock_intensity_w	livestock_feed_ef_n	resourcestat_livestock_r	prodstat_livestock_n	cnst_grazing
		Referenced by:	livestock_efe					
Live Animals	FAO Code	HS+ Code	Parent Product	Production / Stock	CROPS			
					Embodied EF [gha]	Imports _N (Weight-Adj) [t]	Imports EF [gha]	
Asses	1107 0101.20_a		Asses	345	7,565	-	-	-
Buffaloes	946 0102_b		Buffaloes	-	-	-	-	-
Camels	1126 0106.1_a		Camels	-	-	-	-	-
Cattle	866 0102_a		Cattle	327,825	1,034,953	1,286		5,105
Chickens	1057 0105_a		Chickens	59,732	117,519	11,896		17,338

Figure 5-3-2: livestock_intensity shows the Footprint intensity per tonne of traded livestock animal or primary livestock product.

Explanation and Notes:

The function of this sheet is to determine the Footprint intensity of animals and animal products exported from the current country. 'Production/Stock' refers to the total tonnes of animals or products produced nationally in the current year. For each land type used in feeding live animals, listed as CROPS, FISH, and GRAZING, there is calculated an 'Exports Intensity'. 'Embodied EF' is the amount of Footprint of the corresponding land type used in the production of each animal or product type. 'Imports_N (Weight-Adj)' is the total tonnes of each animal or primary animal product imported into the country. 'Imports EF' is the total Footprint of the corresponding land type that is embodied in the imports of each animal or primary animal product. The export intensity is calculated as the weighted average intensity of production and imports.

5.3.3 livestock_feed_ef_n

<div>summary</div> <div>ef_grazing</div>		Refers to: feed_demand_n	grazing_efp	feed_mix_w
		Referenced by: livestock_intensity		
Land Use Type	Expected Feed	Expected EF	Actual EF	Relative Feed Intensity
	[t]	[gha]	[gha]	[]
Crop Land	3,392,450	1,522,479	3,127,856	2.05
Grazing Land	2,676,014	941,001	280,541	0.30
Fishing Grounds	25,321	70,693	22,682	0.32

Name	FAO Code	World TFR	National TFR	Relative Intensity
	[]	[t feed / t LW]	[t feed / t LW]	[]
Buffaloes	946	77	27.79	0.36
Cattle	866	37	14.87	0.40
Chickens	1057	4	2.60	0.68

Figure 5-3-3: livestock_feed_ef_n calculates an adjustment factor to change the observed Ecological Footprint embodied in crop feed and grazing to the actual Ecological Footprint.

Explanation and Notes:

'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.

The calculated feed production is drawn from feed_demand_n, as is the calculated Ecological Footprint. 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. 'Relative Intensity' is the ratio of National to World Total Feed Requirement.

5.3.4 feed_intensity_w

<div>summary</div> <div>ef_grazing</div>		Refers to:	crop_efp	fish_feed_group_yield_n	crop_feed_cnst	cnst_grazing	tyf	efp
		Referenced by:	livestock_intensity_w	feed_demand_n	grazing_efp			
Name	FAO Code	HS+ Code	Primary/Derived	Parent Name	Parent Code	Extr	Yield	
						[t d / t m ²]	[t m ² / t m ²]	
Barley		44 1003	P			1.00	2.12	
Cassava		125 0714.10_a	P			1.00	3.13	
Maize		56 1005_a	P			1.00	4.28	
Oats		75 1004.00a	P			1.00	2.12	

Figure 5-3-4: feed_intensity_w calculates the world average Ecological Footprint per unit of production for livestock feed.

Explanation and Notes:

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.

'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 'IYF' column lists the Intertemporal Yield Factor. The 'Intensity' column calculates the Ecological Footprint per unit of production for each feed type by dividing the equivalence factor by the yield factor.

5.3.5 feed_mix_w

summary

ef_grazing

Refers to:

[External] crop_feed_cnst

Referenced by:

feed_demand_n livestock_intensity_w livestock_feed_ef_n

Name	FAO Code	HS+ Code	Primary/Derived	Grass %	Crop %	Fish %	Crop Total
[]	[]	[]	[]	[]	[]	[]	[t/LW ¹]
Buffaloes		946 0102_b	P	69.0%	31.0%	0.0%	16.15
Cattle		866 0102_a	P	69.0%	31.0%	0.0%	7.79
Chickens		1057 0105_a	P	0.0%	99.0%	1.0%	3.25
Ducks		1068 0105ca	P	0.0%	99.0%	1.0%	6.13
Geese and guinea fowls		1072 0105cb	P	0.0%	99.0%	1.0%	2.52
Turkeys		1079 0105_b	P	0.0%	99.0%	1.0%	2.03

Figure 5-3-5: feed_mix_w shows the percentage of Grass, Crop, and Fish that comprise the diet of each grazing animal.

Explanation and Notes:

'Crop Total' is the sum of all crops consumed by each grazing animal plus grass crops and crop residue in tonnes per live weight. '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.

TABLE 1 (beginning on Row 33) contains 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.

TABLE 2 (beginning on Row 60) contains percentages of every grain consumed by each grazing animal. These percentages are multiplied by the TFRs (listed in the top table) of every animal.

5.3.6 crop_feed_cnst

summary

ef_grazing

Refers to:

[External]

Referenced by:

feed_intensity_w

feed_mix_w

crop_efi_efe

Feed Types	World Quantity	%	Intensity
	[t]	[%]	[gha / t]
Market	1,038,321,000	49.2	-
Grass Crops	971,774,843	46.0	0.09
Residue	101,359,422	4.8	-
TOT	2,111,455,265	100.0	-

Figure 5-3-6: crop_feed_cnst contains constants of world averages of quantities for Market, Grass Crops, and Residue Feed.

Explanation and Notes:

The first column identifies 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.

5.3.7 constant_ag_extr

<div>summary</div> <div>ef_grazing</div>		Refers to: Referenced by: feed_intensity_w livestock_efi_efe crop_efi_efe						
Item	Item Code	Level	Top Parent Code	Top Parent	Parent	Sub-group	Parent Key	Parent code
Wheat	15	1	15	Wheat				
Flour, wheat	16	2	15	Wheat	Wheat	a	Wheata	15
Bran of Wheat	17	2	15	Wheat	Wheat	a	Wheata	15
Macaroni	18	3	15	Wheat	Flour, wheat	a	Flour, wheata	16
Germ of Wheat	19	2	15	Wheat	Wheat	a	Wheata	15
Bread	20	3	15	Wheat	Flour, wheat	b	Flour, wheatb	16
Bulgur	21	2	15	Wheat	Wheat	b	Wheatb	15

Figure 5-3-7: constant_ag_extr contains constants of quantity, value, price, and extraction rate for 588 food products.

Explanation and Notes:

'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. The data come from ProdSTAT and TradeSTAT. 'TCF' comes from FAO Technical Conversion Factors (2000).

5.3.8 const_grazing_npp

<div>summary</div> <div>ef_grazing</div>		Refers to: Referenced by: yf feed_intensity_w		
UN_Country_Code	Name (GFN)	Country Name	Pasture NPP	Pasture Area
			[t dm ha-1 yr-1]	[1000 ha]
2	Afghanistan	Afghanistan	2.67	43252.38
3	Albania	Albania	11.26	261.75
4	Algeria	Algeria	4.38	13024.60
5	American Samoa			
6	Andorra	Andorra	11.65	15.12
7	Angola	Angola	7.47	41105.57

Figure 5-3-8: const_grazing_npp lists the average net primary production of grazing land in every country.

Explanation and Notes:

'Pasture NPP' lists the net primary production of pastureland in that country and 'Pasture Area' lists the surface area of pastureland in that country. Pasture NPP is used in the calculation of Yield Factor and grass yield values.

5.3.9 constant_feed_region

summary	ef_grazing	Referenced by: residue_supply_n
GFN Country Name [-]	FAO Code [-]	Feed Region [-]
Afghanistan	2	SCA
Albania	3	EE
Algeria	4	NAWA
American Samoa	5	LAC
Andorra	6	WE
Angola	7	SSA

Figure 5-3-9: constant_feed_region lists the feed region of every country.

Explanation and Notes:

‘GFN Country 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. Feed Region is referenced in the calculation of the residue feed ratio.

5.3.10 constant_livestock_residue

summary

ef_grazing

Refers to:

Referenced by: residue_supply_n

Crops		E. Asia EA	E. Europe EE	Latin America LAC	N. Africa W. Asia NAWA
a) Harvest factors. Crop residue (g DM/yr) = primary crop harvest (g DM/yr) * harvest factor					
	Wheat, other cereals	1.50	1.50	1.50	1.50
	Rice, Paddy	1.00	1.20	1.20	1.20
	Maize	3.00	1.90	3.00	3.00
	Millet	3.00	1.90	3.00	3.00
	Sorghum	3.00	1.90	3.00	3.00
	Roots and tubers	1.00	1.00	1.00	1.00
	Cassava	0.80	0.80	0.80	0.80
	Sugar cane	0.70	0.70	0.70	0.70

Figure 5-3-10: constant_livestock_residue lists the crop residue feed conversion ratio for major crop types.

Explanation and Notes:

This worksheet displays the regions of the world, including 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 each crop. The final column contains the same information, but for the world (this only applies to the fourth calculation, table d). These values are used in the calculation of Residue Feed, an input for calculating total EF Crop.

5.3.11 constant_livestock_demand

summary

ef_grazing

Refers to:

Referenced by: feed_demand_n

	FAO Code	S. and C. Asia SCA	E. Europe EE	N. Africa and W. Asia NAWA	N. America and Oceania NAO
Species-specific daily feed intake (kg DM/head/day)					
Cattle and buffaloes	866	6.4	9.2	6.8	14.3
Sheep and goats	976	1	1.5	1	1.5
Pigs	1034	0.9	1.3	1.6	1.5
Poultry	1057	0.05	0.08	0.06	0.09
Horses	1096	10	10	10	10

Figure 5-3-11: constant_livestock_demand lists the species-specific daily feed intake of livestock in different parts of the world.

Explanation and Notes:

This worksheet displays the calculated daily feed intake for the species identified in each row, by region and for the world as a whole.

6 Fishing Grounds Footprint

6.1 Description

6.1.1 Overview

The Fishing Grounds Footprint represents the demands of fisheries 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 (Pauly and Christensen 1995). 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 yf 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 2021 tracks the production of 1,941 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 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 Froese and Pauly (2016), many of which have large standard errors. The uncertainty in the fisheries yields for individual species is thus large compared to other products in **NFA 2021**. 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 fisheries stocks are degrading or eroding over time at the species level, this analysis may 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). Future NFA research is looking into ways to incorporate species and geographic variability, based on new data available through SeaAroundUs.

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. Currently, 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. However, Global Footprint Network researchers are exploring ways to refine this calculation.

6.2 Worksheets [\(Data Sources\)](#)

6.2.1 ef_fish

Name [-]	EF _P [gha]	EF _I [gha]	EF _E [gha]	EF _C [gha]
Marine Capture	-	-	-	-
Inland Capture	21,457	-	-	21,457
Fish in Livestock	37,881	27,171	20,637	44,415
Commodities	-	145,590	7,734	137,856
TOTAL	21,457	172,762	28,371	165,847

Figure 6-2-1: ef_fish summarizes the fishing grounds Footprints of production, imports, exports, and consumption.

Explanation and Notes:

ef_fish reports the Footprints of production, imports, exports, and consumption for each category of products ('EF_P', 'EF_I', 'EF_E' and 'EF_C', 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 four categories in this worksheet: 'Marine capture,' 'Inland capture,' 'Fish in Livestock,' 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 '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' and 'Commodities' rows report all trade. Since traded quantities of 'Marine capture' and 'Inland capture' are not available by species, the EF_I and EF_E 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_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 2-1Equation 2-1 to the total EF_P, EF_I, and EF_E.

The trade of fish commodities is calculated in a different manner than other Footprint categories. Here, production, imports, and exports are aggregated with the original formula:

$$EF_C = EF_P + EF_I - EF_E$$

While EF_P is calculated from the specific trophic level of each harvested fish species, EF_I and EF_E apply trophic level at a higher aggregate level since many commodities do not have species level resolution. EF_I uses the average trophic level of the world catch to calculate EF from imports, and EF_E uses the average trophic level of the national catch to calculate EF from exports.

$$EF_I = \frac{I}{Y_{W'}} \quad \text{and} \quad EF_E = \frac{E}{Y_{N'}}$$

6.2.2 fish_efp

summary	ef_fish	Refers to: Referenced by:	fish_capture_yield ef_fish	eqf	iyf	constant_fish_troph cnst_fish			
Common Name (species) [-]	Scientific Name [-]	FishSTAT Code [-]	Marine Production _y [t]	Inland Production _y [t]	Yield [t wha ⁻¹ yr ⁻¹]	IYF [-]	EQF [gha wha ⁻¹]	Marine EF _p [gha]	Inland EF _p [gha]
Fiat needlefish	Ablennes hians	10118			0.01	1.00	0.37	0.00	0.00
Freshwater bream	Abramis brama	2153			0.35	1.00	0.37	0.00	0.00
Freshwater breams nei	Abramis spp	2956			0.35	1.00	0.37	0.00	0.00
Argentine seabass	Acanthistius brasilianus	3081			0.03	1.00	0.37	0.00	0.00
Kinneret bleak	Acanthobrama terraesanctae	10125			0.30	1.00	0.37	0.00	0.00
Wahoo	Acanthocybium solandri	3279			0.01	1.00	0.37	0.00	0.00
Goldsilk seabream	Acanthopagrus berda	2398			0.10	1.00	0.37	0.00	0.00

Figure 6-2-2: fish_efp calculates the Footprint of production of all marine and inland 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.

Explanation and Notes:

fish_efp shows the estimated yield, the equivalence factor for marine fishing grounds, the intertemporal yield factor, and the Footprint of production for each fish species. Following the convention used throughout **NFA 2021**, these are labelled 'Yield,' 'EQF,' 'IYF' and 'EF_p,' respectively.

When available, individual species' average trophic levels are obtained from Froese and Pauly (2016). If a trophic level estimate is not available, average values for the species group are used. The 'EF_p' column calculates the Footprint of production according to [Equation 2-3](#). This column also checks for errors, returning zeroes instead of any error values.

6.2.3 fish_efi_eft

summary

ef_fish

Refers to:

fish_commodity_yield_n eqf

iyf

Referenced by:

ef_fish

ef_crop

Commodity	HS Code	Imports	Exports	Yield _i	Yield _e
[t]	[t]	[t yr ⁻¹]	[t yr ⁻¹]	[t wha ⁻¹ yr ⁻¹]	[t wha ⁻¹ yr ⁻¹]
Abalone (Haliotis spp.), other than live, fresh or chilled	307.89			0.13	0.13
Abalone (Haliotis spp.), live, fresh or chilled	307.81			0.10	0.10
Abalone, prepared or preserved	1605.57			0.24	0.24
Agar - agar	1302.31	6	79	0.00	0.00
Alaska Pollack (Theragra chalcogramma), fillets, frozen	304.75	1019	47	0.01	0.01
Alaska Pollack (Theragra chalcogramma), fresh or chilled	302.55	22	6	0.01	0.01

Figure 6-2-3: fish_efi_eft calculates the Footprint of imported and exported fish for each of the 131 fish commodities reported.

Explanation and Notes:

fish_efi_eft reports the commodity name and the 2002 Harmonized Standard name of the traded products. 'Imports' and 'Exports' shows the tonnes of each product imported and 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 imports for each product, and the Embodied Crop Footprint. These last five columns are labelled 'Yield,' 'EQF,' 'IYF,' 'EF_i,' and 'Embodied Crop Footprint,' respectively.

'Yield' is drawn from fish_commodity_yield_n, applying worldwide average yields to all imported products. 'EQF' is drawn from eqf and 'IYF' is from iyf. The 'EF_i' column calculates the Footprint of production of imported and 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 imports and exports, drawing from fish_commodity_yield_n.

6.2.4 fish_commodity_yield_n

<div>summary</div>		<div>ef_fish</div>		Refers to: fish_group_yield_n Referenced by: fish_efi_efe		constant_fish_extr fish_efi_efe fish_group_yield_w fish_group_yield_n fish_feed_group_yield_n	
Commodity	HS Code	Parent	Feed Group	Extr	Imports Yield		
[-]	[-]	[-]	[-]	[t d (t p) ⁻¹]	[t wha ⁻¹ yr ⁻¹]	[t wha ⁻¹ yr ⁻¹]	
Abalone (Haliotis spp.), other than live, fresh or chilled	307.89	Molluscs	Molluscs, Other	0.26	0.13	0.13	
Abalone (Haliotis spp.), live, fresh or chilled	307.81	Molluscs	Molluscs, Other	0.19	0.10	0.10	
Abalone, prepared or preserved	1605.57	Molluscs	Molluscs, Other	0.47	0.24	0.24	
Agar - agar	1302.31			-	-	-	
Alaska Pollack (Theragra chalcogramma), fillets, frozen	304.75	Cod	Demersal Fish	0.51	0.01	0.01	
Alaska Pollack (Theragra chalcogramma), fresh or chilled	302.55	Cod	Demersal Fish	0.85	0.01	0.01	

Figure 6.2.4 fish_commodity_yield_n calculates the import and export yields for derived products.

Explanation and Notes:

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. 'Feed Group' and 'Extr' show which feed group the fish of the parent product belongs to and the extraction ratio (drawn from FishSTAT) 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.

'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 fish_efi_efe 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.

6.2.5 fish_group_yield_n

summary		ef_fish		Refers to: fish_efp	cnst_fish	fish_commodity_yield_n
				Referenced by: fish_commodity_yield_n	fishmeal_fishes	
Commodity Group	Catch	Effective Trophic Level	PPR	Yield	Imports	
[-]	[t yr ⁻¹]	[-]	[t C pp (t ww fish) ⁻¹]	[t ww fish (ha shelf) ⁻¹ yr ⁻¹]	[t yr ⁻¹]	[t yr ⁻¹]
Seaweeds	-	0.00	0.00	55.53	-	-
Tuna	-	0.00	0.00	0.01	182	182
Anchovies	-	0.00	0.00	0.47	25	25
Carp	5,753	2.95	12.59	0.34	392	392
Pollachius virens	-	0.00	0.00	0.01	83	83
Cod	-	0.00	0.00	0.01	3,613	3,613
Corals	-	0.00	0.00	1.51	45	45
Crab	-	0.00	0.00	0.15	141	141

Figure 6-2-5: 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.

Explanation and Notes:

'Commodity Group' lists the name for the commodity group and 'Catch' shows the capture weight of each commodity group, as the sum of individual species in each group in fish_efp. 'Effective Trophic Level' presents the fractional average trophic level for each group (as per Equation 6.1) and 'PPR' calculates the average primary production required to support a tonne of each group (Equation 6.1). The PPR is used to calculate 'Yield' in the next column, using Equation 6.2.

The 'Imports' column shows the weight of each commodity group imported, and the 'Imports Yield' shows the world-average yield for each commodity group as calculated in fish_group_yield_w.

‘Aquaculture Production N’ and ‘Aquaculture Yield N’ are shown next, and these along with imports and catch are used to determine the ‘Effective Yield N’. ‘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’ calculates the rate of crop land in feed mixes required by a combination of catch, imports, and aquaculture production. ‘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 and their standard errors is available from Froese and Pauly (2016).

6.2.6 fish_group_yield_w

summary	ef_fish	Refers to:	<code>fish_capture_yield</code>	<code>aquaculture_production_w_aqua</code>
		Referenced by:	<code>fish_commodity_yield_n</code>	<code>fish_group_yield_n</code>

Commodity Group [-]	Catch [t yr ⁻¹]	Effective Trophic Level [-]	PPR [t C pp (t ww fish) ⁻¹]	Catch Yield [t ww fish (ha shelf) ⁻¹ yr ⁻¹]	Aqu
Seaweeds	1,173,612	1.00	0.14	30.14	
Tuna	2,581,896	4.36	325.77	0.01	
Anchovies	10,284,102	2.78	8.56	0.50	
Carp	140,303	2.82	9.42	0.45	
Pollachius virens	455,941	4.38	338.30	0.01	
Cod	1,118,378	4.33	299.46	0.01	
Corals	5,526	3.32	29.41	0.14	
Crab	1,393,891	3.49	43.63	0.10	

Figure 6-2-6: `fish_group_yield_w` calculates the world-average yields of 39 major fish commodity groups.

Explanation and Notes: `fish_group_yield_w` is similar to `fish_group_yield_n`, except it contains world data, not national data. See section 6.2.5 above for a description of `fish_group_yield_n`.

6.2.7 aquaculture_yields

summary	ef_fish	Refers to:	<code>fish_feed_group_yield_n</code>	<code>eqf</code>	<code>fish_feed_group_yield_w</code>	<code>constant_aquafeed_factors</code>
		Referenced by:	<code>fish_group_yield_w</code>	<code>fish_group_yield_n</code>		

Commodity Group [-]	Meal Intensity [t fishmeal / t fish]	Oil Intensity [t fish oil / t fish]	Crop Intensity [t crops / t fish]	Fish Intensity N [fish gha / t fish]	Fish Intensity W [fish gha / t fish]	Yield N [t ww fish (ha shelf) ⁻¹ yr ⁻¹]
Seaweeds	0.00	0.00	0.00	0.00	0.00	0.00
Tuna	0.24	0.06	0.91	0.91	0.85	0.38
Anchovies	0.00	0.00	0.00	0.00	0.00	0.00
Carp	0.04	0.00	0.76	0.12	0.12	2.80
Pollachius virens	0.00	0.00	0.00	0.00	0.00	0.00
Cod	0.24	0.06	0.91	0.91	0.85	0.38
Corals	0.00	0.00	0.00	0.00	0.00	0.00
Crab	0.24	0.06	0.91	0.91	0.85	0.38

Figure 6-2-7: `aquaculture_yields` calculates the yield factors for aquaculture production, both national and world.

Explanation and Notes:

‘Meal Intensity’, ‘Oil Intensity,’ and ‘Crop Intensity’ reference feed constants and represent 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 based on the intensities and equivalence factors for Inland Water in eqf. 'Crop Intensity N' and 'Crop Intensity W' are the intensity of cropland Footprint in aquaculture fish feed mixes. 'Crop Intensity W' is calculated from the crop portion of the fish feed mix and the feed rate per ton of fish and 'Crop Intensity N' contain no data or calculations.

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

6.2.8 fish_feed_group_yield_n

summary	ef_fish	Refers to:	fish_capture_yield	fish_commodity_yield_n	fish_f
		Referenced by:	aquaculture_yields	feed_intensity_w	

FAO Category	Feed Category	Catch	Effective Trophic Level
Freshwater Diadrom Fresh	Freshwater Fish	7,394	3.40
Molluscs Excl Cephalop Frsh	Molluscs, Other	-	0.00
Crustaceans Fresh	Crustaceans	-	0.00
Demersal Marine Fish Frsh	Demersal Fish	-	0.00
Pelagic Marine Fish Frsh	Pelagic Fish	-	0.00
	Marine Fish, Other	-	0.00

Fish Group Name [gha t-1]	Imports Intensity (= Production Intensity W) [gha t-1]	Import Quantity [t]	Production Intensity N [gha t-1]
Sardines	0.98	2,055	0.98
Other Fish	0.60		0.60

Intensity of Fishmeal Fish [gha t-1]	Extraction Rate of Fishmeal [-]	Intensity of Fishmeal [gha t-1]
0.98	3.74	3.12

Intensity of Fish oil Fish [gha t-1]	Extraction Rate of Fish oil [-]	Intensity of Fish oil [gha t-1]
0.98	3.23	2.69

Figure 6-2-8: fish_feed_group_yield_n calculates the intensity of fish meal that is fed to livestock and aquaculture fish within a nation.

Explanation and Notes:

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' and are calculated using [Equation 6.1](#). 'Yield' is calculated for domestic catch. These columns are followed by columns for 'Imports' and 'Imports Yield'. The final column is 'Export Yield'.

'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 imports from fish_feed_group_yield_w. 'Exports Yield' is the weighted average yield of production (catch) and imports.

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 ('Production Intensity W' from fish_feed_group_yield_w); this is followed by a column for 'Import Quantity' ('Fish Feed Group'

from `fishmeal_fishes`) 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'. In 'Production Intensity N', the EQF 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`. 'Exports Intensity' calculates the weighted average intensity of production and imports. 'Imports + Production' is simply the weight of imports plus the weight of production.

The third table calculates the Intensity of Fishmeal and Fish Oil used in `aquaculture_yields`. 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.

6.2.9 fish_feed_group_yield_w

summary		ef_fish	Refers to: <code>eqf</code>	<code>fishmeal_fishes</code>	<code>cnst_fish</code>
			Referenced by: <code>aquaculture_yields</code>	<code>fish_feed_group_yield_n</code>	
FAO Category	Feed Category	Catch	Effective Trophic Level	PPR	
Freshwater Diadrom Fish	Freshwater Fish	12,283,217	3.48	42.69	
Molluscs Excl Cephalopods	Molluscs, Other	3,113,805	2.16	2.03	
Crustaceans Fresh	Crustaceans	6,577,197	3.02	14.92	
Demersal Marine Fish Fresh	Demersal Fish	20,890,504	4.01	145.71	
Pelagic Marine Fish Fresh	Pelagic Fish	33,506,079	3.87	103.42	
	Marine Fish, Other	9,360,039	3.10	119.66	

Fish Group Name	Production Intensity W	Production W
[-]	[g ha t ⁻¹]	[t]
Sardines	1.03	4,477,933
Other Fish	0.70	867,856

Figure 6-2-9: `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.

Explanation and Notes:

`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' and are calculated by [Equation 6.1](#). These columns are followed by 'Yield,' which comes from dividing 'Available PP' (from `cnst_fish`) by 'PPR'.

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' (referenced from `fishmeal_fishes`). For 'Production Intensity W', the EQF for Marine (referenced in `eqf`) is divided by 'Effective PPR W' which is calculated in `fishmeal_fishes`.

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. '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'.

The fourth table is for the world average yield for crop products that are used in fishmeal for imported aquaculture commodities. 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'. 'Yield W' references yields calculated in `crop_efp` 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 for cropland in `eqf` to determine the 'Crop Intensity W' of this average yield.

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.

6.2.10 fishmeal_fishes

summary		ef_fish		Refers to: fish_efp	fish_group_yield_n	cnst_fish
				Referenced by: fish_feed_group_yield_n	fish_feed_group_yield_w	
Common Name (species)	Scientific Name	FishSTAT Code	Commodity Group	Production N	Production W	Troph
[t]	[t]	[t]	[t]	[t]	[t]	
Argentine menhaden	Brevoortia pectinata	2898	Other Fish	0	1,832	
Atlantic menhaden	Brevoortia tyrannus	2094	Other Fish	0	177,520	
Brazilian menhaden	Brevoortia aurea	2093	Other Fish	0	1,375	
Capelin	Mallotus villosus	2126	Other Fish	0	282,933	
Gulf menhaden	Brevoortia patronus	2899	Other Fish	0	392,285	
Pacific menhaden	Ethmidium maculatum	2103	Other Fish	0	11,911	
Australian pilchard	Sardinops neopilchardus	3651	Sardines	0	326	

Figure 6-2-10: `fishmeal_fishes` calculates the trophic level and PPR for all of the fish used in fishmeal.

Explanation and Notes:

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'. 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.

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`. 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 the 'Total' of each column.

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

By this equation, embodied primary production increases exponentially with trophic level, assuming a transfer efficiency of 10% between trophic levels all the way up the food chain. With very limited information on the bycatch discard rates associated with different fisheries, we apply an average discard factor 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 2021** 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**.

Equation 6-2

Yield for Aquatic Species

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

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).

6.2.11 aquaculture_production_n

summary

ef_fish

Refers to:
Referenced by:

[External]
fish_group_yield_n

FishSTAT Code [-]	Common Name (species) [-]	Commodity Group [-]	Production
12441	Aba	Other Fish	
2651	Abalones nei	Molluscs	
10183	Adriatic sturgeon	Other Fish	

Figure 6-2-11: aquaculture_production_n is the source data for all fish production from aquaculture operations for a nation.

Explanation and Notes:

This worksheet displays the raw data for national aquaculture production (in tonnes), listed by species name and commodity group.

6.2.12 aquaculture_production_w

summary

ef_fish

Refers to:
Referenced by:

[External]
fish_group_yield_w

FishSTAT Code [-]	Common Name (species) [-]	Commodity Group [-]	Production
12441	Aba	Other Fish	2835
2651	Abalones nei	Molluscs	39224.65
10183	Adriatic sturgeon	Other Fish	220

Figure 6-2-12: aquaculture_production_w is the source data for all fish production from aquaculture operations at the world level.

Explanation and Notes:

Similar to aquaculture_production_n, this worksheet displays raw aquaculture production data listed by species name and commodity group. This worksheet reports data at the world level.

6.2.13 cnst_fish

summary

ef_fish

Refers to:
Referenced by:

[External]
fish_capture_yield fish_group_yield_n

Name	Unit	Value
Available PP	[t C pp (ha shelf) ⁻¹ yr ⁻¹]	4.25
Discard Factor	[-]	1.27
Transfer Efficiency	[-]	0.10

Figure 6-2-13: cnst_fish provides three constant values that are used in fish yield calculations: Available Primary Productivity, Discard Factor, and Transfer Efficiency.

Explanation and Notes:

‘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.

6.2.14 constant_aquafeed_factors

<div>summary</div> <div>ef_fish</div>		Refers to:	[External]
		Referenced by:	aquaculture_yields
Species	Aquaculture Grouping	Commodity Group	Fish Meal Intensity
Aba	Other	Other Fish	0.24
Abalones nei	Other	Molluscs	0.24
Adriatic sturgeon	Other	Other Fish	0.24
African bonytongue	Other	Other Fish	0.24
African catfish	Catfish	Other Fish	0.09

Figure 6-2-14: constant_aquafeed_factors reports the intensity of fish meal, fish oil, and other feed.

Explanation and Notes:

‘Species’ reports the 2002 Harmonized Standard name, ‘Aquaculture Group’ reports the species grouping, and ‘Commodity Group’ reports the aggregated grouping. ‘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.

6.2.15 constant_fish_extr

<div>summary</div> <div>ef_fish</div>		Refers to:	
		Referenced By:	fish_commodity_yield_n
Commodity	HS Code	Extr	
Abalone (Haliotis spp.), other than live, fresh or chilled	307.89	3.88	
Abalone (Haliotis spp.), live, fresh or chilled	307.81	5.23	
Abalone, prepared or preserved	1605.57	2.13	
Agar - agar	1302.31	-	
Alaska Pollack (Theragra chalcogramma), fillets, frozen	304.75	1.97	
Alaska Pollack (Theragra chalcogramma), fresh or chilled	302.55	1.17	
Alaska Pollack (Theragra chalcogramma), frozen	303.67	1.81	
Alaska Pollack (Theragra chalcogramma), meat, frozen	304.94	3.30	

Figure 6-2-15: constant_fish_extr reports the extraction rates of 131 aquatic commodities.

Explanation and Notes:

constant_fish_extr contains one identifying column, ‘Commodity’, reporting the commodity name. ‘Extr’ reports the extraction rate for each commodity.

6.2.16 constant_fish_trophic

summary

ef_fish

Refers to: [External]
Referenced By: fish_efp

Common Name (species) [-]	Scientific Name [-]	FishSTAT code [-]	Trophic Level [-]
Flat needlefish	Ablennes hians	10118	4.50
Freshwater bream	Abramis brama	2153	2.94
Freshwater breams nei	Abramis spp	2956	2.94
Liza abu	Abu mullet	19844	2.60
Argentine seabass	Acanthistius brasiliensis	3081	4.01

Figure 6-2-16: constant_fish_trophic reports the trophic level of 1983 aquatic species.

Explanation and Notes:

'Trophic Level' reports the trophic level of different aquatic species. Where species data are not directly available, the level is a weighted average based on the 2004 world capture production (FISHSTAT) for ISSCAAP group.

7 Forest Products Footprint

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, Mancini et al. (2015), 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 2021** workbook. The calculation of the carbon Footprint is described in [Chapter 3](#).

The **NFA 2021** workbook tracks the production of primary forest products and 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 2015 (FAO ForeSTAT Statistical Database). The product names and codes correspond to those used in this database.

7.1.2 Notes

All primary forest products are reported in units of m³ roundwood equivalent (rwe), since these are cut or otherwise processed from raw harvested wood.

Paper products might be considered tertiary products as they are made from pulp, a derived product. However, the **NFA 2021** workbook treats paper as a derived product. The extraction rates used for paper products convert tonnes of paper directly into a roundwood equivalent.

The 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. Fuelwood has no primary product counted in another category, however, so including fuelwood in the final EF_P does not lead to double counting.

Derived forest products are reported either in units of cubic meters (m³) or in metric tonnes (t). For this reason, each worksheet listing forest products includes a unit column.

Non-timber forest products, such as tree nuts, herbs, and barks, are not currently included in **NFA 2021** 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 will eventually be included.

7.2 Worksheets [\(Data Sources\)](#)

7.2.1 ef_forest_products

Name [-]	EF _P [gha]	EF _I [gha]	EF _E [gha]	EF _C [gha]
Timber Products	1,911,227	3,304,618	1,518,356	3,697,490
Wood Fuel	979,793	32,060	63,547	948,306
TOTAL	2,891,020	3,336,679	1,581,903	4,645,796

Figure 7-2-1: ef_forest_products summarizes the Footprints of production, imports, exports, and consumption both for timber and for fuel wood products.

Explanation and Notes:

‘EF_P,’ ‘EF_I,’ ‘EF_E’ and ‘EF_C’ report the Footprints of production, imports, exports and consumption, respectively, for each category. ‘EF_P,’ ‘EF_I,’ and ‘EF_E’ come directly from forest_efp and forest_efi_efe. ‘EF_C’ is calculated using Equation 2-1. **Equation 2-1**

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 and Biocapacity Accounts were treated as two separate land use types, but now comprise the forest Footprint. The ‘Wood Fuel’ category aggregates the first 3 products in the lists in forest_efp and forest_efi_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_products 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. **Equation 2-1** to the column totals.

7.2.2 forest_efp

summary

ef_forest_products

Refers to:

constant_forest_extr

constant_forest_increment

eqf

iyf

Referenced by:

ef_forest_products

forest_trade

Name	FAO Code	Unit	Production	Yield	IYF	EQF	EF _P
[-]	[-]	[-]	[m3 or t yr-1]	[m³ or t wha⁻¹ yr⁻¹]	[-]	[gha wha⁻¹]	[gha]
Wood Fuel (Total)	1864	m³	2,561,000	3.35	1.00	1.28	979,793
Wood Fuel(C)	1627	m³	75,600	3.35	1.00	1.28	28,923
Wood Fuel(NC)	1628	m³	2,485,400	3.35	1.00	1.28	950,870
Industrial Roundwood (Total)	1865	m³	2,715,000	1.82	1.00	1.28	1,911,227
Industrial Roundwood (C)	1866	m³	505,000	1.82	1.00	1.28	355,495
Industrial Roundwood (NC)	1867	m³	2,210,000	1.82	1.00	1.28	1,555,732
Sawlogs and Veneer Logs (Total)	1868	m³	1,634,500	1.82	1.00	1.28	1,150,608
Sawlogs and Veneer Logs (C)	1601	m³	130,500	1.82	1.00	1.28	91,866

Figure 7-2-2: forest_efp calculates the Footprint of production for all primary forest products harvested in a country.

Explanation and Notes:

forest_efp contains the entire list of 33 forest products, and calculates a Footprint of production for each of them. ‘Name’ identifies categories of forest product, ‘FAO Code’ gives the code used in ForeSTAT to identify the product category, and ‘Unit’ indicates the unit of each product (m³ rwe, m³, or t).

‘Production’ shows production quantities for the various products. ‘Yield’ gives product yields in tonnes per hectare, incorporating extraction rates for derived products. ‘EQF’ provides the equivalence factor for forest land. ‘IYF’ contains the intertemporal yield factors. ‘EF_p’ calculates the forest land Footprint of production for each of the listed products, 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.

7.2.3 forest_efi_efe

summary

ef_forest_products

Refers to:

constant_forest_extr

eqf

iyf

constant_forest_increment

Referenced by:

ef_forest_products

forest_efe

Name	FAO Code	Unit	Imports	Exports	Yield	IYF	EQF	EF _I	EF _E
			[m3 or t yr-1]	[m3 or t yr-1]	[m3 or t wha-1 yr-1]		[gha wha-1]	[gha]	[gha]
Wood Fuel (Total)	1864	m ³	83,800	166,100	3.35	1.00	1.28	32,060	63,547
Wood Fuel(C)	1627	m ³			3.35	1.00	1.28	0	0
Wood Fuel(NC)	1628	m ³			3.35	1.00	1.28	0	0
Industrial Roundwood (Total)	1865	m ³	206,500	660,900	1.82	1.00	1.28	145,366	465,241
Industrial Roundwood (C)	1866	m ³	124,000	213,700	1.82	1.00	1.28	87,290	150,434
Industrial Roundwood (NC)	1867	m ³	82,500	447,200	1.82	1.00	1.28	58,076	314,807
Sawlogs and Veneer Logs (Total)	1868	m ³			1.82	1.00	1.28	0	0
Sawlogs and Veneer Logs (C)	1601	m ³			1.82	1.00	1.28	0	0

Figure 7-2-2: forest_efi_efe calculates the forest Footprint of a country’s imports.

Explanation and Notes:

The *forest_efi* worksheet calculates the Footprint of imports of 33 forest products. ‘Yield’ and ‘EQF’ report yields for imported and exported products, and the equivalence factor for forest land, respectively. ‘IYF’ reports the Intertemporal Yield Factor. ‘EF_I’ and ‘EF_E’ calculate the Footprints of imports and exports for each of the products tracked in the forest land section of **NFA 2021**.

The ‘EF_I’ and ‘EF_E’ columns are calculated according to [Equation 2-3](#). They also check for errors, returning zeroes instead of error values.

7.2.4 constant_forest_extr

summary

ef_forest

Refers to:

[Constant]

Referenced by:

forest_efp forest_efi_e

Name	FAO Code	Unit	P/S	TCF	World
Sawlogs+Veneer Logs (C)	1601	m ³	p	1.00	1.00
Pulpwood,Round&Split(C)	1602	m ³	p	1.00	1.00
Pulpwood,Round&Split(NC)	1603	m ³	p	1.00	1.00
Sawlogs+Veneer Logs (NC)	1604	m ³	p	1.00	1.00
OSB	1606	m ³	s	1.42	1.42
Pulpwood+Particles(C)	1608	m ³		1.00	1.00

Figure 7-2-3: constant_forest_extr reports the extraction rates of 52 forest products.

Explanation and Notes:

‘Name’ reports the name of the product and ‘Code’ reports the FAO Code. ‘Unit’ reports the units in which the product is measured and ‘P/S’ reports whether the product is a primary or a secondary product. ‘TCF’ and ‘World’ report the extraction rates for the forest products. The extraction rate is 1 for all primary products.

7.2.5 constant_forest_increment

summary	ef_forest	Refers to:	[FRA 2010]
		Referenced by:	forest_efp forest_trade_yf
Name	Country	NAI	
		[m3 ub ha-1 yr-1]	
Net Annual Increment	Hungary	4.63	
Net Annual Increment	World	1.82	

Figure 7-2-4: 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.

Explanation and Notes:

constant_forest_increment contains two identifying columns, 'Name', and 'Country', followed by 'NAI'.

8 Built-up Land Footprint

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 2021** workbook tracks infrastructure areas required for housing, transportation, and industrial production. The calculations assume that infrastructure area covers former cropland, and apply the yield and equivalence factors for cropland to the calculation of the Footprint.

8.1.2 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.

The **NFA 2021** 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.

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 **NFA 2021** workbook likely underestimates the actual extent of impermeable surfaces overlaying productive land.

8.2 Worksheets [\(Data Sources\)](#)

8.2.1 ef_built

Name [-]	EF _P [gha]	EF _I [gha]	EF _E [gha]	EF _C [gha]
Infrastructure Area	1,522,629	-	-	1,522,629
TOTAL	1,522,629	-	-	1,522,629

Figure 8-2-1: ef_built summarizes the built-up land Footprints of production and consumption.

Explanation and Notes:

This worksheet reports the Footprints of production, imports, exports, and consumption for infrastructure areas. Since the embodied Footprints of imports and exports are not reported for built-up land, the production and consumption Footprints are equal. Infrastructure includes all housing, transportation and industrial production.

The Footprint of production is drawn from infrastructure_efp for the infrastructure area. The final column in the ef_built table totals the Footprints of production, imports, exports, and consumption for infrastructure areas. Again, the Footprint of consumption equals the Footprint of production because there are no Footprints of Imports or Exports of these areas.

8.2.2 infrastructure_efp

summary

ef_built

Refers to: yf eqf iyf bioproductive_area
 Referenced by: ef_built biocap

Name [-]	Area [ha]	Yield Factor [wha ha ⁻¹]	IYF [-]	EQF [gha ha ⁻¹]	EF _P [gha]
Infrastructure	557,571	1.32	0.99	2.56	1,861,565

Figure 9-2-2: infrastructure_efp reports the Footprint of areas occupied by human settlements and infrastructure.

Explanation and Notes:

‘Yield Factor’ and ‘EQF’ give the yield factor and equivalence factor for cropland. ‘IYF’ reports the Intertemporal Yield Factor. The final column, ‘EF_P,’ calculates the Footprint.

Infrastructure areas (‘Area’) are drawn from bioproductive_area, which contains values from the World Resources Institute Global Land Cover Classification Database, among others. Yield and equivalence factors are drawn from yf and eqf. ‘Yield’ and ‘EQF’ values for cropland are used to calculate the Footprint of infrastructure, following [Equation 2-3](#). ‘IYF’ is from iyf.

9 Biocapacity

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. 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 2021** 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 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.

9.2 Worksheets [\(Data Sources\)](#)

9.2.1 biocap

Land Cover [-]	Area [ha]	YF [wha ha ⁻¹]	IYF [-]	EQF [gha wha ⁻¹]	Biocapacity [gha]
Crop Land	5,324,431	1.28	1.00	2.52	17,250,136
Grazing Land	665,178	1.93	1.00	0.46	586,493
Marine Fishing Grounds	-	-	1.00	0.37	-
Inland Fishing Grounds	128,374	1.00	1.00	0.37	47,202
Forest Land	2,097,050	2.55	1.00	1.29	6,868,102
Infrastructure	548,808	1.28	1.00	2.52	1,778,033

Figure 9-2-1: biocap calculates the biocapacity for all bioproductive land use types in the **NFA 2021** workbook.

Explanation and Notes:

‘Area’ reports the country’s area in hectares of each land use type, taken from `bioproductive_area`. 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, calculated using [Equation 2-2](#).

‘YF’ and ‘EQF’ values are drawn from `yf` and `eqf`. ‘IYF’ 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.

9.2.2 bioproductive_area

<div>summary</div> <div>biocap</div>		Refers to: [External]		const_area_EEZ	const_area_shelf
		Referenced by: biocap		infrastructure_efp	
Source [-]	Land Use Type [-]	Description [-]	Area [000 ha]	World Area [000 ha]	
CORINE	Crop Land	Arable land + Permanent crops	5,553		
CORINE	Fishing Grounds - inland	Inland waters	176		
CORINE	Forest Land	Forests	2,046		
CORINE	Grazing Land	Pastures + Heterogeneous agricultu	878		
CORINE	Infrastructure	Artificial surfaces	558		
FAOSTAT	Crop Land	Arable land and Permanent crops	4,780	1,537,493	
FAOSTAT	Fishing Grounds - inland	Inland water	342	457,490	
FAOSTAT	Forest Land	Forest area	2,011	4,044,222	
FAOSTAT	Grazing Land	Permanent meadows and pastures	1,010	3,374,139	
FAOSTAT	Total Area	Land Area	8,961	13,009,512	
GAEZ	Infrastructure	Settlement and infrastructure	315	171,349	
GLC	Infrastructure	Infrastructure aggregate	237	3,132	
SeaAroundUs	Fishing Grounds - marine	EEZ areas	0	14,177,249	
WRI	Fishing Grounds - marine	Continental shelf area	0	2,521,764	

Figure 9-2-2: bioproductive_area contains the source data for each land use type.

Explanation and Notes:

‘Source’ lists the data sources possibly used for biocapacity calculations of each land type; the use of the most robust dataset from which data are available is prioritized. 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, bioproductive_area lists both EEZ and continental shelf areas, the latter of which is used in the fishing grounds biocapacity calculation.

9.2.3 const_npp_EEZ_shelf_area

summary

biocap

Refers to:

[External]

Referenced by:

yf

bioproductive_area

Country Code	Country Name	EEZArea Individual Land [km2]	AvgPPRate Individual Land [mgC^a-2/day]	EEZArea all land [km2]	AvgPPRate all land [mgC^a-m^2/day]	Shelf [km2]
2	Afghanistan	0	-	-	-	-
3	Albania	11,138	507	11,138	507	5,903
4	Algeria	128,865	480	128,865	480	9,171
5	American Samoa	404,391	184	404,391	184	154
6	Andorra	0	-	-	-	-
7	Angola	501,050	1,411	501,050	1,411	52,869
8	Antigua and Barbuda	107,914	261	107,914	261	3,710
9	Argentina	1 084 386	1 180	1 084 386	1 180	785 879

Figure 9-2-3: const_npp_EEZ_shelf_area reports the Exclusive Economic Zone area, average primary production rate, and continental shelf area for all countries.

Explanation and Notes:

‘EEZArea Individual Land’ reports the EEZ area around the main portion of the country. ‘AvgPPRate Individual 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. ‘Shelf’ reports the area of continental shelf surrounding each country. Within the table rows are several groups of results that report data for multiple countries that previously constituted parts of one country.

10 Yield Factors

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⁻¹

Y_N^L = Yield for a given country and land use type, t nha⁻¹

Y_W^L = World-average yield for a given land use type, t wha⁻¹

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

Equation 10-2

Yield Factors Extended Calculation

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

Where:

YF_N^L = Yield factor for a given country and land use type, wha nha⁻¹

A_N = Area harvested for a given quantity of product in a given country, nha⁻¹

A_W = Area that would be required to produce a given quantity of product using world average land, wha⁻¹

P_N = Amount of given product extracted or waste generated in a country, t yr⁻¹

Y_N = National yield for product extraction, t nha⁻¹ yr⁻¹

Y_W = World-average yield for product extraction, t wha⁻¹ yr⁻¹

10.2 Worksheets

10.2.1 yf

<div>summary</div> <div>biocap</div>		Refers to:	constant_forest_incremen	constant_area_shelf	constant_grazing_npp
		Referenced by:	biocap	infrastructure_efp	
Land use type [-]	National Yield [t ha ⁻¹]	World Yield [t wha ⁻¹]	Yield Factor [wha ha ⁻¹]		
Crop Land	5.95	4.63	1.28		
Grazing Land	11.94	6.19	1.93		
Marine Fishing Grounds		504	0.00		
Inland Fishing Grounds	-	-	1.00		
Forest Land	4.63	1.82	2.55		
Infrastructure	-	-	1.28		

Figure 10-2-1: yf calculates the yield factor for all land use types in NFA 2021.

Explanation and Notes:

‘Land Use Type’ lists all of the land use types with the exception of carbon Footprint. ‘National Yield’ 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. 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.

10.2.2 iyf

<div>summary</div> <div>biocap</div>		Refers to:	[External]
		Referenced by:	biocap infrastructure_efp market_feed_s
Land use type [-]	Inter-temporal yield factor [-]		
Crop Land	0.99		
Grazing Land	1.00		
Infrastructure	0.99		
Forest Land	1.00		
Marine Fishing Grounds	1.00		
Inland Fishing Grounds	1.00		

Figure 10-2-2: iyf reports the intertemporal yield factor for each land use type.

Explanation and Notes:

Intertemporal yield factor (iyf) 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, ignoring 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.

‘Land use type’ reports each land type, except for Carbon. ‘Inter-temporal yield factor’ reports the value of the factor for the given land use type.

Data come from internal Global Footprint Network calculations as entered in **Equation 10-3: 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_w) is thus calculated as:

Equation 10-3

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 P is the amount of a product harvested (or CO_2 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., 2017 for the National Footprint and Biocapacity Accounts 2021 Edition).

11 Equivalence Factors

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 calculated in a satellite workbook to the **NFA 2021** which is available upon request.

Equivalence factors are calculated using suitability indexes from the Global Agro-Ecological Zones (GAEZ) model, combined with information about actual areas of cropland, forest, and grazing area from FAOSTAT (Global Agro-Ecological Zones 2000; FAO ResourceSTAT Statistical Database). The GAEZ model divides all land globally into five categories, each of which is assigned a suitability score:

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

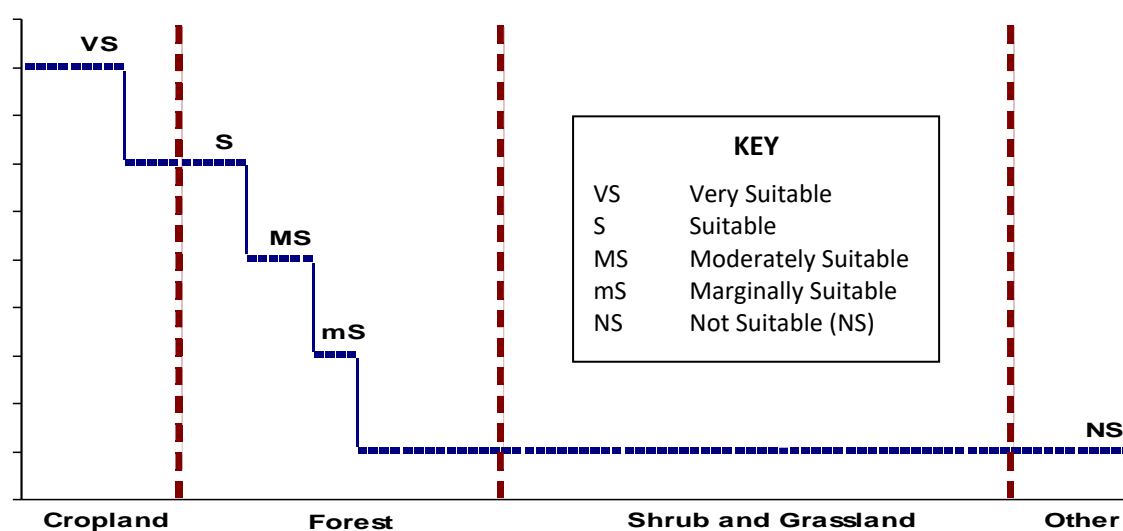


Figure 11-1 A schematic diagram representing the relation of suitability scores (GAEZ) to the Land Types in the National Footprint and Biocapacity Accounts.

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.

The equivalence factor for built up area is set equal to the equivalence factor for cropland, reflecting the assumption that built up areas occupy former cropland.

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

11.2.1 eqf

<div> <div>summary</div> <div>biocap</div> </div>		Refers to:	[External]	
		Referenced by:	biocap	fossil_efp
Land use type		Equivalence Factor		
[-]		[gha wha ⁻¹]		
Crop Land		2.52		
Forest Land		1.29		
Grazing Land		0.46		
Marine Fishing Grounds		0.37		
Infrastructure		2.52		
Inland Fishing Grounds		0.37		
Carbon		1.29		

Figure 11-2-1: eqf lists the equivalence factors for all land use types.

Explanation and Notes:

'Land use type' lists the land use types, breaking fishing grounds in to 'Marine Fishing Grounds' and 'Inland Fishing Grounds'. 'Equivalence Factor' lists the equivalence factors for all land use types. The supporting calculation for these numbers is performed internally by Global Footprint Network, based on the principles described above.

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). See [global hectare](#), [hectare](#), [local hectare](#).

Area type: see [land type](#).

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 regenerate what people demand from those surfaces. Life, including human life, competes for space. The biocapacity of a particular surface represents its ability to renew what people demand. Biocapacity is therefore the ecosystems' capacity to produce biological materials used by people and to absorb waste material generated by humans, under current management schemes and extraction technologies. Biocapacity can change from year to year due to climate, management, and also what portions are considered useful inputs to the human economy. In the National Footprint and Biocapacity Accounts, 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): The amount of [biologically productive land and water](#) area available to support the world's population in a given data year. This area also needs to accommodate the wild species that compete for the same biological material and spaces 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 and marginal areas with patchy vegetation are not included. Biomass that is not of use to humans is also not included.

Carbon Footprint: The carbon Footprint measures CO₂ emissions associated with fossil fuel use. In Ecological Footprint accounts, these amounts are converted into biologically productive areas necessary for absorbing this CO₂. The carbon Footprint is added to the Ecological Footprint because it is a competing use of bioproductive space. Some carbon Footprint assessments express results in tonnes released per year, without translating this amount into area needed to sequester them.

Consumption: Use of goods or of services. The term consumption has two different meanings, depending on context. As commonly used in regard to the Footprint, it refers to the use of goods or services. A consumed good or service embodies all the resources, including energy, necessary to provide it to the consumer. In full life-cycle accounting, everything used along the production chain is taken into account, including any losses along the way. For example, consumed food includes not only the plant or animal matter people eat or waste in the household, but also that lost during processing or harvest, and 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 (economic) [System of National Accounts](#) terminology, intermediate consumption refers to the use of goods and services by a business in providing goods and services to other businesses. Final consumption refers to non-

productive use of goods and services by households, the government, the capital sector, and foreign entities.

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

Consumption Footprint: See [Ecological Footprint of consumption](#).

Consumption Land Use Matrix: Starting with data from the National Footprint and Biocapacity Accounts, a Consumption Land Use Matrix allocates the six major Footprint land uses (shown in column headings) allocated to the five basic [consumption components](#) (row headings). For additional resolution, each consumption component can be disaggregated further. These matrices are often used as a starting point for 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 compared to the national average.

Consumption Land Use Matrix

	Built-up Land	Carbon Footprint	Cropland Footprint	Grazing Footprint	Forest Products Footprint	Fish Footprint	Total
Food							
Shelter							
Mobility							
Goods							
Services							
Total							

Conversion factor: A generic term for factors which 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 same Footprint area more than once. Double counting errors may arise in several ways. For example, when adding the Ecological Footprints in a production chain (e.g., wheat farm, flour mill, and bakery), the study must count the cropland for growing wheat only once to avoid double counting. Similar, but smaller, errors can arise in analyzing a production chain because the end product is used in 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 or 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 deficit/reserve (or biocapacity reserve/deficit): 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 exceeds its population's Footprint. If there is a regional or national ecological deficit, it means that the region is importing biocapacity through trade or liquidating regional ecological assets or emitting wastes into the 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 equal to [overshoot](#) by definition.

Ecological Footprint: A measure of how much area of [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 the world. Without further specification, Ecological Footprint generally refers to the Ecological Footprint of consumption. 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 of consumption (EF_c): 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 carbon dioxide emissions. The consumption Footprint of a nation is calculated in the National Footprint and Biocapacity 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.

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

Ecological Footprint of imports (EF_i): The Footprint embodied in domestically consumed products which are imported from other countries.

Ecological Footprint of exports (EF_e): The Footprint embodied in domestically produced products which are exported and consumed in another country.

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 Committee, composed of scientists and Footprint practitioners from around the world. Standards serve to produce transparent, reliable and mutually comparable results in studies done throughout the Footprint Community. Where Standards are not appropriate, Footprint [Guidelines](#) should be consulted. For more information, consult www.footprintstandards.org.

Ecological reserve (or biocapacity 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 trade of goods.

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](#). Equivalence factors vary by year and land use type. 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.

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 absorb a given quantity of waste, usually expressed as global hectares per tonne. The [National Footprint and Biocapacity Accounts](#) calculate a primary **Footprint Intensity Table** for each country, which includes the global hectares of primary land use type needed to produce or absorb a tonne of product (i.e., global hectares of cropland per tonne of wheat, global hectares of forest per tonne carbon dioxide).

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

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

Global hectare (gha): Global hectares are the accounting unit for Ecological Footprint and biocapacity accounts. These productivity-weighted **biologically productive hectares** allow researchers to report both the biocapacity of the earth or a region, and the demand on biocapacity (the Ecological Footprint). A global hectare is a biologically productive hectare with world average

biological productivity for a given year. Global hectares are needed because different land types have different productivity. A global hectare of, for example, cropland, would occupy a smaller physical area than the much less biologically productive pasture land, as more pasture would be needed to provide the same biocapacity as one hectare of cropland. Because world bioproductivity varies slightly from year to year, the value of a gha may change slightly from year to year.

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

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

IO (Input-Output) analysis: Input-Output (IO, also I-O) analysis is a mathematical tool widely used in economics to analyze the flows of goods and services between sectors in an economy, using data from [IO tables](#). IO analysis assumes that everything produced by one industry is consumed either by other industries or by final consumers, and that these consumption flows can be tracked. If the relevant data are available, IO analyses can be used to track both physical and financial flows. Combined economic-environment models use IO analysis to trace the direct and indirect environmental impacts of industrial activities along production chains, or to assign these impacts to final demand categories. In Footprint studies, IO analysis can be used to apportion Footprints among production activities, or among categories of final demand, and 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 or area type: The Earth's approximately 12 billion hectares of biologically productive land and water areas are categorized into five types: cropland, grazing land, forest land, fishing ground, and built-up land. Forest land serves two distinct, competing uses: Forest products and CO₂ sequestration.

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 amount of Danish hectares equals the amount of bioproductive hectares in Denmark – each Danish hectare would represent an equal share of Denmark's total biocapacity.

National Footprint and Biocapacity Accounts: The central data set that calculates the [Footprint](#) and [biocapacity](#) of the world and more than 200 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 and Biocapacity Accounts are coordinated by Global Footprint Network and their [partners](#).

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

Overshoot: [Global overshoot](#) occurs when humanity's demand on nature exceeds the biosphere's supply, or regenerative capacity. Such overshoot leads to a depletion of Earth's life supporting [natural capital](#) and a buildup of waste. At the global level, [ecological deficit](#) and overshoot are the same, since there is no net-import of resources to the planet. Local overshoot occurs when a local ecosystem is exploited more rapidly than it can renew itself.

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

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. Note that primary product and primary production Footprint are Footprint specific terms. They are not related to and should not be confused with the ecological concepts of primary production, gross primary productivity (GPP) and net primary productivity (NPP).

Production Footprint (also primary demand): see [Ecological Footprint of production \(EF_p\)](#).

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.

Tons, metric (also tonne): One metric ton equals 1000 kg, or 2205 lbs. All figures in the National Footprint and Biocapacity Accounts are reported in metric tons.

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

Yield factor: A factor that account for countries' differing levels of [productivity](#) for a given [land type](#). Yield factors are country-specific and vary by year and land use type. A country's yield factor for any land use type is calculated as the ratio of national average to world average yields. Both [equivalence factors](#) and yield factors allow Ecological Footprint and biocapacity results to be expressed in terms of [global hectares](#).

Appendix A: 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 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⁻¹

IYF = Intertemporal Yield factor of a given land use type for that year, *no units*

EQF = Equivalence factor for given land use type, gha wha⁻¹

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

In calculating Footprints of production, imports, and exports the following formula is used:

Equation 2-3

Ecological Footprint of Yearly Product Extraction or Waste Generation

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

Where:

EF_P = Ecological Footprint associated with a product or waste, gha

P = Amount of product extracted or waste generated, t yr⁻¹

Y_N = National-average yield for product extraction or waste absorption, t nha⁻¹ yr⁻¹

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

EQF = Equivalence factor for given land use type, gha wha⁻¹

IYF = Intertemporal Yield factor of a given land use type, *no units*

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_W = World-average yield for product extraction or waste absorption (t wha⁻¹ yr⁻¹)

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 2021** 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^D = Yield of derived product, (t derived) ha⁻¹ yr⁻¹

Y^P = Yield of parent product, (t primary) ha⁻¹ yr⁻¹

$EXTR$ = Extraction rate, (t derived) (t primary)⁻¹

(5) Equation 6-1: Primary Productivity Required for Yield of Aquatic Species (section 6.2.10)

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)⁻¹

TE = Transfer efficiency of aquatic ecosystems, t feed (t product)⁻¹

- 10% (Pauly and Christensen 1995)

TL = Average fractional trophic level for given species

DR = Discard rate of bycatch

- 1.27, currently applied to all fish species (Pauly and Christensen 1995)

CC = Carbon content of fish biomass, per unit wet weight

- 1/9 (Pauly and Christensen 1995)

(6) Equation 6-2: Yield for Aquatic Species (section 6.2.10)

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

Equation 6-2

Yield for Aquatic Species

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

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

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

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

Equation 10-2

Yield Factors Extended Calculation

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

Where:

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

(9) Equation 10-3: Intertemporal Yield Factor

Equation 10-3

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 CO₂ 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

Appendix B: Data Sources

Table 1: Data Sources for [Carbon Footprint](#)

Data	Worksheet	Data Source(s)
Emissions from fossil fuels	<i>fossil_efp</i>	Marland, G., T.A. Boden, and R. J. Andres. 2007. Global, Regional, and National Fossil Fuel CO ₂ 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. http://wds.iea.org/wds/ (accessed 2020).
International trade quantities by commodity	<i>carbon_efi_efe</i>	UN Commodity Trade Statistics Database. http://comtrade.un.org/ (accessed 2020).
Carbon sequestration factor; Ocean Uptake Fraction; Carbon intensity of total primary energy supply; National and regional electricity carbon intensity values	<i>cnst_carbon</i>	Mancini, M. S., et al. (2015). Ecological Footprint: refining the carbon Footprint calculation. Ecological Indicators, 61: 390-403. S. Khatiwala Univ. of Columbia (email correspondence) Khatiwala, S., Primeau, F., Hall, T. 2009. Reconstruction of the history of anthropogenic CO ₂ concentrations in the ocean. Nature 462: 346-350; Estimates based on data from IEA CO ₂ Emissions from Fuel Combustion Database. 2020. http://wds.iea.org/wds/ (accessed 2020); International Energy Agency. 2015. Key World Energy Statistics. Paris: International Energy Agency (accessed 2020).
Embodied energy of traded commodities	<i>carbon_efi_efe</i>	Global Footprint Network internal database, available upon request. Database compiled using data from Ecoinvent Database, 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 University of York.
Emissions from gas flaring and sources other than fossil fuels	<i>other_co2_efp</i>	International Energy Agency . 2020. CO ₂ Emissions from Fuel Combustion. (accessed 2020).
Emissions from International Transport Bunker Fuels	<i>Int_transport</i>	IEA International Aviation Bunkers and International Marine Bunkers (from IEA 2020 – see above)
International trade in electricity	<i>electricity_trade</i>	International Energy Agency. 2020. Key World Energy Statistics. Paris: International Energy Agency (accessed 2020).

Table 2: Data Sources for [Cropland Footprint](#)

Data	Worksheet	Data Source
Production (tonnes yr ⁻¹) and area (ha)	<i>crop_efp</i>	FAO Production Database. http://faostat3.fao.org/download/Q/*/E (accessed 2020).
Imports and exports (1000 t yr ⁻¹)	<i>crop_efi_efe</i> <i>cnst_ag_extr</i>	FAO Trade Database. http://faostat3.fao.org/download/T/*/E (accessed 2020).
Technical conversion factors for derived agricultural products	<i>extraction rate in</i> <i>cnst_ag_extr</i>	FAO Technical Conversion Factors for Agricultural Commodities (2000). http://www.fao.org/fileadmin/templates/ess/documents/methodology/tcf.pdf (accessed 2008).
Water content of crops (%)	<i>cnst_crop_factor</i>	Fridolin Krausmann, IFF, Wien, Austria (personal communication)

Table 3: Data Sources for [Grazing Footprint](#)

Data	Worksheet	Data Source
Production quantities of livestock products, and livestock populations (tonnes year ⁻¹ or heads or 1000 heads)	<i>prodstat_livestock_n</i> <i>, resourcestat_n</i>	FAO Production Database. http://faostat3.fao.org/download/Q/*/E (accessed 2020).
Imports and exports of livestock (1000 tonnes year ⁻¹)	<i>livestock_efi_efe</i>	FAO Trade Database. http://faostat3.fao.org/download/T/*/E (accessed 2020).
Feed Intake (kg dry matter head ⁻¹ day ⁻¹) and Feed Demand (tonnes dry matter year ⁻¹)	<i>feed_demand_n</i>	Haberl, H., K.H. Erb, F. Krausmann, V. Gaube, A. Bondeau, C. Plutzer, S. Gingrich, W. Lucht and M. Fischer-Kowalski. 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. <i>PNAS</i> 104: 12942-12947.
Dry matter percent (tonnes dry matter crop (tonne crop) ⁻¹)	<i>residue_supply_n</i>	Haberl, H., K.H. Erb, F. Krausmann, V. Gaube, A. Bondeau, C. Plutzer, S. Gingrich, W. Lucht and M. Fischer-Kowalski. 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. <i>PNAS</i> 104: 12942-12947.
Animal weights (tonnes head ⁻¹)	<i>cnst_grazing</i>	Vaclav Smil. 2000. <i>Feeding the World: A Challenge for the Twenty-First Century</i> . Cambridge: MIT Press.
Above-ground NPP %, edible % of above-ground NPP	<i>cnst_grazing</i>	Chad Monfreda (personal communication). 2008. SAGE, University of Wisconsin, Madison.
Number of Animals in stock (heads or 1000 heads)	<i>resourcesat_livestock</i>	FAO Production Database. http://faostat3.fao.org/download/Q/*/E (accessed 2020).

Table 4: Data Sources for [Livestock Trade Calculations](#)

Data	Worksheet	Data Source
Extraction rates , Technical Conversion Factor	<i>livestock_intensity_w</i> , <i>feed_intensity_w</i> , <i>cnst_ag_extr</i>	FAO Technical Conversion Factors for Agricultural Commodities (2000). http://www.fao.org/fileadmin/templates/ess/documents/methodology/tcf.pdf (accessed 2008).
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.
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.

Table 5: Data Sources for [Fishing Grounds Footprint](#)

Data	Worksheet	Data Source
Production, imports, exports (tons)	<i>fish_efp</i> , <i>aquaculture_production</i>	FAO FishStatJ Fisheries Statistical Database. http://www.fao.org/fishery/statistics/software/fishstatj (accessed 2020).
Trophic levels	<i>fish_yield_w</i>	Froese, R. and D. Pauly. (Eds.) 2016. FishBase World Wide Web electronic publication. http://www.fishbase.org (accessed 2020).
Primary Production (mgC/m2/day)	<i>const_npp_EEZ_shelf_area</i>	Sea Around Us Project. Fisheries Centre, Pew Charitable Trusts and the University of British Columbia. 2008. www.seaaroundus.org/data/#/eez (accessed 2014).
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>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>	Conversion Factors from FAO Fisheries Circular No. 847 revision 1 (2000). http://www.fao.org/3/x9144t/x9144t.pdf . (accessed 2020); Indicative Factors from FAO Coordinating Working Party on Fishery Statistics (CWP) Handbook of Fishery Statistical Standards Annex I.1 (2004). http://www.fao.org/3/bt963e/bt963e.pdf or http://www.fao.org/3/j4000e/j4000e.pdf (accessed 2020).

Table 6: Data Sources for [Forest Products Footprint](#)

Data	Worksheet	Data Source
Production, imports, exports (tonnes, m ³ or m ³ roundwood equivalent)	<i>forest_efp</i>	FAO ForeSTAT Statistical Database. http://faostat.fao.org/site/626/default.aspx#ancor (accessed 2020).
Derived product extraction rates (unit primary product / unit derived product)	<i>constant_forest_extr</i>	UNECE and FAO. 2005. <i>European Forest Sector Outlook Study</i> . http://www.unece.org/timber/docs/sp/sp-20.pdf
Net annual increment (m ³ ha ⁻¹ yr ⁻¹)	<i>constant_forest_increment</i>	Global Forest Resources Assessment. 2010. Food and Agriculture Organization of the United Nations. Rome. IPCC. 2006. <i>2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture Forestry and Other Land Use</i> . (accessed 2008). http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Table 7: Data Sources for [Built-up Land Footprint](#)

Data	Worksheet	Data Source
Infrastructure area (ha)	<i>infrastructure_efp</i>	Global Agro-Ecological Zones (GAEZ). FAO and International Institute for Applied Systems Analysis 2000. http://www.fao.org/ag/agl/agll/gaez/index.htm . (accessed 2020); Global Land Cover 2000. Institute for Environment and Sustainability, Joint Research Center and European Commission. Italy: IES. http://www.tem.jrc.it/glc2000/ (accessed 2014); FAO ResourceSTAT Statistical Database. http://faostat3.fao.org/home/E (accessed 2015); Global Land Use Database. Center for Sustainability and the Global Environment, University of Wisconsin-Madison. 1992. https://nelson.wisc.edu/sage/data-and-models/global-land-use/units.php (accessed 2017).

Table 8: Data Sources for [Biocapacity Calculations](#)

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. http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-clc2000-seamless-vector-database (accessed 2015).
Second source for data on cropland, grazing land, other wooded land, inland waters.	<i>bioproductive_area</i> (FAOSTAT)	FAO ResourceSTAT Statistical Database. http://faostat3.fao.org/home/E (accessed 2015).
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. http://www.fao.org/ag/agl/agll/gaez/index.htm . (accessed 2020).
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. http://www.tem.jrc.it/glc2000/ (accessed 2014).
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. https://nelson.wisc.edu/sage/data-and-models/global-land-use/units.php (accessed 2017).
Area of marine continental shelf; Area of marine EEZ	<i>const_npp_EEZ_shelf_area</i>	Sea Around Us Project. Fisheries Centre, Pew Charitable Trusts and the University of British Columbia. 2008. www.seaaroundus.org/data/#/eez (accessed 2014).

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