THE GLOBAL BIODIVERSITY SCORE

GBS Review: Wood logs CommoTool

July 2020 – Corrected version

CDC BIODIVERSITÉ

Content

Note to the reader

GBS review reports are not completely independent from each other. Readers of this report are advised to first read the reports dedicated to **Core concepts of the GBS** (CDC Biodiversité 2020a), **Terrestrial pressures on biodiversity** (CDC Biodiversité 2020d) and **Aquatic pressures on biodiversity** (CDC Biodiversité 2020b) to ensure a good overall comprehension of the tool and the present report. In the reports dealing with pressures on biodiversity, the sections describing default assessment as well as the limitation sections are especially recommended.

The following colour code is used in the report to highlight:

- Assumptions

- Important sections

- Developments of the GBS planned in the future

The GBS review reports are aimed at technical experts looking for an in-depth understanding of the tool and contribute to the transparency that CDC Biodiversité considers key in the development of such a tool. They focus on technical assumptions and principles. Readers looking for a short and easy-to-understand explanation of the GBS or for an overview of existing metrics and tools should instead read the general audience reports published by CDC Biodiversité (CDC Biodiversité 2017; CDC Biodiversité, ASN Bank, and ACTIAM 2018; CDC Biodiversité 2019c).

1 Context

1.1 Why assess the biodiversity impacts of wood log production?

Forests are among the most critical ecosystems on Earth. Aside of playing a key role in the overall Earth system and providing ecosystem services indispensable to human populations, they are the home of some of the richest biodiversity on the planet. Indeed, forests participate to climate and water cycle regulation and are therefore a natural solution to mitigate climate change and ensure clean and plentiful water supply. Human societies rely on forests for food, fuel, shelter and medicine. Forests also provide protection to human populations by reducing erosion, regulating rainfall, recharging groundwater tables and constitute a buffer against the impacts of drought and floods.

Sadly, as demand for commodities grows, forest degradation and deforestation from industrial-scale agriculture, illegal harvesting of timber and mining increases. Forest loss is further exacerbated by urbanization, diseases and fires. The FAO Forest Resource Assessment estimates that more than 5 million ha of forest have been lost between 1995 and 2015 (FAO 2015) and up to 170 million ha of forests could be destroyed by 2030 according to the WWF (WWF 2015). While the unsustainable expansion of commodity production causes permanent damage to ecosystems, displaces local communities and accelerates biodiversity loss, the inability to track where products come from and a lack of consequences for environmental outcomes make it difficult to curb these trends. Notably, charcoal and fuelwood production are pointed out as a primary cause of forest loss and forest degradation in the Congo Basin and East Africa, while unsustainable logging is an important cause of forest loss and forest degradation in almost all deforestation fronts identified by the WWF. The map of world deforestation fronts identified by the WWF is reproduced on Figure 1. Red areas delineate zones where deforestation is most likely to occur, while the figures represent the projected deforestation between 2010 and 2030 in each zone (the size of the area in red is thus not proportional to the projected deforestation, as only part of it may be deforested).

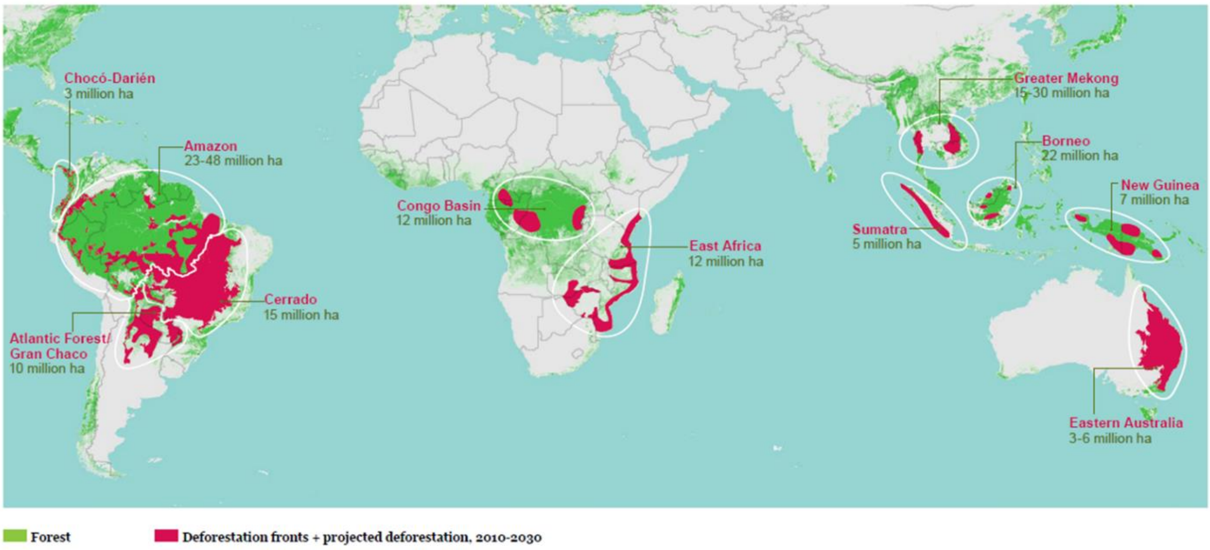

Figure 1: Worlds deforestation fronts and projected deforestation. Source: (WWF 2015)

Considering that logging, notably unsustainable logging, is a major cause of habitat deprivation and habitat loss for biodiversity, accounting for the biodiversity impacts of wood production in the GBS is needed to get a good picture of companies' impacts and provide leverage for positive change in this realm. Figure 2 provides an estimation of the role of wood production in terrestrial biodiversity losses in 2010 and its expected evolution until 2050 under a business-as-usual scenario. This work from the PBL (Netherlands Environmental Agency) is not peer-reviewed but relies on the widely used IMAGE integrated assessment model and is, to our knowledge, the only work providing an estimate of future biodiversity impacts caused by wood production until 2050.

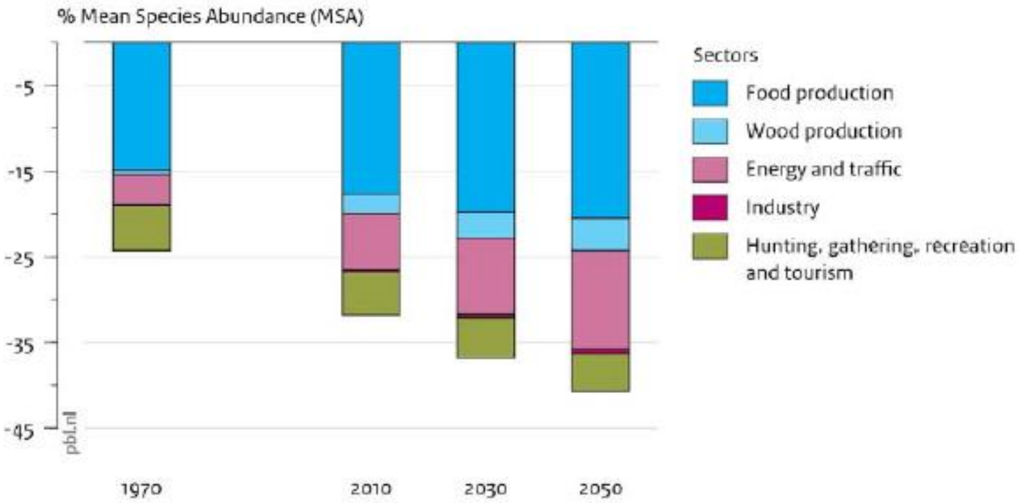

Figure 2: Attribution of terrestrial biodiversity impacts in MSA% to different production sectors under the Trend scenario Source: (Kok et al. 2014)

Restoration programmes and investments directed to forests are growing, as well as the surface of protected areas. Sustainable forest management, improved land tenure, conservation and restoration are all valuable strategies for preserving forests and maintaining biodiversity. Improved forest monitoring can help companies make more sustainable purchasing decisions, facilitate action against illegal clearing and enable policymakers to create more informed land use allocations. The wood logs CommoTool of the GBS provides companies with quantified information on the biodiversity impact of their wood production and purchases of wood products, thus enabling better inform decisions and actions towards value chains with limited impacts on forests.

1.2 Place of the wood logs CommoTool in the GBS framework

The goal of the wood logs CommoTool is to determine the **biodiversity impacts of a given tonnage of wood log**. This report explains how the **biodiversity impact factors databases for wood logs production** are constructed.

As a reminder, the evaluation of biodiversity impacts of economic activies with the GBS follows a stepwise approach according to the best data available at each step of the impact assessment (CDC Biodiversité 2020a). The wood logs CommoTool provides **biodiversity impact factors linking tonnages of wood logs to impacts on biodiversity in MSA.km².** It fits in the stepwise framework in two ways, as illustrated by Figure 3.

In default assessments, the results of the wood logs CommoTool feed the M matrix dedicated to wood products documented in EXIOBASE material account. The M matrices are the tables which gather biodiversity loss factors (in MSA.km²/t of commodity). They are combined to other matrixes which translate monetary data into inventories of raw materials and emissions in the Input-Output modelling framework (CDC Biodiversité 2019b).

In refined assessments, if “Inventory” data like wood log quantities purchased or produced (Scope 1) are available, biodiversity impact factors linking tonnages of wood logs to impacts on biodiversity in MSA.km² can be applied directly to the company’s inventory.

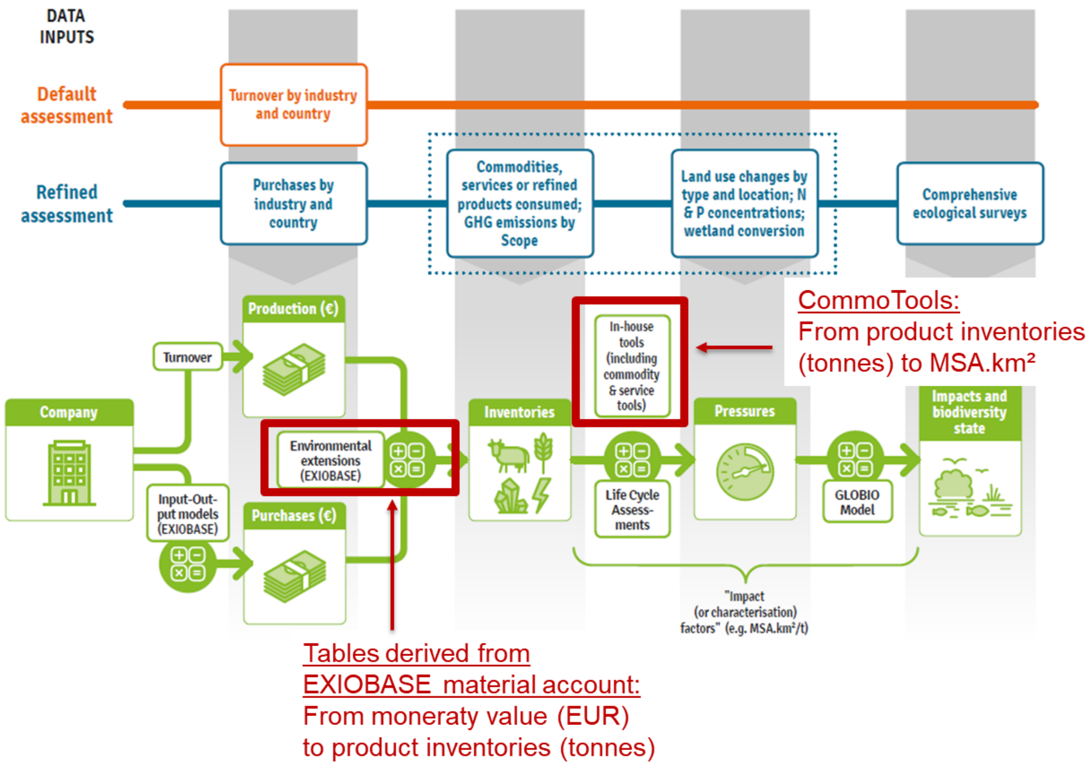

Figure 3: Woodlog CommoTool in the GBS stepwise approach

1.3 Wood logs CommoTool perimeter

A “WOOD LOG” DEFINITION AND COMMOTOOL ITEMS

Wood products are numerous and the vocabulary used to designate the output of wood production is rich. The purpose of GBS CommoTools is to compute the biodiversity impact factors related to the production of raw materials in their most raw “out-of-the-field” form, excluding transformation processes as much as possible. Hence, transformed wood products such as pulp wood, wood chips and fibreboard are not included in the CommoTool. Provides a simplified view of the wood industry and the wood logs CommoTool perimeter.

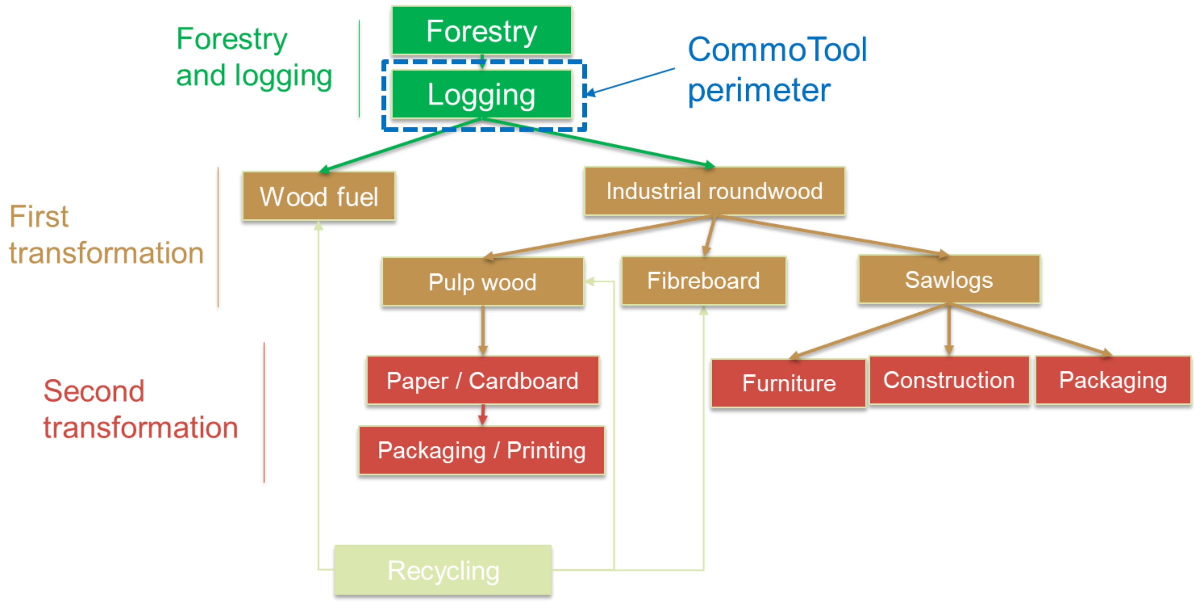

Figure 4: Simplified view of the wood industry and wood logs CommoTool perimeter

Most often, wood production data distinguish two “raw” wood categories: **wood fuel** and **industrial roundwood**. “Wood fuel” designates “*roundwood that will be used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel), round or split, and wood that will be used for the production of charcoal (e.g. in pit kilns and portable ovens), wood pellets and other agglomerates*”[1], while “industrial roundwood” designates “*all roundwood except wood fuel*”[2]. The term **“wood log” is thus chosen here to refer to both wood fuel and industrial roundwood**. Also, **coniferous** (softwood) and **non-coniferous** (hardwood) wood are distinguished.

The wood logs CommoTool thus provides biodiversity impact factors related to the production of hardwood and softwood per GLOBIO country and per EXIOBASE region.

B PRESSURES CONSIDERED

[1] FAOSTAT definition, http://www.fao.org/forestry/34572-0902b3c041384fd87f2451da2bb9237.pdf
[2] FAOSTAT definition, http://www.fao.org/forestry/34572-0902b3c041384fd87f2451da2bb9237.pdf

As a reminder, the pressures accounted for in the GBS are:

- Terrestrial pressures: land use (LU), encroachment (E), fragmentation (F), atmospheric nitrogen deposition (N); climate change (CC);
- Aquatic pressures: land use in catchment of rivers (LUR) and wetlands (LUW), wetland conversion (WC), hydrological disturbance (HD_{Water}, HD_{Infra} and HD_{CC}), freshwater eutrophication (FE).

HD_{Water} is the share of hydrological disturbance caused by water abstraction and water management on waterbodies (rivers, lakes, wetlands). Conceptually, all water abstractions should be considered. However, we do not have yet a found a satisfying method to dimension the impacts of green water, *i.e.* water related evapotranspiration of the vegetation. Thus, only blue water consumption is considered. Indeed, consumption and withdrawal data related to blue water are more easily available and their impact on the flow of rivers and wetlands is more direct. Hence, as in the crops CommoTool, green water consumption related to vegetation growth is considered to have zero biodiversity impact in the wood logs CommoTool.

2 Wood logs CommoTool overview

2.1 Dimensioning the biodiversity impacts of wood production

In the wood logs CommoTool, the dimensioning step determines the contribution of wood production to the biodiversity impact in each selected geographical region. The general concept is that **biodiversity impact factors** (expressed in MSA.km² per unit of pressure) calculated for terrestrial and freshwater biodiversity are combined to **relevant data related to wood** such as wood yields, wood type or GHG emissions per tonne of wood produced. At the end of the computation process, **the biodiversity impact factors** obtained **(in MSA.km² per tonne of wood commodity)** can be declined at different geographical scales. For more details about terrestrial and aquatic biodiversity impacts intensities, please refer to dedicated review reports (CDC Biodiversité 2020d; 2020b).

To make a parallel with the LCA framework, the wood logs CommoTool uses several types of data and characterisation factors, as described in Figure 5. For instance, for land use, a given tonnage of wood plays the role of the **LCA inventory** data in the GBS. It is linked to an occupied area, which is a **midpoint**, through a **midpoint characterisation factor** based on the wood yield. The midpoint is linked to an **endpoint impact** in MSA.km² through a **midpoint to endpoint characterisation factor** which corresponds to the impact intensities in MSA.km²/unit of pressure (here the area dedicated to crops). The impact factors in MSA.km²/t constituting the wood logs CommoTool are a **combination of the midpoint and endpoint characterisation factors.**

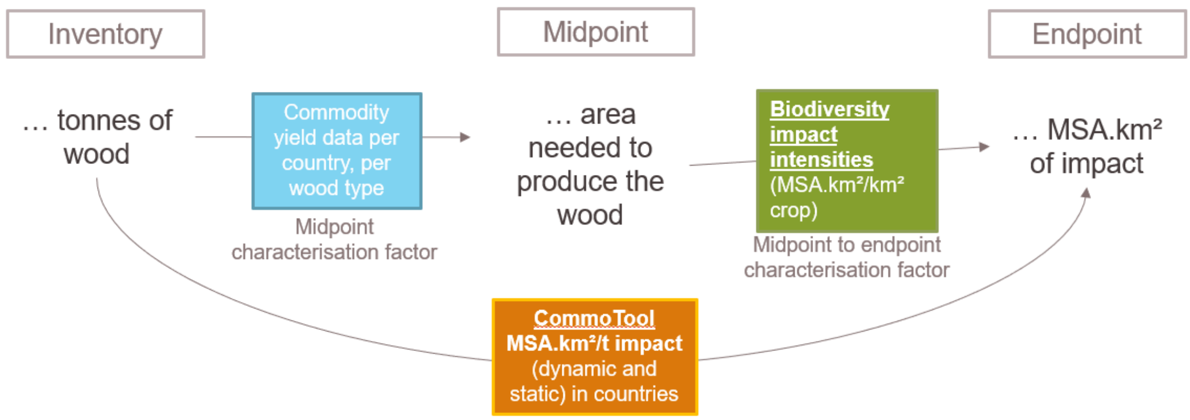

Figure 5: Impact factors used or constructed in the wood logs CommoTool within the LCA framework

2.2 Attributing the impacts of wood log production

Some pressures do not originate from wood log production and are thus not attributed to it. The GLOBIO and GLOBIO-Aquatic models provide some elements to determine which pressures on biodiversity are caused by forestry systems. Please refer to the reports dedicated to terrestrial (CDC Biodiversité 2020d) and aquatic (CDC Biodiversité 2020b) pressures for more details. Pressures considered in the wood logs CommoTool and associated attributions are indicated on Figure 6. Note that **only Scope 1 impacts are assessed in the CommoTool.**

Climate change: as presented in (CDC Biodiversité 2020d), climate change impact is assessed based on a pressure-impact relationship involving GHG emissions. The Integrated Absolute Global Temperature Potential on a 100-year horizon (IAGTP) of each GHG is used to deduce the temperature increase induced by the emissions, and the biodiversity loss factor related to temperature increase (in MSA.km²/°C) is then applied. Thus, 100% of the CC impacts associated to GHG emitted by wood log production are attributed to it. In terms of carbon dioxide emissions, and consistently with the choices underlying the crops CommoTool, only emissions due to the burning of fossil fuels are considered. Carbon dioxide emissions linked to wood production but coming from other sources (biogenic, land use change) are not attributed to wood production.

Land use: 4 non-natural forest land uses exist in GLOBIO cause-effect relationships, with MSA values ranging from 30% (Plantations) to 85% (Reduced impact logging). Wood production thus contributes to the pressure and the impacts of LU change and occupation are attributed to those land uses as described in

(CDC Biodiversité 2020d). Consistently with the crops CommoTool, the land use pressure due to wood production is assumed to originate only from the planted forest areas and does not include built up areas used for instance for storage or manufacture. More details on impact computation are provided in Section 3.

Encroachment and Fragmentation: according to GLOBIO cause-effect relationships, these pressures are caused only by croplands, cultivated grazing areas and urban areas – defined as "human" land uses, while forest areas are subjected to them (and not causing them). The impacts related to E and F are thus not attributed to wood log production.

Atmospheric nitrogen deposition: in the GLOBIO-IMAGE framework, the sources of nitrogen are croplands and urban areas, while natural and exploited forests are impacted by nitrogen deposition. N is thus not included in the wood logs CommoTool.

Land use in catchment of rivers: according to GLOBIO-Aquatic cause-effect relationships, only "human" land uses contribute to the pressure on rivers. Since exploited forests are not classified in this category, LUR are not attributed to wood log production. On the contrary, LUW depends on the intensity of land uses in the catchment of wetlands, all non-natural land uses contributing to the pressure. LUW is thus included in the CommoTool.

Wetland conversion: **in default assessments**, the impacts dimensioned are limited to those caused only by agricultural lands (CDC Biodiversité 2020b) so none is attributed to wood log production. Unfortunately, we have not been able to dimension (and thus attribute) impacts caused by conversion of wetlands into forest for wood log production in default assessments. **In refined assessments**, when company data reveal wetland conversion due to wood production, 100% of the impacts is attributed to wood log production.

Hydrological disturbance: in the GBS, the HD related impacts are split between climate change, water use and infrastructures (dams). We consider that very little blue water (ground water and river water) is used in forestry systems – (Schyns, Booij, and Hoekstra 2017) estimate that only 4% of the total water consumed by roundwood production is blue. 100% of the CC of HD (referred to as HD_{CC} in the remaining of this report) are attributed to the GHG emitted by wood log production. In future versions of the tool, the impacts of blue water consumption, and thus biodiversity impact factors for HDWater, might be added.

Freshwater eutrophication: in the GLOBIO-IMAGE scenario, only croplands and urban areas are considered as sources of N and P leaching into aquatic ecosystems (Janse, Bakkenes, and Meijer 2016). Thus, **in default assessments**, only the impacts caused by croplands and urban areas are dimensioned (CDC Biodiversité 2020b) so none is attributed to wood log production. We have not been able to dimension the impacts caused by N and P emissions from wood log production in default assessment. Though examples of increased nutrient leaching related to conversion from natural forests or low-impact forestry into plantations exist, few literature is available, especially at more global scales. One might thus assume that leaching has not been identified as a global issue for wood production. Indeed, based on LCA impact data, terrestrial and freshwater eutrophication due to wood production is respectively 100 and 200 times lower than those due to maize cultivation[3]. **In refined assessments**, we similarly consider that the impact due to N and P from the forestry sector is negligible (dimensioning) and attribute no impact to wood log production.

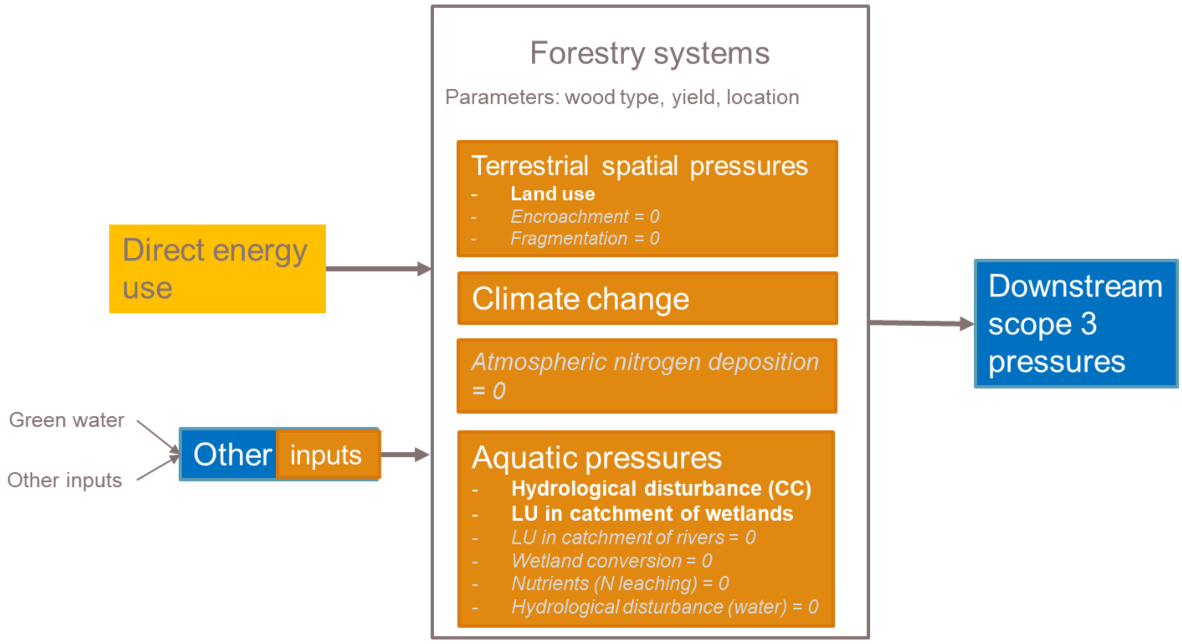

Figure 6: Pressures attributed to wood log production in the CommoTool

3 Dimensioning the impacts of wood log production – Default assessment

3.1 Data used

[3] Figures computed based on the impacts of the corresponding PEF processes.

Considering that the pressures included in the wood logs CommoTool are LU, LUW and CC (see Section 1.3B), dimensioning the impacts of wood log production requires essentially to know the **implicit area**, *i.e.* the area occupied by the production, and **GHG emissions** related to the production of one tonne of wood log. As for the biodiversity impact factors related to other raw materials (see (CDC Biodiversité 2019a) and (CDC Biodiversité 2020c)), **yield** is used to deduce the implicit area occupied by the production.

A ANNUAL YIELD DATA

In the case of wood log production, yield is not as simple a notion as for crop production. Indeed, wood production spans over several years as the age of stands reaches easily more than 60 years for some species. Wood production is less predictable than for instance wheat production because of the uncertainties due to extreme events and tree growth patterns. The production is also dependent on management choices such as thinning regimes, tree spacing, species mixing, etc. Unfortunately, FAO does not report average national wood yield per wood item as it does for crops. Other data sources must thus be found. Yield models considering these parameters exist, giving tables related to each management and species choice. An example of such a table, output of the model Forest Yield (a computer-based yield model for forest management in Britain, (R.W. Matthiews et al. 2016)), is presented in Figure 7. The original title of the table is kept to illustrate how specific such results are. Considering that the wood logs CommoTool requires to know the annual yield for wood log production in all countries, such yield models are not fit for our purpose and are therefore not used.

Table 1 The yield table for yield class 10 Scots pine planted at 1.4 m spacing and subject to an intermediate thinning regime.

1st thin delay	1st thin type	1st thin age	2nd thin age	Max MAI age	Sub thin type	Late thin age	Late thin cycle
0 years	Intermediate	25 years	30 years	70 years	Intermediate	N/A	N/A

Stand age (years)	Top height (m)	Maincrop after thinning					Yield from thinnings					Cumulative production		MAI
		Trees per ha	Mean dbh cm	BA m^2 ha^{-1}	Mean vol m^3	Vol m^3 ha^{-1}	Trees per ha	Mean dbh cm	BA m^2 ha^{-1}	Mean vol m^3	Vol m^3 ha^{-1}	BA m^2 ha^{-1}	Vol m^3 ha^{-1}	Vol m^3 ha^{-1} yr^{-1}
20	8.1	4186	9	25	0.02	64	0	0	0	0.00	0	25	64	3.2
25	10.2	2187	11	20	0.04	77	1481	10	13	0.02	35	33	112	4.5
30	12.1	1433	13	20	0.07	101	753	11	8	0.05	35	40	171	5.7
35	13.9	1056	16	22	0.13	132	377	14	6	0.09	35	48	237	6.8
40	15.6	831	19	25	0.20	167	225	16	5	0.16	35	55	307	7.7
45	17.1	681	23	27	0.30	204	150	19	4	0.23	35	63	379	8.4
50	18.5	575	26	30	0.42	240	106	22	4	0.33	35	69	450	9.0
55	19.8	497	29	32	0.55	273	79	25	4	0.45	35	75	518	9.4
60	20.9	436	31	34	0.70	304	60	28	4	0.58	35	80	584	9.7
65	22.0	391	34	35	0.85	331	46	31	3	0.73	33	85	644	9.9

Figure 7: Example yield table. Source: (R.W. Matthiews et al. 2016)

Then, two options remain: 1) computing national yields based on production and forestry area per country, or 2) doing so based on LCA data. Though offering a lower geographical precision, the second option was chosen over the first one. Indeed, yield computation based on production and forestry areas was explored and showed several limitations. The first limitation is inconsistency between the results obtained using different databases; national yields computed based on FAO production and FRA forest areas are different from the ones obtained based on FAO production and GLOBIO forest areas, and also different from the yields based on EXIOBASE material and resources accounts. Also, we encountered data gaps in terms of country coverage and abherent results. An FAO yield database was found, providing national yield range per tree species, but the species as weel as the country coverage were incomplete. For these reasons, we rely for nom on the second option which, though providing limited geographical differentiation, are full coverage and peer-reviewed. Computations based on the first option may be used in the future to refine the results and provide additional impact factors since we recently got access to computed peer-reviewed national yield data from (Schyns, Booij, and Hoekstra 2017). More is said on this subject in Section 6.1.

The Product Environmental Footprint (PEF) is a methodology by the European Commission's Joint Research Center (JRC) which is based on Life Cycle Assessment. Joined to the *Environmental Footprint* LCIA method is the PEF LCA dataset, both resulting from a three-year multi-stakeholder testing period. The dataset gathers input and output data for hundreds of processes, including wood production. To our knowledge, it is the only open access LCA database providing such good country and material coverage. Wood related processes include processes concerning hardwood, softwood and eucalyptus forestry, bark chips, wood chips, fibreboard and sawnwood production, as well as wood residues management. As explained in Section 1.3A, the CommoTool is interested into the rawest form of the wood, hence only the 14 processes related to logging are used. The processes distinguish hardwood and softwood logging, as well as 2 management types and 3 or 4 geographic regions. The processes consider the production of 1 kg of wood and the general information attached to the processes specify that they all concern mixed species. Hardwood forestry processes are for wet wood with a water content of 0.5 (unitless) and a wet density of 1025 kg/m^3. For softwood forestry processes, the water content of wood is also 0.5 but the wet density is 850 kg/m^3. Thus, a water content of 50% is considered for all items of the wood logw CommoTool. The textbox below provides additional information on the subject. The 14 processes are listed on Table 1. An input and an output table are attached to each process, documenting interesting information used for the computation of impact factors.

Units and volumes of wood

Existing units as well as reporting metrics, especially of wood volumes, are numerous. Notably, wood volume units include cubic meters, steres, tons, stacked cubic meters… Volumes can be reported "underbark" or "including bark" and a certain water content is assumed.

Conversion factors between these metrics exist, they are notably gathered in the Definitions document of the FAO accompanying the Joint Forest Sector questionnaire[4]. Thus, a clear definition of the choices made regarding data unit is important. For instance, EXIOBASE m^3 to ton factors are 0.68 t/m^3 for hardwood and 0.52 t/m^3 for softwood, FAO considers factors of respectively 0.75 and

[4] The document is available at: http://www.fao.org/forestry/7800-0aded052ed8904ee31f045d5a3f79ae1d.pdf

0.62 t/m^3. This difference might be due to a difference in the water content considered, although we could not find information on this point.

In the wood logs CommoTool, the water content considered for all items is 50%. We did not need to use conversion factors yet since PEF data are per kg and the CommoTool impact factors are per ton. In Section 5.2 comparing EXIOBASE and FAO wood production (FAOSTAT 2016), EXIOBASE conversion factors were used as we know that they were the ones used by EXIOBASE team to convert FAO data to the material account. If the choice of conversion factors is required later, for instance if companies provide wood volumes in m^3, we shall recall that results will be impacted. Indeed, relying FAO conversion factors would lead to higher impacts than relying on EXIOBASE conversion factors.

For each process, the **inputs table** notably document the surface area of forest required to produce 1 kg of output. Yields are computed based on these surface areas following the methodology explained in Section 3.2.B.1. Section 3.2.B.2 presents how yields are then used to compute the biodiversity impact factors related to LU.

Table 1: Wood forestry processes in the PEF database

Hardwood forestry, at forest, non-sustainable managed, per kg wood – EU 28+3
Hardwood forestry, at forest, non-sustainable managed, per kg wood – US and CA
Hardwood forestry, at forest, non-sustainable managed, per kg wood – World (without EU 28+3, US and CA)
Hardwood forestry, at forest, sustainable managed, per kg wood – EU 28+3
Hardwood forestry, at forest, sustainable managed, per kg wood – US and CA
Hardwood forestry, at forest, sustainable managed, per kg wood – World (without EU 28+3, US and CA)
Softwood forestry, at forest, non-sustainable managed, per kg wood – EU 28+3
Softwood forestry, at forest, non-sustainable managed, per kg wood – FI and SE
Softwood forestry, at forest, non-sustainable managed, per kg wood – US and CA
Softwood forestry, at forest, non-sustainable managed, per kg wood – World (without EU 28+3, US and CA)
Softwood forestry, at forest, sustainable managed, per kg wood – EU 28+3
Softwood forestry, at forest, sustainable managed, per kg wood – FI and SE
Softwood forestry, at forest, sustainable managed, per kg wood – US and CA
Softwood forestry, at forest, sustainable managed, per kg wood – World (without EU 28+3, US and CA)

B EMISSION DATA

The **ouput table** of each PEF LCA process lists notably the emissions of GHGs due to the production of 1 kg of output. These emissions are used to compute the GHG emissions for each process, as explained in Section 3.2.C.1, comparison to GHG emissions computed based on other sources is also provided. Section

3.2.C.2 presents how GHG emissions are then used to compute the biodiversity impact factors related to the pressures CC (impacting terrestrial biodviersity) and HD_{CC} (impacting aquatic biodiversity).

C TEST: COMPARISON OF GLOBIO AND FAO FOREST AREAS

FAO global Forest Resource Assessment 2015 (FAO 2015) provides detailed data on forest areas for the year 2015 and their evolution since 1990. Forest areas are classified into different categories and documented per country and world regions, and trends and annual changes are also provided. Eventhough the forest categories do not match that of GLOBIO, it is important to make sure that global figures are consistent. Indeed, GLOBIO forest areas are used to compute biodiversity intensities involved in the computation of biodiversity impact factors. Yet, for any given year, land use changes affecting forests used in the GBS default assessments are proxies linearly interpolated from GLOBIO-IMAGE forest areas in 2010 and 2050 (see (CDC Biodiversité 2020d) for explanations on the lack of appropriate current data and the need to use proxies). Differences in annual land use changes can thus be expected, but global figures should not be too far from real data to ensure the validity of the CommoTool outputs.

Table 2 presents the total forest areas per GLOBIO forest land use type in 2010 (GLOBIO-IMAGE output) and the projected area in 2015 (linearly interpolated) for comparison with FRA 2015 presented in Table 3. Total forest areas are not perfectly aligned and the results show that projected GLOBIO forest areas overestimate real forest areas by 13.7% (5.5 million km²) in 2015. Yet, the difference remains acceptable. Also, the share of natural forests is lower in GLOBIO-IMAGE output (83%) than in FRA data (85%), causing static impacts to possibly be slightly overestimated.

Table 2: GLOBIO-IMAGE forest areas in 2010 and 2015 per forest land use type

GLOBIO forest type	Total area 2010	Projected area 2015
Total forest areas	**46 million km²**	**45.5 million km²**
Natural forest	**39 million km²**	**38 million km²**
Reduced impact logging	27,000 km²	36,000 km²
Selective logging	700,000 km²	770,000 km²
Harvested forest	5 million km²	5,4 million km²
Plantation	1 million km²	1 million km²

Table 3: FRA 2015 forest areas

FRA forest type	Total area 2015
Total forest areas	**40 million km²**
Primary forest	**12 million km²**
Other naturally regenerated forest	**22 million km²**
Planted forest	2.8 million km²
Other exploited forests	3.2 million km²

3.2 Methodology to compute biodiversity impact factors related to wood logs production

A COMPUTATION PROCEDURE

Figure 8 presents the computation procedure for the biodiversity impact factors related to wood production

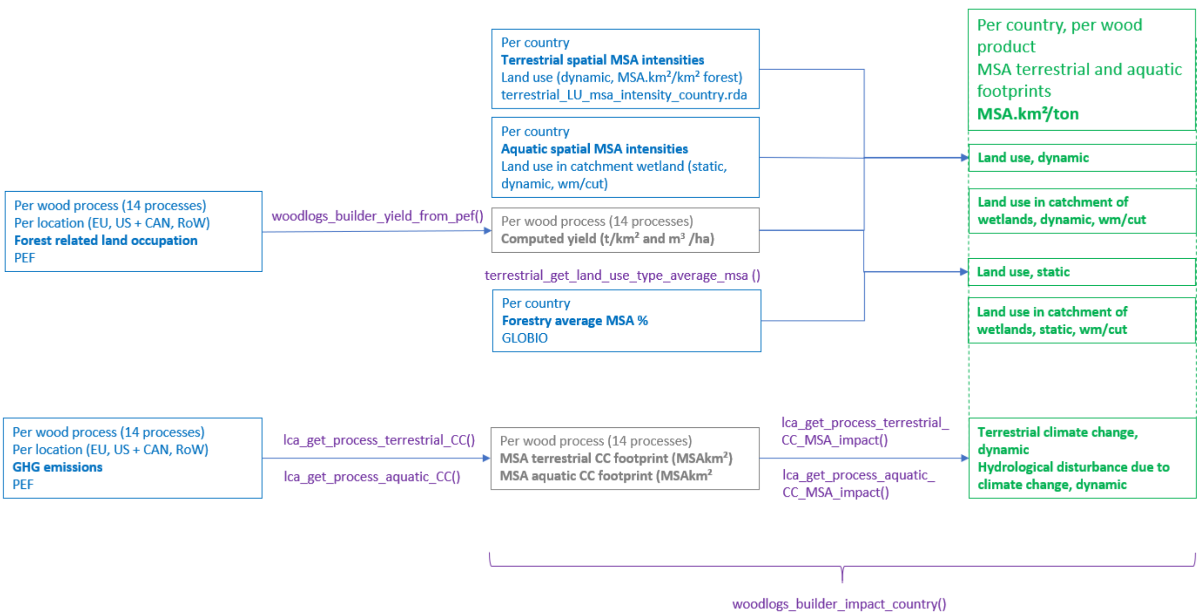

Figure 8: Computation procedure for the biodiversity impact factors related to the production of wood logs

B LAND USE IMPACT FACTORS

3.2.B.1 Yield computation

The input table attached to each LCA PEF process documents the list of inputs required to produce 1 kg of wood. The inputs fall into 2 broad categories: land use (distinguishing land occupation and land transformation) and resource use (from air, ground and water). For each category, numerous flows are listed. For instance, the land use category includes flows of arable land, forest land and construction site, while the resource use category includes flows of biogenic carbon dioxide, water and various minerals. In total, 452 flows are listed in the input table of each process.

In each process, flows related to land use are used by the GBS to compute the area required to produce 1 kg of wood. The corresponding yield in t/km² is then computed based on this surface area. The computation involves several assumptions and choices.

1) Only the surface area of the flows "**forest, used**", "**forest, intensive**" and **"forest, extensive**" belonging to the **category Land use/Land occupation** are considered in the yield computation. The land occupation of other land uses (arable land, grassland, etc.) is indeed assumed to be occupied for other reasons than tree growth so 0% of the impact of these surfaces is attributed to wood production. The surface area concerned is very limited anyway, representing less than 1% of the total land occupation.

2) Following PEF, we assume that the **output is linearly dependent on the surface area**, *i.e.* the area required to produce 1 t of output of each process is equal to 1000x the area required to produce 1 kg of output.

3) We assume that the production of wood logs does not involve multiple harvests within one year and, thus, that the area occupied over one year (m^2) is equal to the time-integrated area (m^2.y).

The surface area of forest land occupied are documented in m².y in the input table. For each process, the total forest land occupied for the three flows listed above is computed by the function `woodlogs_builder_yield_from_pef()`. From the output figure in m².y occupied by the production of 1 kg of output, an annual yield in t/km² is thus computed. Results are presented in Table 5.

In future versions of the tool, we will refine yield data to better account for national differences and varying management practices. Ways to do so are explored in Section 5.

Computed yields are presented in Table 4 . They call for several observations.

Table 4: Yield per PEF process. EU: European Union, US: United States, CA: Canada, FI: Finland, SE: Sweden, RoW: Rest of World

Wood type	Management type	Location	PEF Yield (t/km²)
Hardwood	Non-sustainable	EU, US, CA	349.5
		RoW	728.0

	Sustainable	EU, US, CA	699.0
		RoW	1 455.8
Softwood	Non-sustainable	EU, US, CA	284.8
		FI, SE	257.6
		RoW	255.6
	Sustainable	EU, US, CA	564.1
		FI, SE	515.2
		RoW	511.2

First, the yield computed in the EU, the US and Canada (CA) is the same for all processes. Thus, the **location differentiation is limited**. For hardwood, only two locations can be distinguished (EU-US-CA *vs* Rest of World), while three can be distinguished for softwood as Finland (FI) and Sweden (SE) are singled out. However, the yield difference between FI-SE and Rest of World (RoW) is small. In total, 10 different yields are obtained.

Second, the yield of hardwood is a higher than that of softwood. This ranking is not surprinsing considering the RoW region (encompassing tropical regions where softwood grows very rapidely)

Third, while the yield difference between locations is limited for softwood, **the yield for hardwood in the region Rest of the World is much higher than in other regions** (ratio superior to 2). This is consistent with the much higher productivity of wood in tropical regions compared to temperate regions like Europe, the US and Canada.

Last, for all processes and locations, the **yield ratio between wood managed sustainably and non-sustainably is equal to 2**, the yield for sustainable wood being twice as large as that of non-sustainable wood. Investigating the inputs of each process reveals that the difference is due to sustainable wood occupying twice lower a surface area of each of the three forest land uses. This difference surely comes from the assumptions concerning the definition of “sustainable” and “non-sustainable” management and the underlying computation of surfaces in PEF data. Unfortunately, we were not able to find any documentation on these assumptions. Hence, we consider the yield difference between sustainable and non-sustainable wood as abnormal and chose to keep only the “non-sustainable” management type.

We consider that the yield difference between sustainable and non-sustainable wood in PEF is abnormal. Hence, only the “non-sustainable” management type is kept for default assessments. The items of the wood logs CommoTool are “Hardwood, non-sustainable” and “Softwood, non-sustainable” (see Table 5).

In future versions of the tool, we will refine yield data to better account for national differences and varying management practices. Ways to do so are explored in Section 5.

As for the biodiversity impact factors related to crops, forestry yields are used to compute the implicit area related to the production of 1 tonne of wood. The implicit area (km^2/t) is computed as:

$$implicit\ area = \frac{1}{yield}.$$

Table 5 presents the yield and implicit area for each item of the wood logs CommoTool. The implicit area is used to compute the biodiversity impact factors related to LU, as explained in what follows.

Table 5: Yield and implicit area for each item of the CommoTool. EU: European Union, US: United States, CA: Canada, FI: Finland, SE: Sweden, RoW: Rest of World

Wood type	Management type	Location	CommoTool Yield (t/km²)	Implicit area (m²/t)
Hardwood	Non-sustainable	EU, US, CA	349.5	2 861
		RoW	728.0	1 374
Softwood	Non-sustainable	EU, US, CA	284.8	3 511
		FI, SE	257.6	3 882
		RoW	255.6	3 912

3.2.B.2 Biodiversity impact factors related to LU

For terrestrial land use, **biodiversity impact factors from the terrestrial module are expressed in MSA.km²/km² area of impacting land use type** per country or EXIOBASE region. In the CommoTool, the impact factors are linked to **1 tonne of a specific wood log item** based on the implicit area. The unit in the final impact factor tables is **MSA.km²/t of wood**.

For a reminder on how biodiversity intensities per land use type are computed, see (CDC Biodiversité 2020d).

Four non-natural forest land use types are distinguished the GBS impact factors: Forestry reduced impact logging, Forestry selective logging, Forestry harvest and Forestry plantation. A correspondence table between GLOBIO forestry land uses and PEF forest area types was established. Based on the correspondence table, MSA values and biodiversity intensities of PEF forest areas are computed as national weighted averages of the corresponding values for GLOBIO land uses. As explained hereafter and in (CDC Biodiversité 2020d), MSA values and biodiversity intensities are used to compute respectively static and dynamic biodiversity impact factors.

Table 6 summarises the correspondence table and computation method used.

Table 6: Correspondence table between GLOBIO and PEF forest land uses and associated MSA values and intensities

GLOBIO land use	PEF forest area input	MSA value (%)	Biodiversity intensity (MSA.km²/km²)
Forestry – Plantation	Forest, intensive	Average of the MSA% of GLOBIO land uses (40%)	National weighted average of the biodiversity intensities of plantations and harvested forests
Forestry – Harvest			
Forestry – Selective logging	Forest, extensive	Average of the MSA% of GLOBIO land uses (77.5%)	National weighted average of the biodiversity intensities of selective and reduced impact logging land uses
Forestry – Reduced impact logging			
All forestry types	Forest, used	National weighted average of the MSA values of the 4 forest land uses	National weighted average of the biodiversity intensities of the 4 forest land uses

In Step 1 of the following code bloc, the biodiversity dynamic impact intensities for PEF forestry types (`pef_forest_intensity_MSAkm2_per_km2`) are combined to their corresponding share in the total forest area occupied by wood production (`forest_area_share`) and to the yield data in t/km² (`yield_t_per_km2`) to obtain the **dynamic biodiversity impact factor of 1 tonne of wood (in MSA.km²/t of wood)**. The **static biodiversity impact factor of 1 tonne of wood** is calculated considering that the area occupied by the wood production is its implicit area and the corresponding MSA (`average_msa` (details in (CDC Biodiversité 2020d))) is computed for each PEF forest type as explained in Table 6.

In Step 2, the **static and dynamic impact factors of 1t of wood per PEF forest type are summed to get the overall impact of 1t of wood.**

Mathematically, in each country or EXIOBASE region and for each wood type (hardwood, softwood):

$$impact\ factor_{LU,dynamic} = \sum_{\substack{pef\ forest\ type= \\ intensive, \\ extensive, \\ used}} share_{\substack{pef\ forest\ type \\ in\ total\ occupied \\ area}} \times impact\ factor_{LU,dynamic,pef\ forest\ type}$$

$$impact\ factor_{LU,static} = \sum_{\substack{pef\ forest\ type= \\ intensive, \\ extensive, \\ used}} share_{\substack{pef\ forest\ type \\ in\ total\ occupied \\ area}} \times impact\ factor_{LU,static,pef\ forest\ type}$$

with

$$impact\ factor_{LU,dynamic,pef\ forest\ type} = \frac{intensity_{LU,pef\ forest\ type}}{yield}$$

$$impact\ factor_{LU,static,pef\ forest\ type} = \frac{1 - MSA_{pef\ forest\ type}}{yield}.$$

<u>COMPUTE THE LU DYNAMIC AND STATIC BIODIVERSITY IMPACT FACTORS IN MSA.KM²/T OF WOOD</u>

```
# STEP 1: Compute the land use impacts in MSA.km2/ton: impacts are computed per forest type
and then summed
 mutate(# dynamic impacts
        msa_land_use_dynamic_MSAkm2_per_ton = forest_area_share *
                              pef_forest_intensity_MSAkm2_per_km2 / yield_t_per_km2,
        # static impacts
        msa_land_use_static_MSAkm2_per_ton = (forest_area_share * (1 – average_msa)) /
                                                  yield_t_per_km2)

# STEP 2: Regroup at the wanted level and sum the impacts
 group_by([…]) %>%
 summarise(msa_land_use_dynamic_MSAkm2_per_ton = sum(msa_land_use_dynamic_MSAkm2_per_ton),
           msa_land_use_static_MSAkm2_per_ton = sum(msa_land_use_static_MSAkm2_per_ton))
```

Although the yield differentiation is limited, differences in the biodiversity intensity of forest areas per country generates variation in the biodiversity impact factors per wood item computed by the CommoTool. Biodiversity intensities are currently computed based on GLOBIO-IMAGE modelled land use changes. Thus, we only speak about "expected land use changes" and "expected intensification". If real data is used in the future, analyses will be centered on intensification and land use changes that actually occurred in, for instance, the past year. Biodiversity intensities notably vary according to two components that are key to assess the impacts of wood production:

- The average forest management in the country: `average_msa` is higher in countries where less-impacting forest land uses occupy a relatively more important area than impactful forest land uses. Hence, the static impact of wood production is higher in countries where Plantations and Clear-cut harvests are more widespread.

- The national forest trends: `pef_forest_intensity_MSAkm2_per_km2` embeds the national trend in terms of forest expansion and intensification. Countries where exploited forests are expected to expand at the expense of natural areas or where logging is expected to intensify get a higher intensity. Hence, the dynamic impact of wood production is higher in countries where exploited forests are expected to cause biodiversity loss, especially through deforestation of natural forests.

More details on the interpretation of biodiversity impact factors can be found in the GBS report dealing with terrestrial pressures (CDC Biodiversité 2020d).

Since they involve country-specific yields, the computed impact factors fall into data quality tier 2. They are now considered to be the central impact factor value.

Considering that information on the origin of PEF reported forest areas per process is limited and that the respective share of the three forest types does not vary a lot across processes, a **second calculation method is envisaged**. This method would no longer distinguish PEF forest types and would simply allocate the average national MSA values and biodiversity intensity of all GLOBIO forestry land uses to the whole area occupied by wood production. **The method yielding the highest impacts would be considered as conservative, while the other values would be considered central**.

Also, optimistic impact factor values could be computed using PEF yields obtained for sustainable wood management.

3.2.B.3 Biodiversity impact factors related to LUW

Static and dynamic biodiversity intensities related to the pressure LUW are expressed in MSAkm²/km² of intensity weighted area. For each PEF forest area type, impact factors related to land use in catchment of wetlands follow the same relationship for static (using static intensities) and dynamic (using dynamic intensities):

$$impact\ factor_{LUW,pef\ forest\ type} = \frac{intensity_{LUW,pef\ forest\ type} \times (1 - MSA_{pef\ forest\ type})}{yield}.$$

Similarly as for the impact factors related to terrestrial LU, impacts are aggregated per ton of wood based on the share of the PEF forest type in the total land occupation. The following code block shows the computation lines involving the variables already described. Two values are computed, a central (with `_wm`) and a conservative (with `_cut`) one, based on the two calculation modes for the biodiversity intensities. The calculation modes are explained in (CDC Biodiversité 2020b).

<u>COMPUTE THE LUW DYNAMIC AND STATIC BIODIVERSITY IMPACT FACTORS IN MSA.KM²/T OF WOOD</u>

```
# STEP 1: Compute the land use in catchment of wetlands impacts in MSA.km2/ton: impacts are
computed per forest type and then summed
 mutate(# dynamic impacts
        msa_aquatic_land_use_wetland_dynamic_wm_MSAkm2_per_ton = forest_area_share *
                    MSA_intensity_wetland_LU_dynamic_wm * (1 – average_msa) /
                    yield_t_per_km2,
        msa_aquatic_land_use_wetland_dynamic_cut_MSAkm2_per_ton = forest_area_share *
                    MSA_intensity_wetland_LU_dynamic_cut * (1 - average_msa) /
                    yield_t_per_km2,
        # static impacts
```

```
        msa_aquatic_land_use_wetland_static_wm_MSAkm2_per_ton = forest_area_share *
                    MSA_intensity_wetland_LU_static_wm * (1 - average_msa) /
                    yield_t_per_km2,
        msa_aquatic_land_use_wetland_static_cut_MSAkm2_per_ton = forest_area_share *
                    MSA_intensity_wetland_LU_static_cut * (1 - average_msa) /
                    yield_t_per_km2) %>%

# STEP 2: Regroup at the wanted level and sum the impacts
 group_by([…]) %>%
 summarise(msa_aquatic_land_use_wetland_dynamic_wm_MSAkm2_per_ton =
                    sum(msa_aquatic_land_use_wetland_dynamic_wm_MSAkm2_per_ton),
          msa_aquatic_land_use_wetland_dynamic_cut_MSAkm2_per_ton =
                    sum(msa_aquatic_land_use_wetland_dynamic_cut_MSAkm2_per_ton),
          msa_aquatic_land_use_wetland_static_wm_MSAkm2_per_ton =
                    sum(msa_aquatic_land_use_wetland_static_wm_MSAkm2_per_ton),
          msa_aquatic_land_use_wetland_static_cut_MSAkm2_per_ton =
                    sum(msa_aquatic_land_use_wetland_static_cut_MSAkm2_per_ton))
```

Since they involve country-specific yields, the computed impact factors fall into data quality tier 2. The `_wm` impact factor is considered central, while the `_cut` impact factor is considered conservative.

C CLIMATE CHANGE IMPACT FACTORS

3.2.C.1 GHG emissions computation

The output table attached to each LCA PEF process documents the list of outputs generated by the production of 1 kg of wood. The outputs fall into 2 broad categories: emissions (distinguishing emissions to air, soil and water) and wastes. For each category, numerous flows are listed. For instance, the emissions category includes flows of gases, pollutants and heavy metals, while the waste category includes production residues and radioactive waste. In total, 1 877 flows are listed in the output table of each process.

For each process, total GHG emissions caused by the production of 1 kg of output is computed thanks to the function `lca_get_process_ghg_emissions()`. GHG related emissions to air are extracted from the output tables and the global warming potentials for a 100-year time horizon are used to convert the quantities of each GHG into kg CO_2-eq. Also, note that the ouput tables distinguish three types of carbon dioxide emissions according to the source: "carbon dioxide (biogenic)[5]", "carbon dioxide (fossil)" and "carbon dioxide (land use change)".

Consistently with the crop CommoTool in which biogenic and land use change related carbon emissions are ignored, only "carbon dioxide (fossil)" is considered in the computation.

[5] Biogenic carbon designates the CO_2 emissions related to the natural carbon cycle, as well as those resulting from the combustion, harvest, digestion, fermentation, decomposition or processing of biologically based materials.

GHG emissions per wood log item are presented in Table 7 . Three main observations should be done.

Second, for the perimeter of emissions considered, **GHG emissions due to hardwood production in the European Union, the United States and Canada are very close**.

Last, GHG emissions are globally pretty similar for all wood log items. Only the region Rest of World does stand out with higher emissions related to the production of hardwood.

An important topic related to forestry is carbon storage during tree growth. In the LCA PEF framework, such carbon intake would be documented as a process input. However, general information specifies that "*Input "Carbon dioxide in air" is set to zero*" for all processes, *i.e.* carbon storage is set to zero. Consequently, in the wood logs CommoTool and for default assessments**, carbon storage during tree growth is not considered in the biodiversity impact factor of wood production related to the pressure Climate Change**. As explained in Section 4, carbon storage can be taken into account in refined assessments.

3.2.C.2 Biodiversity impact factors related to CC and HD_{CC}

Terrestrial Climate change (CC) and freshwater Hydrological disturbance due to climate change (HD_{CC}) are assessed using the pressure-impact relationships detailed in the terrestrial (CDC Biodiversité 2020d) and freshwater module documents (CDC Biodiversité 2020b). The relationships link a **biodiversity impact in MSA.km² to a given GHG emission in tonnes CO_2-eq** and are transcripted in the functions `ghg_get_emission_MSA_impact()` and `ghg_get_emission_MSA_impact_aquatic()`.

Both functions are embedded in the LCA functions `lca_get_process_terrestrial_CC_MSA_impact()` and `lca_get_process_aquatic_CC_MSA_impact()`, which allow the computation of the CC and HD_{CC} biodiversity impact factors for all processes. Impact factors per tonne of wood produced are presented in Table 7. As for other raw materials, only dynamic impacts are computed for CC related pressures.

The impact factors for CC and HD_{CC} both fall into data quality tier 1 (CDC Biodiversité 2020d; 2020b). In GBS 1.0, the central, conservative and optimistc impact factors are considered equal. In future versions of the tool, the three values might be distinguished.

Table 7: GHG emissions per wood item computed based on PEF output tables and dynamic biodiversity impact factors related to CC and HD_{CC} for each wood production process. EU: European Union, US: United States, CA: Canada, FI: Finland, SE: Sweden, RoW: Rest of World

Wood type	Management type	Location	GHG emissions (kg CO_2-eq/t)	CC impact factor (MSA.km²/t)	HD_{CC} impact factor (MSA.km²/t)
Hardwood	Non-sustainable	EU	21.5	$9.41.10^{-8}$	$7.24.10^{-10}$
		US, CA	21.6	$9.45.10^{-8}$	$7.28.10^{-10}$
		RoW	34.4	$1.50.10^{-7}$	$1.16.10^{-9}$

Softwood	Non-sustainable	EU, FI, SE	16.2	$7.06.10^{-8}$	$5.43.10^{-10}$
		US, CA	16.7	$7.30.10^{-8}$	$5.61.10^{-10}$
		RoW	15.9	$6.97.10^{-7}$	$5.36.10^{-9}$

Table 8 synthesises biodiversity impact factors computation methodology, while Figure 9 presents the overall structure of the impact factors database.

Table 8: Synthesis of the methodology and wood logs CommoTool coverage for each pressure

Pressure		Land Use (LU)	Land use in catchment of wetlands (LUW)	Climate change (CC)	Hydrological disturbance due to CC (HD_{CC})
Biodiversity impact intensity unit		MSA.km²/km² of land use type (exploited forest)	MSA.km²/km² of intensity weighted area	MSA.km² / kg CO_2-eq emitted	
CommoTool	Wood logs CommoTool impact unit	**MSA.km² / tonne of wood**			
	Detail level (geographic, items)	GLOBIO countries PEF items			
	Data quality tier	2	2	1	

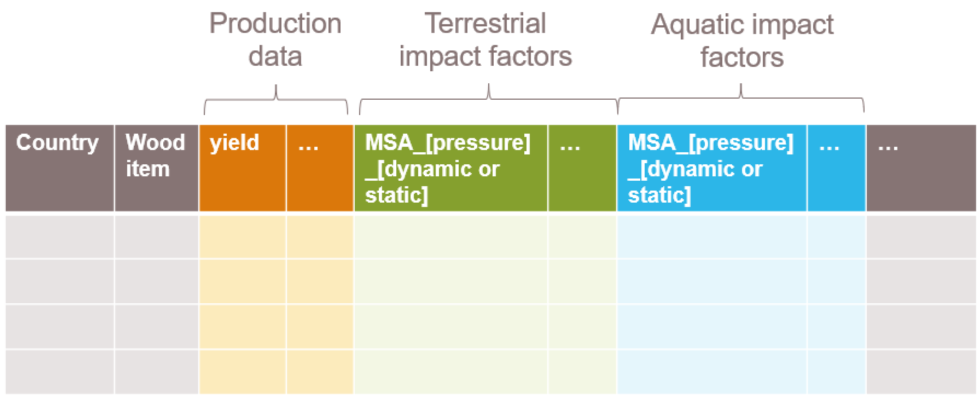

Figure 9: Simplified structure of the biodiversity impact factors database obtained through the wood logs CommoTool

3.3 Example

A INPUT DATA

We illustrate the methodology using a fictive sourcing of wood among 10 countries and one EXIOBASE region. The sourcing **mixes hardwood and softwood.** The quantity is set to 1 tonne in all sourcing locations, so that the total amount sourced is 11 tonnes. **The chosen countries are among the current biggest producers of wood, either of wood fuel or industrial roundwood**, except France which is introduced to increase location variability among the sourcing of softwood. The example input data are saved `example_woodlogs.rda` file in `GBStoolbox` package.

The **biodiversity impact factor (in MSA.km²/t) for the location (country or EXIOBASE region) and wood item (hardwood or softwood, sustainable or non-sustainable) is applied to each observation**. The calculation process is carried out thanks to the pre-treatment and evaluator functions dedicated to wood logs, `commodity_evaluator (commodity_type = “woodlogs”)` and `commodity_evaluator(commodity_type = “woodlogs”)`, and to the biodiversity impact factors gathered in `GBStoolbox::woodlogs_MSA_country` and `GBStoolbos::woodlogs_MSA_EXIOBASE_region.rda_`. Main results

The **total dynamic impact of the sourcing is 132 MSA.m², 96% of which is due to LU** (3% to LUW, 1% to CC and a negligible share to HD_{CC}). This overwhelming share is not surprising, considering that **the biodiversity impact factors related to LUW, CC and HD_{CC} are very small** (see Table 7). **The total static impact of the sourcing amounts to 16 973 MSA.m², 96% of which is due to LU** (4% to LUW). Again, this overwhelming share is not surprising, considering that **the biodiversity impact factors related to LUW are very small**. Considering that biodiversity impacts related to LUW, CC and HD_{CC} are very small, we focus hereafter on the impacts related to LU.

Figure 10 and Figure 11 show the dynamic and static biodiversity impacts related to land use in each sourcing location. Studying the land use impact per location and wood type allows to distinguish the yield effect from the location effect. Annual yields per location are presented on Figure 12.

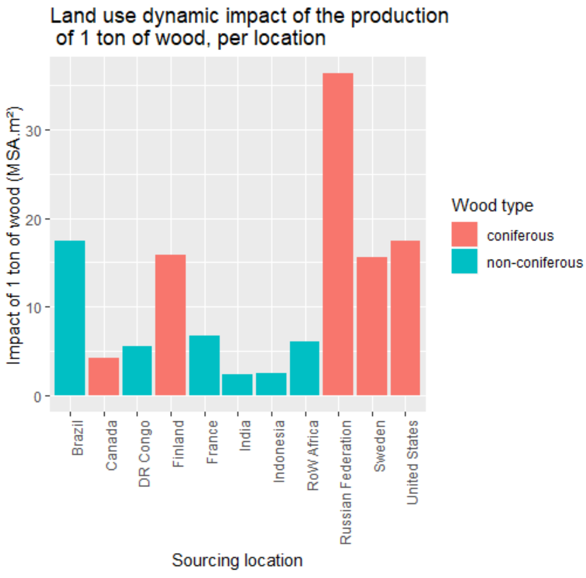

Figure 10: Land use dynamic impact of the production of 1 ton of wood, per location

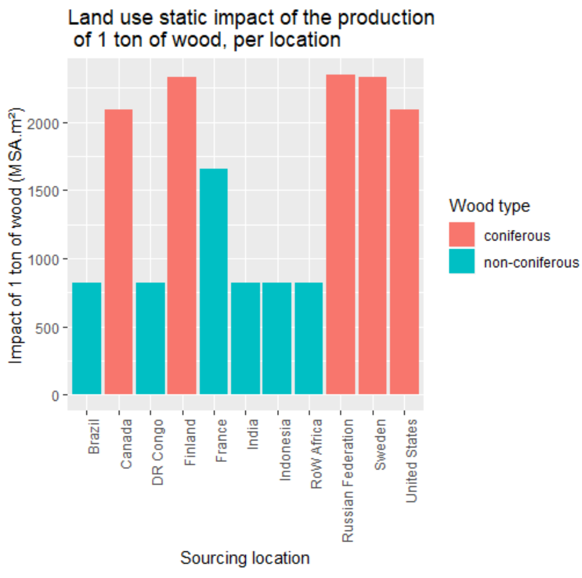

Figure 11: Land use static impact of the production of 1 ton of wood, per location

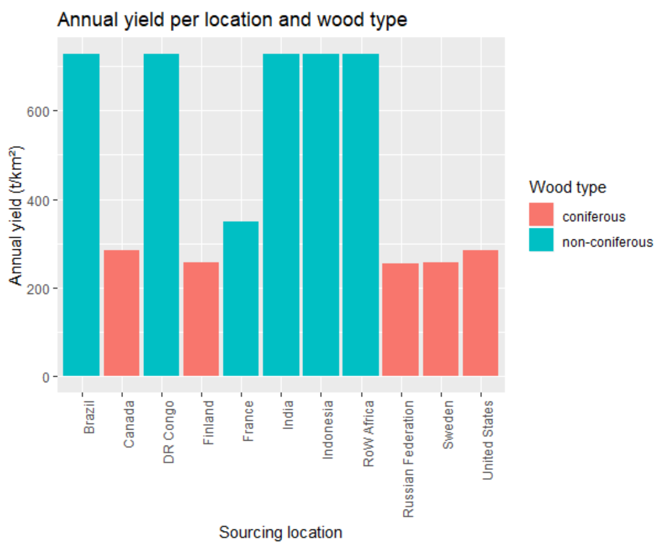

Figure 12: Annual yield per location

Results indicate that, for land use static impacts, the yield effect dominates the location effect. Indeed, coniferous wood – which yield is relatively low (between 255 and 285 t/km², cf. Table 5) – has a much higher impact than non-coniferous wood – which yield is better (between 350 and 730 t/km²). The higher impact of hardwood production in France than in other countries is due to a lower yield in this region (350 t/km² in the EU region against 730 t/km² in the RoW region).

On the contrary, the yield and local land use dynamics are more balanced for dynamic impacts. Indeed, although softwood production tends to have a higher dynamic impact than hardwood production, variation across locations is much higher: up to a factor 2.5 for softwood production and a factor 14 for hardwood. Hence, country-specific forest trends play an important role in determining the land use dynamic impact of wood production. Especially, it is interesting to compare these results to the deforestation fronts identified by the WWF (WWF 2015). The sensitivity of wood production in Brazil (17 MSA.m^2/t) is very well captured by the results. For comparison, the default land use dynamic impact of soybeans production in Brazil is 9.8 MSA.m^2/t (CDC Biodiversité 2019a). To a lesser extent, African logging fronts also show up, hardwood production having a relatively higher dynamic impact in DRC and RoW Africa than in other locations. Although important losses of natural forests are expected in these regions, forestry intensity remains relatively low, explaining the lower dynamic biodiversity impacts of wood production there. On the contrary, the Indonesian logging front is not well captured. This is due to the loss of Indonesian natural forests being caused also largely by croplands in GLOBIO-IMAGE outputs. In France, harvested forests are expected to expand at the expense of natural habitats, causing a relatively high biodiversity dynamic impact factor there. Also, the area of harvested forests in Russia is expected to double in GLOBIO-IMAGE model, notably at the expense of natural forests, explaining the relatively higher dynamic impact of softwood production there compared to other locations.

3.4 Tests

A WOOD LOGS PRODUCTION IMPACTS

Various tests are performed to check that impact factors for wood logs commodities are consistent with GLOBIO-IMAGE outputs, meaning that the order of magnitude of the total impacts obtained by applying impact factors to EXIOBASE world production are consistent with total impacts from GLOBIO-IMAGE outputs. As developed in Section 5.2, EXIOBASE wood production may be a bit overestimated. However, since these are the data that will be used in default assessments, it is important to run the test on them rather than on, for instance, FAO data. Moreover, if the test concludes that the computed impacts are consistent with the expectations from GLOBIO-IMAGE, we will conclude that this would also be the case of the impacts of wood production documented by FAO.

Table 13 and Table 14 present the results. The total Scope 1 dynamic and static impacts of EXIOBASE total wood production are displayed per pressure. The results are obtained by simply applying the biodiversity impact factors computed at the EXIOBASE region level to the total wood production – splitted by wood type – documented in EXIOBASE material account. Section 5 provides details on the linkage between the wood logs CommoTool outputs and EXIOBASE data. **Total Scope 1 dynamic impacts amount to 27 721 MSA.km^2, while total Scope 1 static impacts amount to 3 420 622 MSA.km^2**. As identified in the example, impacts related to terrestrial land use constitute accounts for the major part of both dynamic (97.3%) and static (95.5%) impacts.

Consequently, and because the contribution of wood production to other pressures (CC, LUW, HD_{CC}) cannot be isolated in GLOBIO output data, we focus the comparison on the pressure LU. The comparison reveals that impacts computed on EXIOBASE wood production are almost perfectly aligned (13% gap) with the impacts computed on GLOBIO-IMAGE output. Since wood production is not the only cause of exploited forests land use changes, biodiversity losses related to forest areas land use changes in GLOBIO-IMAGE cannot be allocated to it. Thus, dynamic Scope 1 impacts of wood production can only be compared to the predicted total Scope 1 annual biodiversity loss. This predicted loss is around 330 000 MSA.km^2. Considering that the computed impact of wood production represents 10% of this amount, biodiversity impact factors seem reasonable. Thus, we conclude that **LU static and dynamic biodiversity impact factors are validated.**

Table 9: Scope 1 dynamic impacts of the total wood production in EXIOBASE

Pressure	Biodiversity impacted	Scope 1 dynamic impact of the EXIOBASE total wood production (MSA.km^2)	Share
Land use	Terrestrial	26 967	97.3%
Climate change	Terrestrial	306	1%
Land use in catchment of wetlands	Aquatic	445	1.7%
Hydrological disturbance due to climate change	Aquatic	3	0%
Total		**27 721**	**100%**

Table 10: Scope 1 static impacts of the total wood production in EXIOBASE

Pressure	Biodiversity impacted	Scope 1 static impact of the EXIOBASE total wood production (MSA.km^2)	Share
Land use	Terrestrial	3 325 053	95.5%
Land use in catchment of wetlands	Aquatic	155 609	4.5%
Total		**3 480 662**	**100%**

Table 11: Comparison between the impacts of EXIOBASE wood production and GLOBIO-IMAGE non-natural forest areas

Pressure	Scope 1 impact of EXIOBASE total production	Scope 1 impacts in GLOBIO-IMAGE results	Gap	Test result
Land use, static	3 325 053 MSA.km²	3 815 980 MSA.km²	13%	In line

B FORESTRY AREAS

In order to check the yields computed based on PEF data, the total implicit area corresponding to EXIOBASE wood production is compared to the forestry areas in GLOBIO-IMAGE and FAO FRA for the year 2010. EXIOBASE contains the 2011 wood production, so that a small gap between 2011 production implicit area and 2010 forestry area is to be expected. Yet, linearly extrapolating 2010 data from GLOBIO-IMAGE and FAO FRA would have introduced an additional bias in the data, with no guarantee that the computed areas fit real 2011 areas. Hence, we decided to stick to 2010 data – which are real data in FAO FRA – in the comparison.

- The total extraction of coniferous and non-coniferous wood in EXIOBASE material account for the year 2011 is combined to the yield computed per wood type and PEF location (see Table 4) to deduce the corresponding forested area;
- The total area of non-natural forests in GLOBIO-IMAGE 2010 data is computed by adding up the surface areas corresponding to all the forestry land-uses except "Natural forest"[6];
- The total "Production forest" area for the year 2010 is taken directly from FAO FRA data (FAO 2015), assuming that "Production forest" corresponds to the area of exploited forests.

Table 12 presents the results. **The forested area computed by applying wood yields to EXIOBASE wood production data is comprised between GLOBIO-IMAGE 2010 forestry area and FAO FRA 2010 production forest area**. The exploited forest areas in GLOBIO-IMAGE and FAO FRA for the year 2010 is significantly different, due to several factors including the fact that GLOBIO-IMAGE non-natural forest areas are partly modelled, so that the delineation of "Production forest" in FAO FRA data may not fit that of non-natural forests in GLOBIO-IMAGE. Indeed, FAO "Production forest area" is defined as *"Forest area designated primarily for production of wood, fibre, bio-energy and/or non-wood forest products"*[7]. In GLOBIO-IMAGE, land use areas are based on real land cover data from GLC 2000 combined to assumptions on management intensities (Stehfest et al. 2014; Schipper et al. 2016). The fact that the implicit area is comprised between the two values gives however **confidence on the computed yields, which we can consider realistic**.

[6] These land-uses are: "Forestry - Plantation", "Forestry - Harvest", "Forestry – Selective logging" and "Forestry – Reduced impact logging".
[7] Definition sourced from the Annex 2 of FRA 2010 "Terms and definitions used in FRA 2010", available at http://www.fao.org/3/i1757e/i1757e13.pdf

Table 12: Comparison of EXIOBASE wood production implicit area with forest area data in GLOBIO-IMAGE and FAO FRA data

Implicit forested area of EXIOBASE wood production	GLOBIO-IMAGE 2010 non-natural forest area	FAO FRA 2010 Production forest area
8 389 875 km²	6 769 783 km²	11 357 781 km²
Ratio of implicit forest area to forest area	1.24	0.74

4 Dimensioning the impacts of wood log production – Refined assessment

4.1 Refined land use impacts

The previous sections build the wood logs CommoTool land use impact factors based on regional wood production yields computed based on LCA PEF data. If the assessed entity can provide **custom and more precise yield data**, PEF process yields can be replaced by the custom ones to obtain more consistent land use biodiversity impact factors. For instance, if the company-specific yield is 300 t/km², the refined impact factors for all pressures are computed as explained in Section 3.1C where PEF yield (`yield_t_per_km2`) are replaced by 300 t/km².

Default assessments are based on the average forestry management practices and expected land use changes per country. If companies can provide data on the management practices of their wood production or purchases, the land use biodiversity intensity can be refined to better reflect companies' impacts. As well, if companies provide data related to the actual land occupation and land use changes of the wood produced or bought, the data can be used to compute the associated refined land use static and dynamic impacts.

4.2 Refined climate change impacts

The previous sections build the wood logs CommoTool climate change impact factors based on GHG emissions per process computed based on LCA PEF data. If the assessed entity can provide **custom and more precise GHG emissions data covering the same perimeter as that of process emissions**, process emissions (from Table 7) can be replaced by the custom ones (in kg CO_2-eq/kg of wood): they would then be combined to the terrestrial and aquatic impact factors in MSA.km^2/kg CO_2-eq (CDC Biodiversité 2020b; 2020d) to obtain specific climate change biodiversity impact factors (MSA.km^2/t).

4.3 Refined wetland conversion impacts

As explained in Section 2.2, wetland conversion impacts are not attributed to wood production in default assessments. In refined assessments, if company data enable to link wetland conversion to wood production, for instance if land use data reveal that exploited forests from which the wood originates expanded over wetland areas, the impacts related to this pressure will be assessed.

5 Linkage with the input-output approach

5.1 M Matrix

The output of the wood logs CommoTool is concretely two **tables of characterisation factors for each pressure on biodiversity** with the units of **MSA.km²/t of wood. One provides impact factors at the {PEF wood item; GLOBIO country} level, the other one at the {PEF item; EXIOBASE region} level** (details below).

The **M matrix** in the Input-Output modelling framework ((CDC Biodiversité 2019b), (Stadler et al. 2018)) is the matrix of biodiversity impacts, gathering **characterisation factors in MSA.km² per tonne of raw material or commodity**. Using the results of the wood logs CommoTool in the M matrix dedicated to wood thus requires bridging the item and geographical perimeters of the CommoTool with that of EXIOBASE.

Logging related extractions are easily identifiable in **EXIOBASE material account** since their names are of the form “Forestry – [..]”. As with Primary crop items, “Used” and “Unused” extractions are distinguished. The naming is similar so that the correspondence table works for both categories. However, only used extractions will be considered in impact computation. Logging items distinguishes coniferous and non-coniferous wood, as well as industrial roundwood and wood fuel. The fifth item is “Kapok fruit”, referring to the FAO crop item “Kapok fruit”. The sixth item is “Natural gums”, certainly referring the FAO crop item “Gums, natural”. FAO standards and definitions for this item specifies: *“Including inter alia: balata (Manilkara bidentata); ceara (Manihot glaziovii); chicle gum (Achras zapota); guayule (Parthenium argentatum); gutta-percha (Palachium gutta); jelutong (Dieva costulana). Extracted from the latex of trees of various species. Although similar to rubber in many ways, natural gums are usually less elastic”*.

The correspondence with the CommoTool item is quite straightforward and presented in Table 13. As the CommoTool does not distinguish wood fuel from industrial roundwood, the match with EXIOBASE item is only made on wood type (coniferous or non-coniferous). The match is made with non-sustainable items since EXIOBASE material account contains no information on forestry management. In the future, we will use FAO data to compute the yields of the items “Kapok fruit” and “Gums, natural” and the related biodiversity impact factors so that they will be additional items in the wood logs CommoTool. This was not done here due to time constraints.

Table 13: Correspondence between EXIOBASE items and the wood logs CommoTool items

EXIOBASE item	Wood logs CommoTool Item
Forestry – non-coniferous – Wood fuel	Hardwood, non-sustainable
Forestry – non-coniferous – Industrial roundwood	Hardwood, non-sustainable
Forestry – coniferous – Wood fuel	Softwood, non-sustainable
Forestry – coniferous – Industrial roundwood	Softwood, non-sustainable
Forestry – Natural Gums	*Natural gums – to be added*
Forestry – Kapok fruit	*Kapok fruit – to be added*

The geographical match is done between PEF locations and EXIOBASE regions following the explanations in Table 14. For CC, HD_{Water} and HD_{CC}, the match is straightforward: the impact factors presented in Table 7 are simply spread across the EXIOBASE regions based on the correspondence table. For land use impacts, the yield per location is spread across the corresponding EXIOBASE regions and the biodiversity impact factors are computed following the methodology explained in Section 3.2.B.2 using intensities and MSA values computed at the EXIOBASE region level instead of GLOBIO country level (see (CDC Biodiversité 2020d) for more details on the computation of biodiversity intensities).

Table 14: Correspondence between PEF locations and EXIOBASE regions

EXIOBASE region	PEF location
All regions belonging to the region group “European Union” except Finland and Sweden	EU
Finland	FI
Sweden	SE
United States	US
Canada	CA
All other regions	RoW

5.2 Test: Comparison of EXIOBASE and FAO wood production

Even though wood production data from FAO are not used to compute in the computation of biodiversity impact factors, we wanted to make sure whether the total extraction of wood documented in EXIOBASE is in line with real data. This should be the case as EXIOBASE Supplementary information states that wood extraction data are based on FAOSTAT production data. FAOSTAT data are in m^3 and factors were applied to convert them into tonnes in EXIOBASE (0.52 t/m^3 for softwood and 0.68 t/m^3 for hardwood). We thus apply the same factors to convert EXIOBASE quantities back into m^3. Computations are done in `test_compare_fao_exiobase_wood_production`.

The total extraction of wood in EXIOBASE material account is 3 965 898 188 m^3, while FAOSTAT reports a total wood production of 3 624 040 482 m^3 for the year 2011. The 9.8% oversetimation (341 857 706 m^3) might be explained by

- the fact that EXIOBASE used different years for some countries, as they did for crop production (CDC Biodiversité 2019a);
- double counting in FAOSTAT data not accounted for by EXIOBASE team when they manipulated the data to compute the material account.

Indeed, studying FAOSTAT wood production data per country reveals double-counting of the Chinese production since the production is reported both at the most global level (country “China” with country code

351) and at the disaggregated level (countries “China, mainland”, “China, Hong Kong SAR”, “China, Macao SAR” and “China, Taiwan Province of” with country codes respectively 41, 96, 128 and 214). In FAOSTAT wood production data, both “China” (total production of 346 358 990 m^3) and “China, mainland” (total production of 344 799 171 m^3) are reported. These amounts being really clause to the total production gap between EXIOBASE and FAOSTAT, the double-counting assumption seem plausible.

The **comparison of EXIOBASE and FAOSTAT wood production at the EXIOBASE region level** reveals several gaps. Notably, for 40 of the 49 regions, EXIOBASE quantities overestimate FAO quantities by 9.8-10.1%. This ressembles to a spreading of the aforementioned error to the various regions of the model due to modelling processes. Contact will be taken with the EXIOBASE team to further investigate this point. 4 regions (RoW Middle East, South Korea, Italy and Luxembourg) display higher production gaps, but the overall share of production concerned is very small (0.5%).

6 Limits and perspectives

6.1 Underlying data limitations

Yields, involved in the computation of implicit areas, play a critical role in the computation of biodiversity impact factors for wood log production. As detailed in Section 3.1A, yields were computed based on limited data (LCA PEF wood production processes), inducing **limited differentiation among wood types and locations**. Yields per country can also be computed thanks to the combination of wood production data (such as FAOSTAT production) and data on forest areas (such as FRA 2015). Example of such combinations exist in the literature. For instance, (Schyns, Booij, and Hoekstra 2017) used this methodology to compute wood water footprint. Although suffering from uncertainties underlined by the authors, this method leads to an increased geographical granularity. Average yields obtained by this approach are globally consistent with the yields used in the CommoTool, so that such data could be used in a future version of the tool to refine impact factors related to land use.

Though present in the data, yield difference related to management practices is not exploited due to lacking information on the assumptions underlying land occupation data for each process. This choice is less impactful than the aforementioned limitation, for management practices are not distinguished in EXIOBASE items. Yet, the possibility to consider several management practices is kept in the construction of the CommoTool and will be easily implemented when more data is available. In particular, practices less impactful for biodiversity can be considered by applying the biodiversity intensity related to a specific forest type (such as Selective logging) instead of the average forestry intensity.

As explained at several stages of this report, default dynamic impacts are computed based on GLOBIO-IMAGE outputs. In particular, dynamic land use impacts are based on expected land use changes, which present limitations. Getting access to real land use changes, for instance thanks to satellite images, would improve the biodiversity impact factors.

6.2 Methodology and assumptions limitations

Limitations regarding the biodiversity intensities related to terrestrial and aquatic pressures are described in the corresponding reports (CDC Biodiversité 2020d; 2020b) and are thus not repeated here.

As explained in Section 3.2.B.2, land use change risk is embedded in dynamic impact factors related to land use. However, this risk is based on GLOBIO-IMAGE output for the SSP2 scenario, thus depending on the scenario and modelling assumptions and suffering from the large regional scale in the IMAGE framework. These assumptions do not necessarily fit reality and better data on land use change is available, notably thanks to satellite imaging. Although these data also present limitations and uncertainties, ways to use this data in the computation of country specific impact factors will be explored in the future. For now, we stick to the land use change risk embedded in GLOBIO-IMAGE outputs. Land use change data provided by companies, notably zero-deforestation commitments, is taken into account in the qualitative part of the biodiversity assessments.

The GBS already enables the computation of the biodiversity impacts related to carbon offset and reforestation programs, as illustrated by the case study done with Veolia Eau d'Ile-de-France (detailed results will be part of the coming GBS publication in early 2020). As explained in Section 3.2.C.1, it was decided not to consider carbon storage during tree growth in the wood logs CommoTool. This choice is also due to **difficulties related to the timeframe of such impacts**. Indeed, carbon storage occurs at varying paces along tree growth, with storage difference between tree species and management practices. Moreover, the carbon stored during tree growth is released in the atmosphere rapidly once the wood is burned (wood fuel, charcoal) or later in the life cycle of wood products (paper, pulp, furniture, packaging, etc.). Considering that the tree species, age at falling and ultimate use of the wood obtained are unknown, **setting carbon storage impacts to zero, though conservative, fits a desire to avoid numerous arbitrary assumptions**. Also, carbon storage was set to 0 in the crops CommoTool, so consistency is maintained here. We might however refine this assumption in the future, especially in the cases of climate dedicated forestry like REDD+ programs.

6.3 Uncertainties

As mentioned throughout the text, uncertainties should be tackled by including the possibility to use multiple calculation modes, with central, pessimistic and optimistic values of both collected corporate data inputs and characterization factors.

Sensitivity tests comparing the results of several versions ot the wood logs CommoTool, as was done for the crops CommoTool (CDC Biodiversité 2019a), should also feed the reflexion about uncertainties embedded in the GBS.

References

CDC Biodiversité. 2017. ‘Global Biodiversity Score: Measuring a Company’s Biodiversity Footprint’. 11. Biodiv’2050 Outlook.

———. 2019a. ‘GBS Review: Crops CommoTool’.

———. 2019b. ‘GBS Review: Input Output Modelling’.

———. 2019c. ‘Global Biodiversity Score: A Tool to Establish and Measure Corporate and Financial Commitments for Biodiversity’. 14. Biodiv’2050 Outlook. CDC Biodiversité.

———. 2020a. ‘GBS Review: Core Concepts’.

———. 2020b. ‘GBS Review: Freshwater Pressures on Biodiversity’.

———. 2020c. ‘GBS Review: Mining CommoTool’.

———. 2020d. ‘GBS Review: Terrestrial Pressures on Biodiversity’.

CDC Biodiversité, ASN Bank, and ACTIAM. 2018. ‘Common Ground in Biodiversity Footprint Methodologies for the Financial Sector’. Paris: ACTIAM, ASN Bank, CDC Biodiversité. Supported by Finance in Motion. https://www.asnbank.nl/web/file?uuid=b71cf717-b0a6-47b0-8b96-47b6aefd2a07&owner=6916ad14-918d-4ea8-80ac-f71f0ff1928e&contentid=2412.

FAO. 2015. ‘Forest Resource Assessment’.

FAOSTAT. 2016. ‘Wood Production Data’.

Janse, Jan H., Michel Bakkenes, and J. Meijer. 2016. ‘Globio-Aquatic’. *Technical Model Description* 1.

Kok, Marcel, Rob Alkemade, Michel Bakkenes, Eline Boelee, Villy Christensen, M. Van Eerdt, Stefan van der Esch, Jan Janse, SISE Karlsson-Vinkhuyzen, and Tom Kram. 2014. *How Sectors Can Contribute to Sustainable Use and Conservation of Biodiversity*. 79. PBL.

R.W. Matthiews, T.A.R Jenkins, E.D. Mackie, and E.C. Dick. 2016. ‘Forest Yield: A Handbook on Forest Growth and Yield Tables for British Forestry’. Forestry Commision, Edinburgh.

Schipper, Aafke M., Johan R. Meijer, Rob Alkemade, and Mark A. J. Huijbregts. 2016. ‘The GLOBIO Model: A Technical Description of Version 3.5’. The Hague: Netherlands Environmental Agency (PBL). http://www.pbl.nl/sites/default/files/cms/publicaties/pbl_publication_2369.pdf.

Schyns, Joep F., Martijn J. Booij, and Arjen Y. Hoekstra. 2017. ‘The Water Footprint of Wood for Lumber, Pulp, Paper, Fuel and Firewood’. *Advances in Water Resources* 107 (September): 490–501. https://doi.org/10.1016/j.advwatres.2017.05.013.

Stadler, Konstantin, Richard Wood, Tatyana Bulavskaya, Carl-Johan Södersten, Moana Simas, Sarah Schmidt, Arkaitz Usubiaga, José Acosta-Fernández, Jeroen Kuenen, and Martin Bruckner. 2018. ‘EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables’. *Journal of Industrial Ecology* 22 (3): 502–515.

Stehfest, Elke, Detlef van Vuuren, L. Bouwman, and Tom Kram. 2014. *Integrated Assessment of Global Environmental Change with IMAGE 3.0: Model Description and Policy Applications*. Netherlands Environmental Assessment Agency (PBL).

WWF. 2015. ‘Saving Forests at Risk’. In *WWF Living Forests Report: Chapter 5*.

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