THE GLOBAL BIODIVERSITY SCORE

GBS Review: Freshwater pressures on biodiversity

July 2020 – Final version

Content

Note to the reader

Global Biodiversity Score (GBS) review reports are not completely independent from each other. Readers of this report are advised to read the report dedicated to Core concepts (CDC Biodiversité 2020a) to ensure a good overall comprehension of the tool and the present report.

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 2019).

1 Aquatic pressures: purpose and context

1.1 Purpose and context

Inland aquatic ecosystems – rivers, lakes, and wetlands – represent 11-13 million km², or 8-9% of the Earth's continental surface (Lehner and Döll 2004). They host a high and unique biodiversity delivering important ecosystem services. Biodiversity in freshwater ecosystems is undergoing a rapid and global decline. Hence the need for adequate policies, regulations and tools to understand and halt this decline. PBL scientists recently developed the GLOBIO-Aquatic model (J. H. Janse et al. 2015), counterpart of the GLOBIO terrestrial model, focusing on the biodiversity of inland surface aquatic ecosystems. Thus, we are currently developing the GBS methodology to include aquatic biodiversity based on the GLOBIO-Aquatic model. According to the model's results and as illustrated by Figure 3, the world average aquatic mean species abundance has decreased to 76.1% in 2000 and is predicted to drop to 74.5% by 2050 in the OECD baseline scenario (the same scenario as for GLOBIO Terrestrial, it is also called "SSP2" for Shared Socioeconomic Pathway, a middle-of-the-road scenario in terms of socioeconomic predictions). The highest impacts are occurring in Central Africa (Figure 2). Assessing the impact of economic activities on freshwater ecosystems with the GBS is therefore crucial to complete the assessment on terrestrial ecosystems and provide a comprehensive analysis of companies' biodiversity footprint.

This report presents how impacts on aquatic biodiversity are included in the GBS tool. Each section presents one of the pressures covered by the GLOBIO-Aquatic cause-effect relationships, the procedure followed to compute the related characterization factors used in default assessments and describes how a refined assessment can be run for some pressures, based on company data. Figure 1 shows the linkages with the overall GBS approach: the "default" approach uses the area circled in orange while the "refined" approach circled in purple allows to directly use pressure-related corporate data inputs to assess impacts.

More precisely, the "Aquatic module" described in this report builds "impact intensities", which can also be called midpoint to endpoint characterisation factors as explained in the Core concept review document (CDC Biodiversité 2020a). For each pressure, these impact intensities link midpoints such as land occupation, greenhouse gas (GHG) emissions, water consumed or withdrawn and phosphorous emissions to impacts on biodiversity expressed in MSA.km². Impact intensities are calculated at various geographical levels, from watershed to EXIOBASE regions (*e.g.* China) to match the potential granularity of corporate data inputs. The Aquatic module is only one part of the GBS, as illustrated by Figure 1: to assess the impacts of economic activities using the GBS, when corporate data inputs are not available at the midpoint level, its impact intensities are combined to midpoints calculated as outputs from the GBS' input-output modelling or commodity tools (CommoTools).

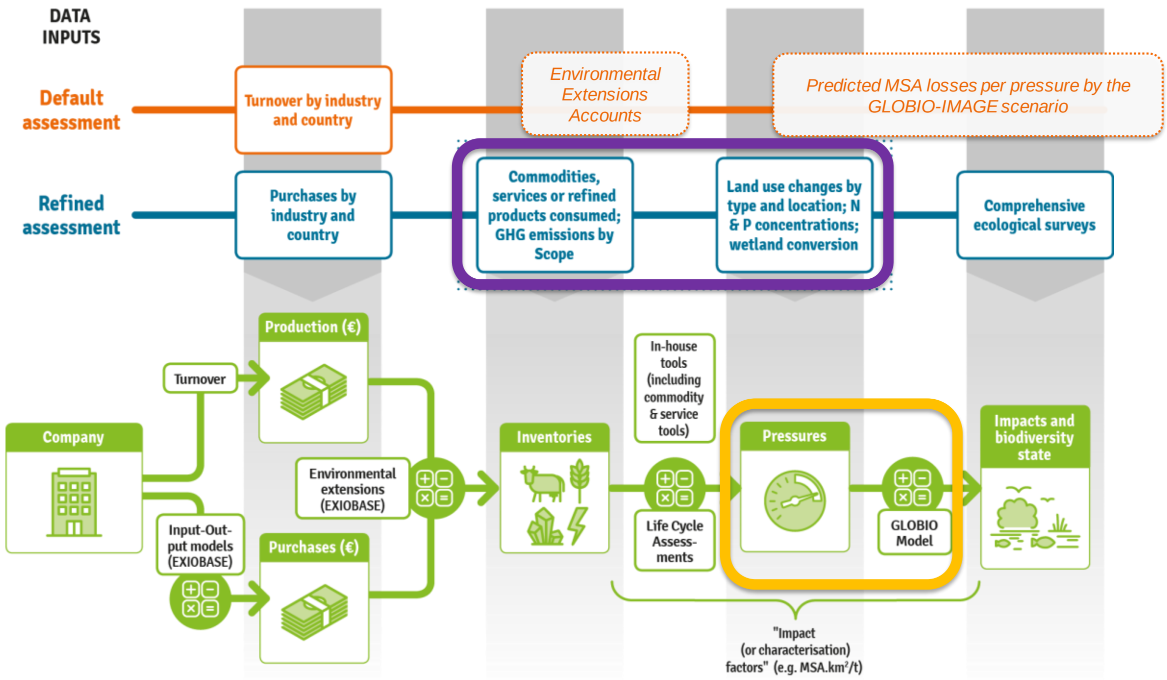

Figure 1: Link between the content of this report and the GBS framework

1.2 Overview of the GLOBIO-Aquatic model

As with the terrestrial model, the PBL's GLOBIO framework provides both cause-effect relationships and projections of global aquatic biodiversity evolution up to 2050. Three types of freshwater ecosystems – lakes, rivers and wetlands [1] – and four pressures – drainage of wetlands, land use changes in catchment of water bodies, nutrient loading and hydrological disturbance – are considered in the cause-effect relationships. We refer readers interested into a more detailed description of GLOBIO-Aquatic to the scientific paper (J. H. Janse et al. 2015) and the technical description of the model (Jan H. Janse, Bakkenes, and Meijer 2016).

Projections up to 2050 are evaluated through a chain of global models and maps involving the IMAGE model for land use and climate change (Stehfest et al. 2014) the PCR-GLOBWB hydrological model (Van Beek and Bierkens 2009), the Global Nutrient Model (Beusen 2014)and the Global Lakes and Wetlands Database (GLWD) a map of water bodies (Lehner and Döll 2004). The forecasts up to 2050 of this patchwork of models is referred to hereafter as the GLOBIO-IMAGE scenario. This scenario, by spatially estimating pressures' intensities which are then translated into biodiversity impacts with GLOBIO-Aquatic's cause-effect relationships, provides information on the evolution of biodiversity intactness in freshwater ecosystems at the same spatial scale as the GLOBIO terrestrial model (0.5° by 0.5° grid cells). The catchment approach is applied by including upstream-downstream spatial relationships between grid cells based on flow direction: the biodiversity impacts on a water body depends on the intensity of drivers on all upstream cells.

The PCR-GLOBWB 1.0 model includes "exchange with the underlying groundwater reservoir [such as] deep percolation and capillary rise"[2]. The GLOBIO-IMAGE scenario thus takes into account groundwater.

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[1] The GWLD "largely [refers] to lakes as permanent still water bodies (lentic water bodies) without direct connection to the sea". It also includes "saline lakes and lagoons (but not 'lagoon areas') as lakes, while excluding intermittent or ephemeral water bodies". It includes both natural and manmade reservoirs as lakes. The definition of wetlands generally follows the Ramsar Convention definition of wetlands, which basically includes non-lake, non-river water bodies with a depth lower than 6m. Large rivers are also considered "lotic wetlands" (Lehner and Döll 2004). Wetlands include classes 4 to 12 of the GWLD, *i.e.* freshwater marshes, floodplains, swamp forests, flooded forests, coastal wetlands (mangroves, estuaries, deltas, lagoons), pans, brackish/saline wetlands, bogs, fens, mires, intermittent wetlands/lakes

[2] http://www.globalhydrology.nl/models/pcr-globwb-1-0/ and its version 2.0 includes even more refined analyses of the translations of water demand on groundwater withdrawal: http://www.globalhydrology.nl/models/pcr-globwb-2-0/

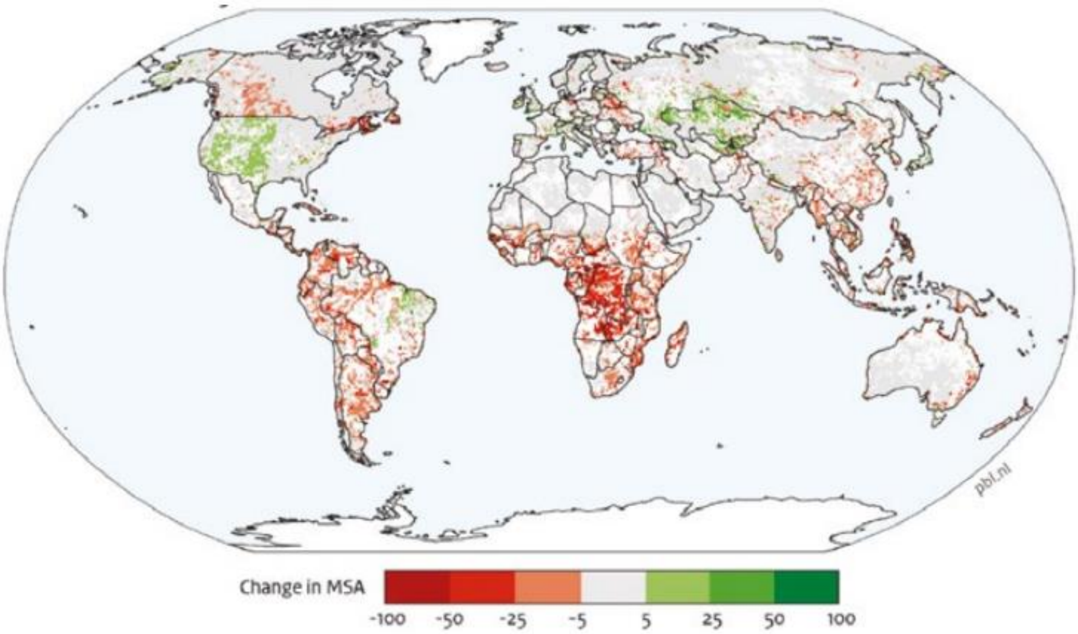

Figure 2: Map of the difference between mean freshwater MSA between 2000 and 2050 (J.H. Janse et al., 2015). The change is expressed in absolute MSA, so a +50 increase can signify a rise from 10% to 60% or from 25% to 75% for instance

Pressure/ Footprint (MSA.km²)	Static 2010	Static 2050	Dynamic 2000-2050
Rivers HD	50 533	50 337	-195
Wetlands HD	546 405	538 435	-7 970
Wetlands Conversion	552 372	592 334	39 962
Rivers LU	49 229	56 837	7 608
Wetlands LU	771 093	873 497	102 403
Wetlands Local LU	488 067	504 316	16 249
Lakes	157 381	174 480	17 099
Total	**2 615 079**	**2 790 235**	**175 156**
MSA%	**76.1%**	**74.5%**	**1.6%**

Figure 3: Aquatic MSA 2000-2050 summary (J. H. Janse et al. 2015)

1.3 Pressures covered

GLOBIO Aquatic covers the following IPBES main drivers of biodiversity loss:

- Land / sea use change[3]: Land use in catchment of rivers and wetlands, Wetland conversion;
- Direct exploitation: Hydrological disturbance, since the impacts of over-withdrawal of water beyond the capacity of natural ecosystems is taken into account. The pressures associated to unsustainable freshwater fishing are not yet covered;
- Pollution: Nutrient emissions. Pollution related to pesticides and ecotoxicity is covered in the Ecotoxicity review document (CDC Biodiversité 2020b). Other pollution sources such as plastic pollution are not covered yet;
- Climate change: Hydrological disturbance, as it also includes the impact of climate change on rivers and floodplain wetlands and swamps.

The following driver is not yet covered: Invasive alien species.

The GBS will be regularly updated and it aims to cover all the main drivers of biodiversity loss as listed by the IPBES. As soon as reliable data are available, the GBS will include impacts from the pressures currently not covered in its assessments.

2 Land use in catchment of rivers and wetlands

2.1 Context

A GLOBIO CAUSE-EFFECT RELATIONSHIP

This driver accounts for the indirect impact of upstream land use changes on downstream water bodies, considering that land use type is a proxy for the nutrient emissions leaching to the ecosystems. Land use type in the catchment proxy is treated slightly differently for rivers and wetlands. For rivers, the criterion is whether the land use type is natural or not (Figure 4). For wetlands land use management intensity is considered (Figure 5). For more details about land use types please refer to GBS Review: Terrestrial pressures on biodiversity (CDC Biodiversité 2020c).

[3] Sea use change is not assessed in this module.

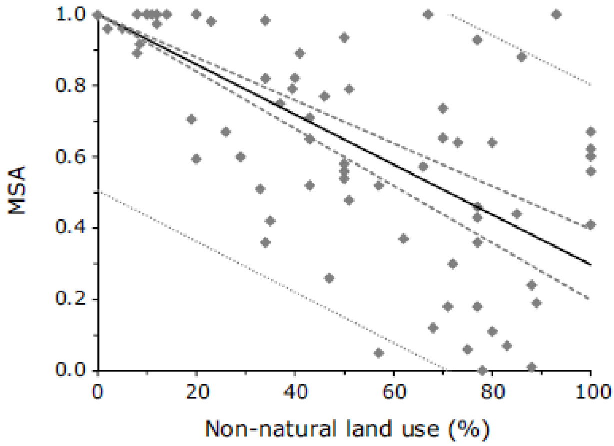

Figure 4: MSA in rivers and streams in relation to land use in the catchment (J. H. Janse et al. 2015)

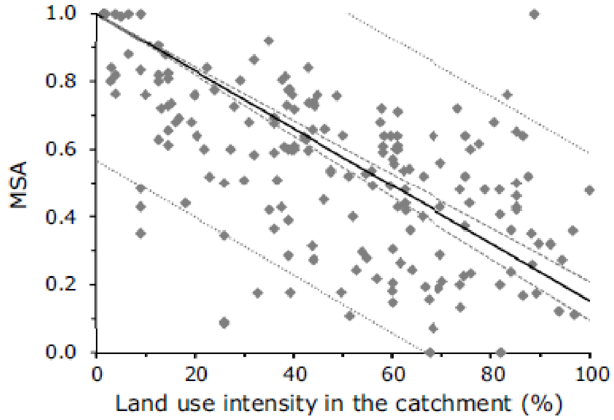

Figure 5:MSA in wetlands in relation to catchment land use intensity (J. H. Janse et al. 2015)

B GLOBIO-IMAGE SCENARIO

Projections of land use change in each grid cell are derived from the terrestrial GLOBIO-IMAGE scenario. For more details about land use coverage estimation in GLOBIO-IMAGE, please refer to GBS Review: Terrestrial pressures on biodiversity (CDC Biodiversité 2020c).

2.2 Default assessment – Dimensioning

In the GBS, the default assessment of the extent of the impact of the Land use in catchment pressure is not based on a direct cause-effect relationship applied to pressure data. Instead, due to a lack of pressure data in appropriate format, we rely on the assessments made in the GLOBIO-IMAGE scenario to dimension the impacts.

2.3 Default assessment – Attributing the impact

The impacts dimensioned in the GLOBIO-IMAGE scenario are attributed to area of non-human land uses. The following sections detail the GBS approach.

A GLOBAL LAYOUT

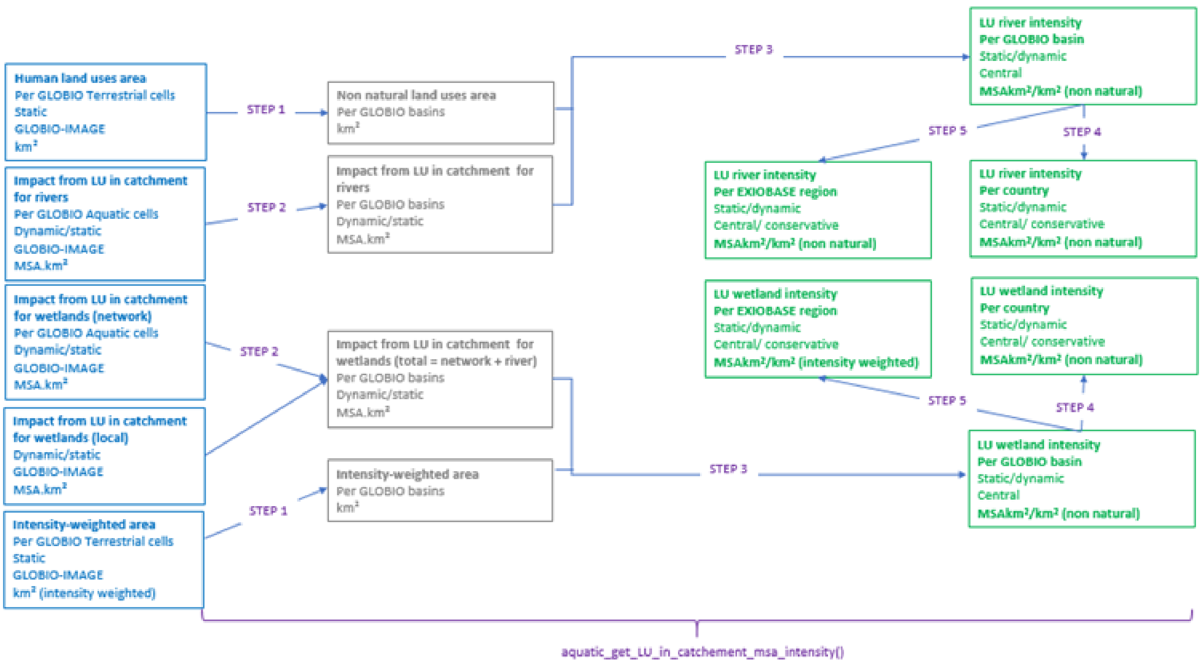

Figure 6: General layout for land use in the catchment for rivers and wetlands default assessment

B DETAILS ABOUT LAND USES

The procedure followed to compute the impact intensities related to land use in catchment is almost identical for rivers and wetlands, the only difference coming from how land use types are considered impactful in the cause-effect relationships:

- **for rivers**, all human land uses (croplands, pastures and urban areas) are considered equally impactful;
- **for wetlands**, land use intensity needs to be evaluated. By definition, land use intensity is equal to 1-MSA%. For instance, a grazing area of MSA 60% has a 40% intensity whereas an intensive agricultural area of MSA% 10% has a 90% intensity. Land use intensity weighted area is defined as the product of the area (in km²) by the intensity (%). For instance, 100 km² of grazing area

equals to 40%*100 = 40 km² of land use intensity weighted area where the same surface of intensive agriculture equals to 90%*100=90 km² of land use intensity weighted area.

C IMPLEMENTATION

We work at the basin level to be consistent with GLOBIO-Aquatic where computations are done at the catchment level. Land uses of all the cells belonging to the basin are considered equally, independently from the relative position of the cell (upstream or downstream) in the hydraulic network. This is an important assumption as, ideally, we should take into account the fact that a pressure applied upstream of a water body is potentially more impactful than a pressure applied downstream as it will affect a bigger portion of the water body.

To compute intensities (MSA.km²/km²) at the basin level we compute from GLOBIO-IMAGE data:

- (STEP1) the area (km²) of human land uses (static), meaning the combined area of all agricultural land uses, pastures and urban areas,

- the intensity weighted area (km²) of terrestrial land use types (static),

- (STEP2) impacts (MSA.km²) due to the pressure land use in catchment for rivers, distinguishing the total impact for current year (static impact) and the annual change (dynamic impact),

- impacts (MSA.km²) due to the pressure land use in catchment for wetlands, distinguishing the total impact for current year (static impact) and the annual change (dynamic impact).

As a reminder, static (total for current year) and dynamic (annual change) values are computed doing on a linear interpolation of 2000 and 2050 impacts.

(STEP3) At the basin level, static and dynamic intensities related to land use in catchment for rivers ($MSA.km^2/km^2$) are computed by dividing respectively the static and dynamic impacts by the area of human land uses (static). Similarly, static and dynamic intensities for land use in catchment for wetlands ($MSA.km^2/km^2$) are computed by dividing respectively static and dynamic impacts by the land use intensity weighted area (static). Therefore, we get 4 intensities at the basin level:

- land use in **rivers'** catchment expressed in MSA.km² per km² of human land use type area: static and dynamic
- land use in **wetlands'** catchment expressed in MSA.km² per km² of land use intensity weighted area: static and dynamic

The intensities fall into the data quality tier 2.

(STEP4 & 5) To allow analysis at various spatial resolutions, intensities are also computed at the country and EXIOBASE region levels. Indeed, depending on the context, companies or investors need different spatial granularity. The process used for land use in catchment of rivers at the country level is described here. For land use in the catchment of wetlands, the computation is similar except that the land use intensity weighted area is used instead of the area of human land uses in the catchment. The computation process is identical at the EXIOBASE region level. Intensities at the country and EXIOBASE region level also fall into the data quality tier 2.

First, basin intensities and the associated area of human land uses is determined for each country. If a basin spreads across multiple countries, the area of human land uses for each country is computed directly using GLOBIO cells data. Once this process is done, a list of basin intensities and associated areas of human land uses is obtained for each country. Then, two intensity values are computed at the country level. The first intensity, corresponding to an "central" calculation mode, is computed as the average of basin intensities within the country weighted by the share of the area of human land uses related to each basin in the total area of all human land uses within the country. The second intensity is more conservative. It is also the weighted average of basin intensities in the country, but only applied to the X% of areas of human land uses with the highest basin intensities. The cutoff value X is now set at 20%.

Depending on the context, users might want to use either the "central" or "conservative" calculation mode. For instance, if a company owns agricultural lands in a country but doesn't know where they are located and therefore to which basins they belong, the "central" intensity gives a location neutral estimation as if the lands where equally allocated in the various basins of the country. On the other hand, the "conservative" intensities give a location pessimistic estimation assuming that lands are located in the basins where intensities are the highest.

2.4 Limits and future developments

In our approach, position in the hydraulic network is not considered. All impactful areas (human land uses for rivers and land use intensities for wetlands) are equally weighted in the basin. This assumption could be changed to reach a better spatial accuracy within the basin in the next versions of the tool and take into account that an area located upstream of a water body is potentially more impactful than an area located downstream.

3 Hydrological disturbance: introduction

3.1 Context

A GLOBIO CAUSE-EFFECT RELATIONSHIP

Hydrological disturbance is defined as the deviation of the current river flow from the natural one. Causes of deviation include climate change (changes in rainfall or evaporation), anthropic water abstraction and river dams used for hydropower, water storage and/or other purposes. Data on existing river dams are taken from the Global Rivers and Dams (GRanD) database (Lehner et al. 2011) documenting the location and use of over 7000 dams in the world and the projection of future dams is taken from (Fekete et al. 2010). The deviation between natural and current (impacted) flow patterns is determined by the models PCR-GLOBWB (Van Beek and Bierkens 2009) and LPJmL (Biemans et al. 2011). It is calculated as the "amended annual proportional flow deviation" or AAPFD, expressed in cubic meters (Ladson et al. 1999) and defined as:

$$AAPFD = \left[\sum_{i=1}^{12}\left(\frac{Q_i - Q_{i0}}{\overline{Q_{i0}}}\right)^2\right]^{\frac{1}{2}},$$

with Q_i the runoff in month *i*, Q_{i0} the natural runoff in month *i* and $\overline{Q_{i0}}$ the yearly average natural runoff.

The biodiversity impact of flow deviation in rivers and wetlands connected to rivers (*i.e.* floodplain wetlands) is represented in Figure 7 and Figure 8.

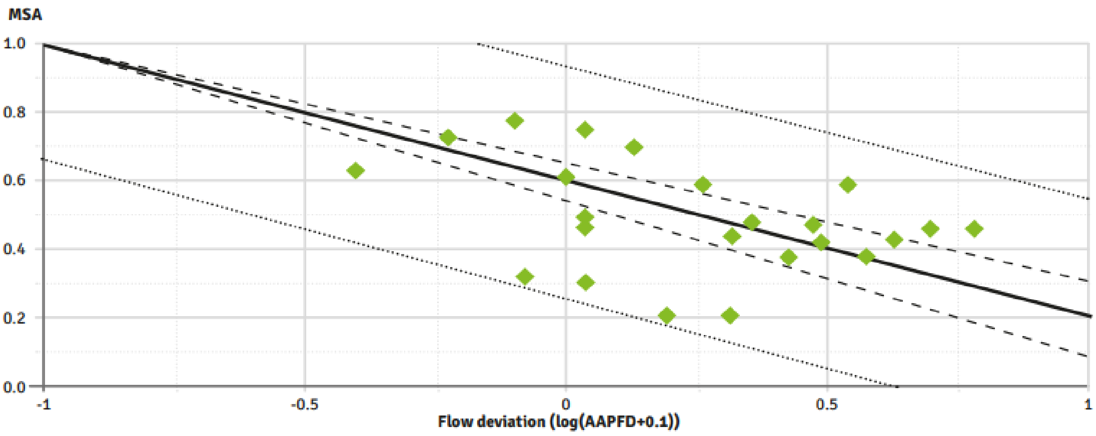

Figure 7: MSA in rivers and streams in relation to flow disturbance including regression line (black line), confidence interval (dashed lines) and prediction interval (dotted lines). Source: (J. H. Janse et al. 2015)

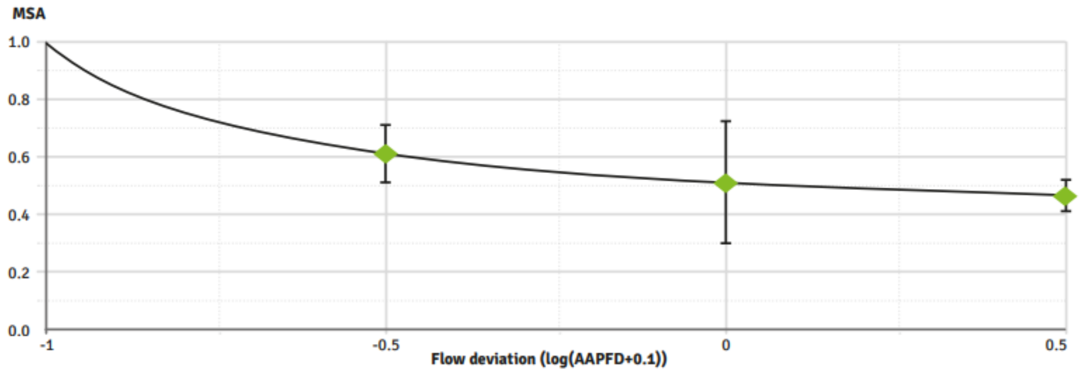

Figure 8: MSA in floodplain wetlands in relation to flow disturbance for three intensities of hydrological alteration, mean effect and standard error. Source: (J. H. Janse et al. 2015)

B GLOBIO-IMAGE SCENARIO

As shown by Figure 3 , the GLOBIO-IMAGE scenario predicts that the biodiversity impact due to hydrological disturbances will slightly decrease globally over the period 2000-2050. As illustrated by Figure 9 and Figure 10, the dynamic impacts – where biodiversity losses and gains occur over the period – are very location dependent, some regions depicting predicted gains (in blue on the maps) and other regions depicting predicted losses (in red on the maps).

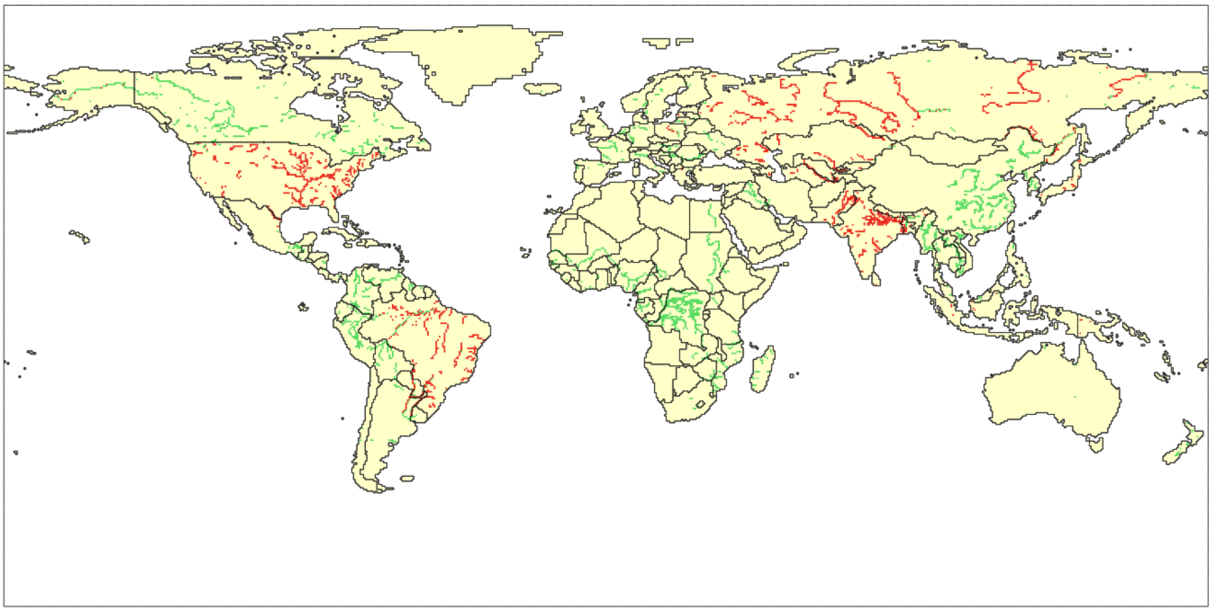

Figure 9: Biodiversity losses and gains due to hydrological disturbance for rivers predicted between 2000 and 2050 in the GLOBIO-IMAGE scenario

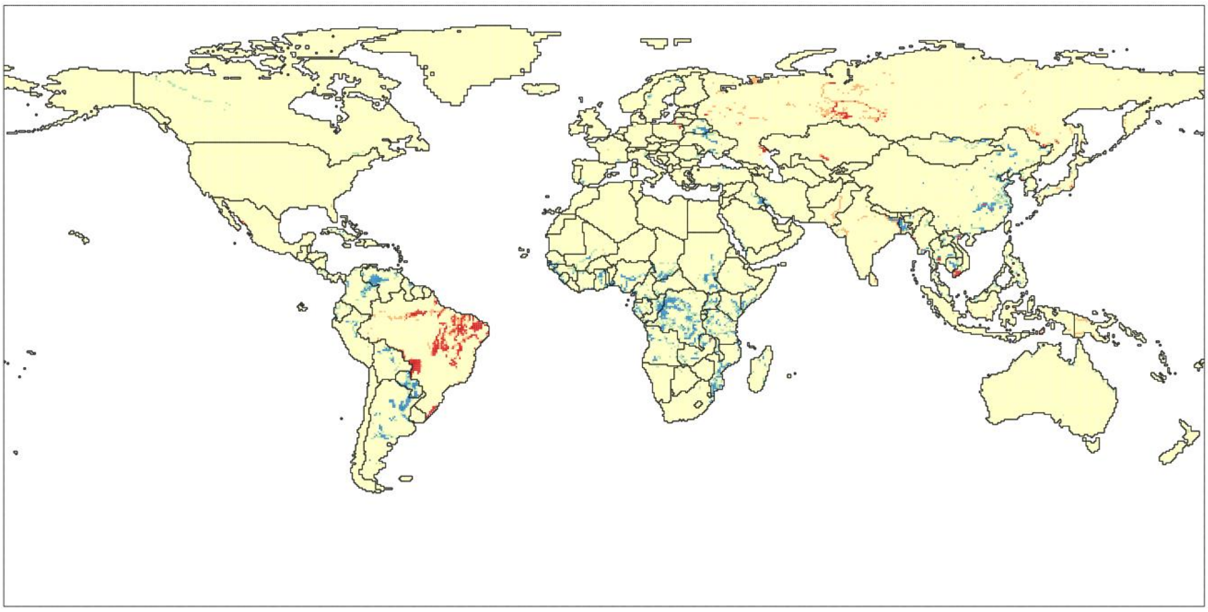

Figure 10: Biodiversity losses and gains due to hydrological disturbance for wetlands predicted between 2000 and 2050 in the GLOBIO-IMAGE scenario

3.2 Default assessment: preliminary attribution of impacts

A CONCEPT

In the GLOBIO-IMAGE scenario, MSA impacts due to hydrological disturbances are reported separately for rivers and wetlands. This split is not reproduced in the GBS since, contrary to land use change in catchment, the process to compute the impact intensities of hydrological disturbance is identical for rivers and wetlands. Therefore, impacts due to hydrological disturbance of wetlands and rivers are summed from the start and referred to simply as impacts due to hydrological disturbance.

Applying GLOBIO-Aquatic hydrological disturbance pressure-impact relationship requires knowing the flow deviation (AAPFD) of the rivers and wetlands involved in the assessments. Unfortunately, the data needed to calculate the flow deviation directly is not available. We thus seek to approximate AAPFD with other measures. In the GLOBIO-IMAGE scenario, flow deviation is implicitly a function of 3 sub-drivers: climate change, water use and occurrence of infrastructure, as explained in 3.1A. This function is not written in equations and varies across water bodies. Ideally, we would need to get to the core of the GLOBIO-Aquatic cause-effect relationships (in particular PCR-GLOBWB and LPJmL-hydrology models) and assess for each water body, the monthly flow deviation and the weight of each of the sub-drivers regarding that flow deviation. Doing so, we would be able to allocate the MSA impacts due to HD in each water body to the sub-drivers according to their contribution to the water body's AAPFD. This in-depth attribution is considered for the next version of the GBS. For GBS 1.0, we did not manage to get access to the LPJmL and PCR-GLOBWB models. Thus, as detailed below, a very rough attribution is established at the basin level to approximate the contribution of the 3 sub-drivers to the AAPFD. Thus, we never directly calculate the AAPFD but rely instead on attributing the HD static impacts to dams, water use and climate change. The static impacts of the year assessed are calculated through a linear interpolation based on impacts evaluated by the PBL in 2000 and 2050.

We use infrastructure data provided by GRanD (Lehner et al. 2011). The dataset, also used in GLOBIO-IMAGE, documents and locates about 7000 river dams[4], which are the biggest at a global level (out of a total of about 50 000). It also specifies the main and secondary uses of each dam. Only the main use is of interest to us and we regroup them in 2 categories: hydrological energy production (a use category in GRanD) and direct water use (all the other uses in GRanD).

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B IMPLEMENTATION

(STEP 1, see Figure 12 and Figure 13) At the basin level and based on GRanD, we check if there is at least one dam. If not, we consider that infrastructure does not play a role in hydrological disturbance and, consequently, impacts are split equally between direct water use and climate change, each getting half of the total impacts. If there is at least one dam, impacts due to hydrological disturbance are split equally between the three possible causes: infrastructure, direct water use and climate change. When there is an infrastructure bucket, *i.e.* several dams, the uses of the dams present are checked: hydrological energy production or direct water use. If only one use is represented, the impact of the full bucket (1/3 of the total impacts due to hydrological disturbance) is allocated to this use, otherwise the bucket is split equally between hydrological energy production and direct water use. At the end of this process all impacts are allocated to the 3 categories direct water use, hydrological energy production and climate change. Every time there was an allocation to be done between different categories, we chose to do it the simplest way, meaning equally. Indeed, as this choice is arbitrary, it was decided to go with the simplest decision process.

A summary of the different weights attributed to the categories depending on the configuration is presented in Figure 11. The allocation process described previously to split hydrological disturbance impacts between energy production, direct water use and climate change is run on the impact data related to year 2050. As shown by Figure 11, only dams' occurrence is considered in the impacts allocation rule. Therefore, the attribution of 2050 impacts is based on GRanD infrastructure map for 2010 and not on a projected map of infrastructures in 2050, which is a limitation. No assumption on water use in 2050 is needed nor used in the allocation process.

[4] The present model does not cover the (combined) effects of the smaller dams, which may have relatively little impact on water flow but still have a direct fragmenting effect.

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Dams' type occurrence		Split at the bassin level		
Hydrological energy production	Other uses	Hydrological energy production	Direct water use	Climate change
No	No	0	1/2	1/2
Yes	No	1/3	1/3	1/3
No	Yes	0	1/3 + 1/3	1/3
Yes	Yes	1/6	1/3 + 1/6	1/3

Figure 11: Weighting summary for the allocation of impacts due to hydrological disturbance

C LIMITS AND FUTURE DEVELOPMENTS

Attribution in 2050 is based on 2011 GRanD infrastructure map. Implicitly, it assumes that the dam locations in 2050 are unchanged compared to the latest year for which data are available in GRanD (it should be noted that this influences only the allocation of impacts; GLOBIO-IMAGE forecasts do include an updated map of dams for 2050 when they dimension the HD impacts in 2050). This is not satisfactory, and a possible upgrade would be to access dams' projection map used in GLOBIO-IMAGE. This upgrade is included in the broader upgrade planned for hydrological disturbance pressure's impacts allocation.

Generally, we acknowledge the current weaknesses of the impact intensities related to hydrological disturbance due to a lack of access to the underlying models LPJmL and PCR_GLOBWB. We hope to get access to these models to improve the calculations in the next version of the GBS.

At this stage, biodiversity intensities related to hydrological disturbance are preliminary and call for additional work. Hence, regarding this pressure the GBS must be considered more as a risk screening tool than as a footprint assessment tool.

However, we know that the more a company withdraw water, the bigger the potential flow deviation is, and the bigger the potential impacts on hydrological disturbance are (and more withdrawal of water will not lead to less flow deviation and gains of biodiversity). Situations where companies discharge more water in ecosystems than has been withdrawn would not fit this pattern (but should be extremely rare) and should thus be dealt with cautiously in the GBS. Beyond such exceptions, the intensities calculated for the hydrological disturbance pressure should be positively correlated with the actual impacts (so that if the GBS assesses an impact as negative, it is not in truth positive).

4 Hydrological disturbance due to climate change

4.1 Default assessment - Dimensioning

A GENERAL LAYOUT

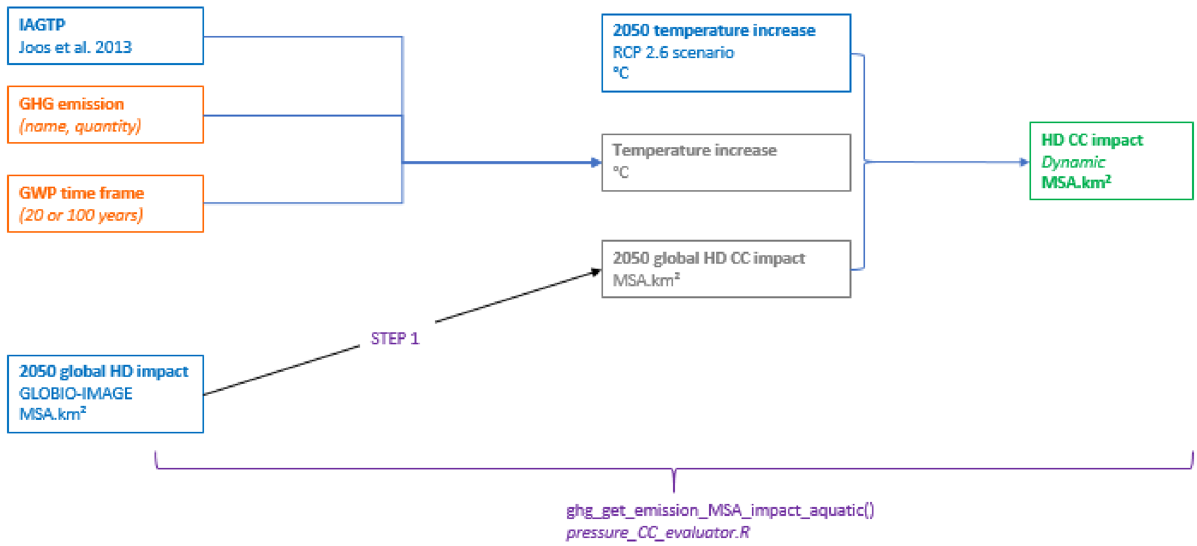

Figure 12: General layout for hydrological disturbance due to climate change default assessment

B IMPLEMENTATION

Impacts attributed to climate change are aggregated globally to compute the total impact attributed to climate change in 2050. As the GLOBIO-IMAGE scenario is based on the RCP2.6 scenario which implies a 2.5°C global temperature increase by 2050, we consider that the total hydrological disturbance impacts attributed to climate change are due to this 2.5°C temperature increase. The dynamic impact of a GHG emission on aquatic ecosystems due to hydrological disturbance is computed as its contribution to the global temperature increase. This contribution is estimated based on the integrated absolute global mean temperature potential (IAGTP) of CO_2 for a 100-year time horizon: $4.76.10^{-14}$ °C.yr.kg CO_2 $^{-1}$ (Joos et al. 2013). For more details about the IAGTP, please refer to the report dedicated to terrestrial pressures (CDC Biodiversité 2020c). The impact associated to the emission is then simply computed as a proportion of the total loss estimated for 2050 relatively to the associated temperature increase of 2.5°C. For instance, 1% of the total loss would be allocated to an emission causing a temperature increase of 0.025°C.

C LIMITS AND FUTURE DEVELOPMENTS

The computation of HD_{CC} biodiversity intensities will be improved when the allocation rule is upgraded as presented in Section 3.2C.

4.2 Default assessment – Attributing the impacts

Past emissions generated the static impacts, which are not attributed to any economic activity.

100% of the impacts dimensioned for GHG emitted during the period assessed with the GBS are attributed to the emission source, as dynamic impacts.

5 Hydrological disturbance due to direct water consumption and withdrawal

5.1 Default assessment – Dimensioning the impact

As for impacts related to land use in catchment, in the GBS, the default assessment of the extent of the impact of the Hydrological disturbance due to water consumption and withdrawal pressure is not based on a direct cause-effect relationship applied to pressure data. Instead, due to a lack of pressure data in appropriate format, we rely on the assessments made in the GLOBIO-IMAGE scenario to dimension the impacts.

5.2 Default assessment – Attributing the impact

A GENERAL LAYOUT

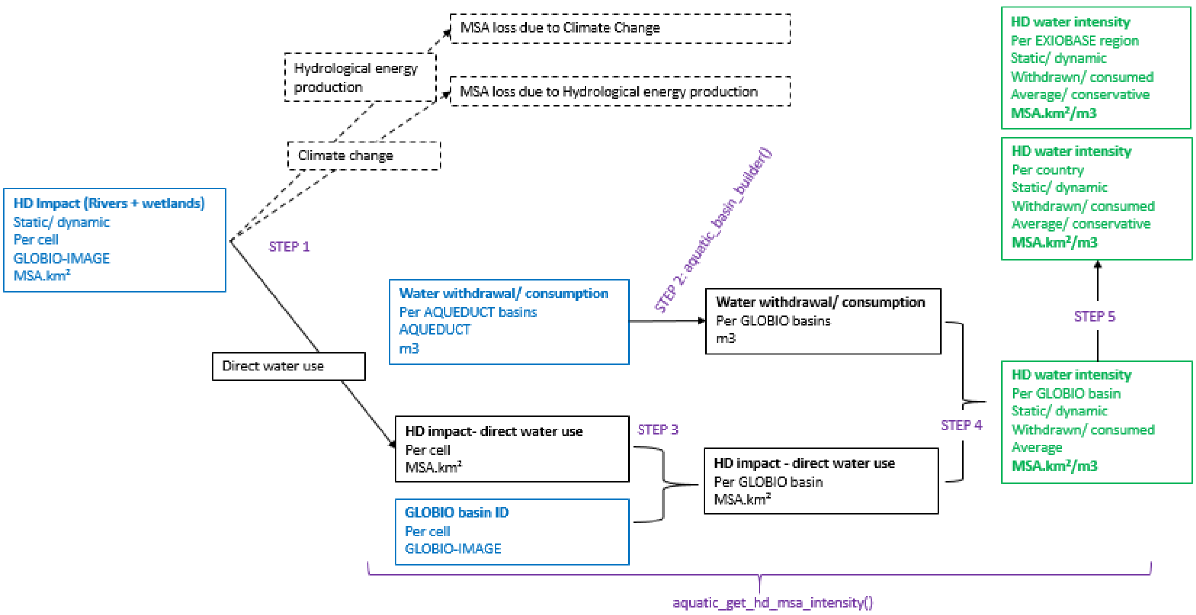

Figure 13: General layout for hydrological disturbance due to direct water use default assessment

B PRELIMINARY WORK TO EVALUATE WATER WITHDRAWAL AND WATER CONSUMPTION FOR EACH BASIN

(STEP 2) Linking a water consumption or extraction to the related aquatic biodiversity impacts requires to know the total annual water consumption and extraction at the basin level. Since we could not get it directly from the GLOBIO-IMAGE scenario, we used the AQUEDUCT database (Gassert et al. 2014). AQUEDUCT references the total (surface and groundwater) water consumption and water extraction volumes for 25 010 basins (19 555 with positive water withdrawal volume). Surface and groundwater is currently not distinguished and 1 m^3 extracted from surface or groundwater aquifers in the same watershed is currently associated to the same impact. In future versions, we will explore the possibility to distinguish impacts from groundwater and surface withdrawals.

Since the GLOBIO-IMAGE scenario considers only 6292 basins, using AQUEDUCT date requires to link AQUEDUCT basins to that of the GLOBIO-IMAGE scenario. Generally speaking, GLOBIO-IMAGE basins either fit or gather AQUEDUCT basins. Indeed, the spatial structure of AQUEDUCT and GLOBIO basins is comparable as shown by Figure 14. We note that the regrouping of basins in GLOBIO-IMAGE leads in certain cases to much bigger basins than in AQUEDUCT's (especially for large rivers such as the Nile, Amazon or Congo rivers). Also, the allocation to fixed 0.5° by 0.5° cells is more approximative for smaller basins, therefore the uncertainty of intensities for such basins is higher due to the higher uncertainty in associated AQUEDUCT water withdrawal or consumption data.

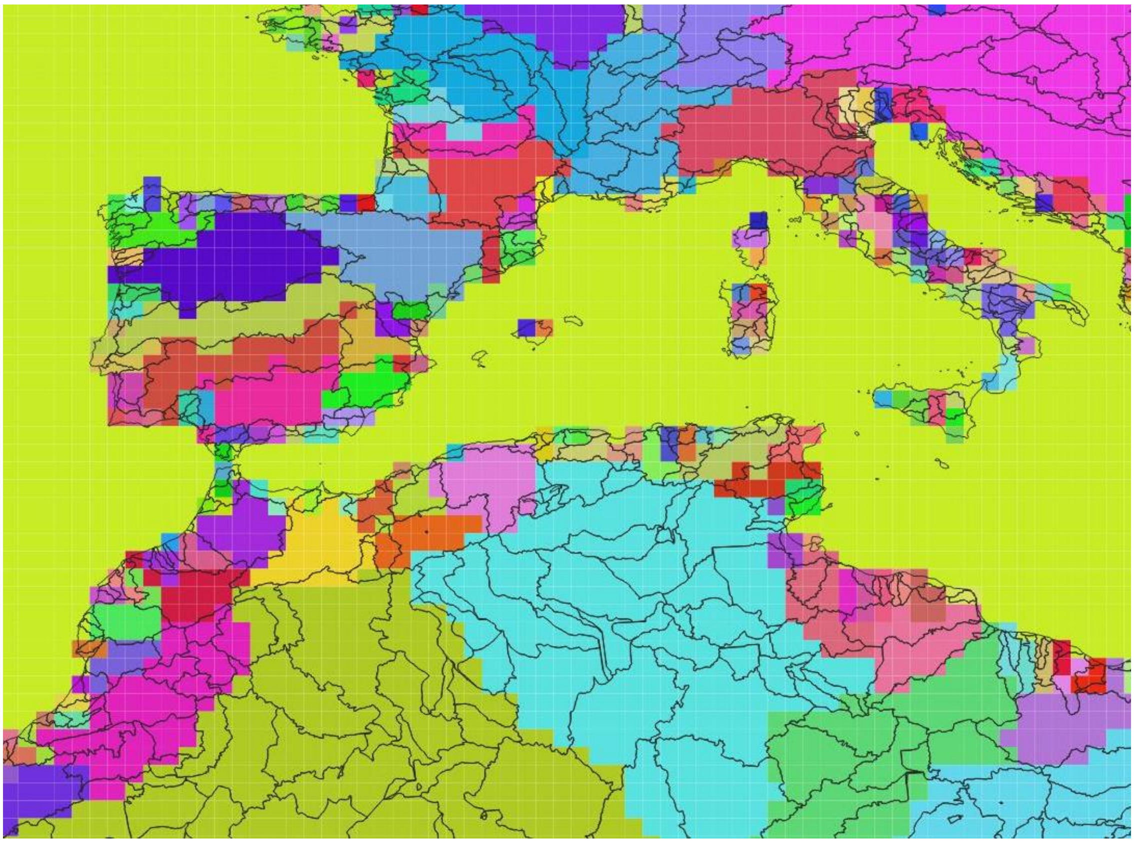

Figure 14: AQUEDUCT basins (black lines) and GLOBIO-IMAGE scenario's basins (colored cells). Generally, GLOBIO-IMAGE scenario's basins are a gathering of AQUEDUCT basins.

AQUEDUCT water withdrawal data are allocated to GLOBIO-IMAGE basins based on the GPS coordinates of AQUEDUCT basins polygons. The GPS coordinates of the center of the AQUEDUCT basin is used to identify the corresponding GLOBIO-IMAGE cell. For more details on how linking GPS coordinates to IMAGE-GLOBIO cells' index, please refer to the report on terrestrial pressures (CDC Biodiversité 2020c). Then, GLOBIO-IMAGE table linking each cell index to the corresponding basin is used to identify the GLOBIO-IMAGE basin in which the GPS coordinate falls. If the cell index computed with the GPS coordinates is not in the table, we search for a listed one in the level 1 surrounding cells, as illustrated by Figure 15. At the end of the allocation process, 99.8% of total AQUEDUCT water withdrawal ($1.13.10^{13}$ m^3) and 99.9% of total AQUEDUCT water consumption ($6.3.10^{12}$ m^3) are allocated.

85495	85496	85497	85498	85499
85855	85856	85857	85858	85859
86215	86216	86217	86218	86219
86575	86576	86577	86578	86579
86935	86936	86937	86938	86939

	Current cell
	Surrounding level 1
	Surrounding level 2

Figure 15: Cells reference ID and surrounding levels

C IMPLEMENTATION

Intensities are first computed at the basin level. We compute both intensities for water consumption and water withdrawal.

(STEP 3) For each basin we compute:

- The total dynamic impact due to hydrological disturbance linked to direct water use (MSA.km²). Gains are capped to 0 to reflect the conservative stance adopted by the GBS in default assessments. Hence, if no data is available to demonstrate that AAPFD is lower (leading to less biodiversity being lost), gains are ignored;

- The total static impact due to hydrological disturbance linked to direct water use (MSA.km²).

(STEP 4) Each intensity (consumption dynamic, consumption static, withdrawal dynamic, withdrawal static) is then simply computed by dividing the impacts (expressed MSA.km²) by the total corresponding water volume. Intensities are therefore expressed in MSA.km² per m^3 of water (consumed or withdrawn) and fall into the data quality tier 2.

The meaning of the static impact intensities is relatively straightforward. Different levels of flow deviation (AAPFD) exert different intensity of pressures on aquatic ecosystems. Flow deviation is in a way similar to land use management intensity. A more intense management is associated to a more degraded habitat for terrestrial biodiversity and as long as this intensity is maintained, a static biodiversity impact is associated to the land use. Similarly, a higher flow deviation means a more degraded habitat for freshwater biodiversity and each level flow deviation is associated to a static impact. Rates of water withdrawal (or consumption) directly impact runoff and thus AAPFD: a given rate can thus be associated to a given level of static impact. We do not have access to water withdrawal rates and thus have to make assumptions to approximate them. We assume that water withdrawal rate i proportional to yearly water withdrawals. Under this assumption, a given level of water withdrawal is associated to a given static impact.

Just as we associated land occupation in each country to average national land use changes to assess an average dynamic impact from land use change in the terrestrial review document (CDC Biodiversité 2020c), an average hydrological disturbance change by water basin can be associated to water withdrawal (or consumption) in each basin. The dynamic impact intensity thus represents an average situation in the water basin (and as noted above, dynamic gains of biodiversity in this “average situation” are ignored).

We chose to keep both consumption and withdrawal water intensities. At first glance, consumption might look more relevant regarding the AAPFD as the water flow is impacted by the quantity of water which is subtracted to the water network. However, in practice, even if the water withdrawn is released in the water network, it can affect the flow if for instance the withdrawal and the release occur at different levels of the network. Furthermore, doing so gives more flexibility in terms of data that can be collected.

(STEP 5) As for the pressure land use in the catchment, “central” and “conservative” intensities are computed at country and EXIOBASE region levels. We describe the computation for countries, the process is identical for EXIOBASE regions. First, all the basin intensities and their associated water volumes (extracted and withdrawn) are determined for each country. If a basin spreads across multiple countries, the water volumes are allocated to each country in proportion to the number of cells they have in common with the basin. For instance, as illustrated in Figure 16, if basin B has 10 cells and a withdrawal volume of 100 m^3 and is spread across 2 countries with 6 cells on country C1 and 4 cells on country C2, then 60 m^3 and 40 m^3 are respectively allocated to country C1 and C2. Once this allocation process is done for each country, a list of intensities and associated water volumes is obtained. The “central” intensity is computed as the average of intensities weighted by the water volume taking into account all water volumes within the country. The “conservative” intensities are computed as the average of intensities weighted by the water volume taking into account the 20% water volumes with the highest intensities within the country.

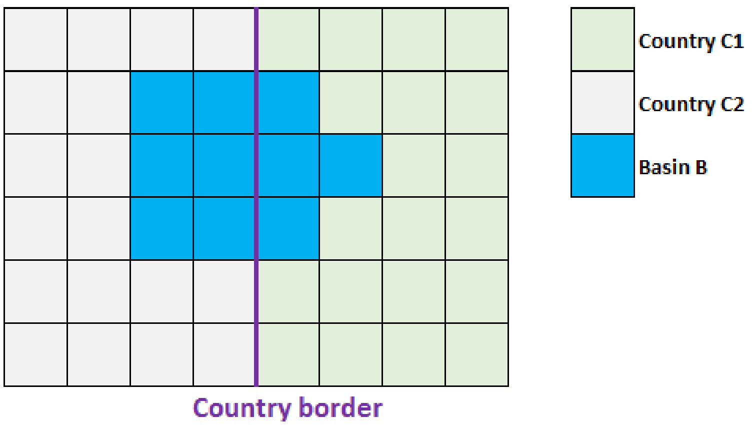

Figure 16: Illustration of allocation for a basin across 2 countries

5.3 Refined assessment

A DIMENSIONING THE IMPACT

The impact factors built for default assessment (MSA.km^2/m^3 consumed or withdrawn) can be applied directly to water consumption or withdrawal data from the companies assessed. In this case, we consider that the impact factors make it possible to dimension the impact.

Further, when the flow deviation of rivers and streams or wetlands induced by a given economic activity can be measured directly, the cause-effect relationship can be used directly to assess the corresponding biodiversity impact in MSA%. This MSA% will then have to be multiplied by the surface of the impacted aquatic ecosystem to get an impact expressed in MSA.km². For rivers and streams, the relevant surface is that of the part located downstream of where the flow deviation occurs as we consider that the upstream part is not impacted. For wetlands, the full surface area of the wetland should be used.

B ATTRIBUTING THE IMPACT

The impacts assessed through the use of the impact factors based on water consumption or water withdrawal are entirely attributed to the business responsible for the water use.

Similarly, the business responsible for the flow deviation is attributed the entirety of the impact assessed.

6 Wetland conversion

6.1 Context

A GLOBIO CAUSE-EFFECT RELATIONSHIP

This driver deals with the direct impacts of conversion and draining of wetlands for human purposes. There is no cause-effect relationship for this pressure. The biodiversity impact of conversion is straightforward, the aquatic MSA drops from its current value to 0%.

B GLOBIO-IMAGE SCENARIO

Global wetland area has indeed decreased by over 60% since 1900 (Davidson 2014), due mainly to agricultural expansion (Van Asselen et al. 2013). As no historical wetland map is available, conversions are derived indirectly in GLOBIO-IMAGE scenario based on a conservative guess of the minimal wetland area required to meet the projected increase in agricultural demand if all non-wetland natural areas have been used. The two hypotheses underlying the methodology are thus: 1) wetlands are converted solely into agricultural land and 2) they are converted only after all other natural areas in the cell have been converted. This method likely underestimates the biodiversity loss due to wetland conversion.

6.2 Default assessment

A GENERAL LAYOUT

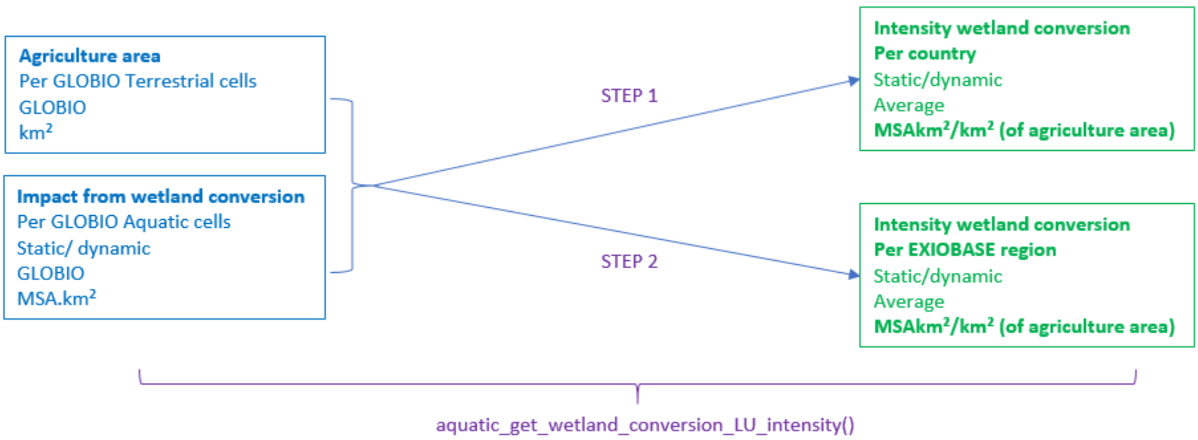

Figure 17: General layout for wetland conversion default assessment

B DIMENSIONING THE IMPACT

As for other impacts, in the GBS, the default assessment of the extent of the impact of the Wetland conversion pressure is not based on a direct cause-effect relationship applied to pressure data. Instead, due to a lack of pressure data in appropriate format, we rely on the assessments made in the GLOBIO-IMAGE scenario to dimension the impacts.

C IMPLEMENTATION – ATTRIBUTING THE IMPACT

(STEP1 & 2) In GLOBIO-IMAGE scenario, the assumption is made that wetlands are converted only for agriculture use. Therefore, in default assessments, impacts related to wetland loss can be attributed only to conversion to agriculture. The computation rule for intensities is straightforward and is the same at country and EXIOBASE region levels. For each spatial entity, the total static and dynamic impacts and the total agriculture area are computed by summing cell levels values. Then intensities are computed by diving the impacts by the agricultural land area. The intensities are expressed in MSA.km² per km² of agricultural land and fall into the quality tier 2.

By doing so, we assume that within each geographical unit, all agricultural lands participate equally to wetland conversion. To get an order of magnitude, based on GLOBIO-IMAGE data, we estimate that the average global dynamic intensity for agricultural land for wetland conversion is 0.6 MSA.m² per hectare per year, meaning that each year on average 1 hectare of agricultural land will expend by 0.6 m² by converting wetland. This is a global average and obviously the dynamic impacts will be very different between countries. The average global intensity falls into data quality tier 1.

6.3 Refined assessment

A DIMENSIONING THE IMPACT

In a refined approach, land conversion data can be used directly. For instance, if a surface of wetland S (MSA = w%) is converted into a terrestrial land use type (MSA = x%), the impact can be assessed directly. Regarding aquatic biodiversity, the conversion leads to a loss of $(w - x) \times S$ MSA.km². On the other hand, there is a gain of terrestrial biodiversity of $x \times S$ MSA.km².

B ATTRIBUTING THE IMPACT

100% of the impact dimensioned is attributed to the final land use.

6.4 Limits and future developments

As discussed in the terrestrial pressures report (CDC Biodiversité 2020c) land coverage predictions in the GLOBIO-IMAGE scenarios can be improved. For wetland conversion, an extra layer of uncertainty is added in default assessments as conversions are derived indirectly, based on a conservative guess of the minimal wetland area required to meet the projected increase in agricultural demand. This is key topic of improvement for later versions of the GBS. We could use external data based on national reports or, ideally, satellite-based observations.

Also, for default assessment intensities, at the moment we only consider the aquatic biodiversity loss. It would be more consistent to also consider the associated terrestrial biodiversity gains, the same way it is done for the refined assessment.

7 Nutrient emissions

7.1 Context

A GLOBIO CAUSE-EFFECT RELATIONSHIP

In GLOBIO-Aquatic, freshwater nutrient emission (eutrophication) is evaluated only for lakes. The impact on wetlands and rivers is not included due to data limitations. GLOBIO-Aquatic uses the accumulated total N and P concentrations as drivers of biodiversity loss in lakes with a differentiated impact between shallow (average depth inferior to 3 meters) and deep lakes and in rivers. Figure 18 shows the results obtained for phosphorus concentrations.

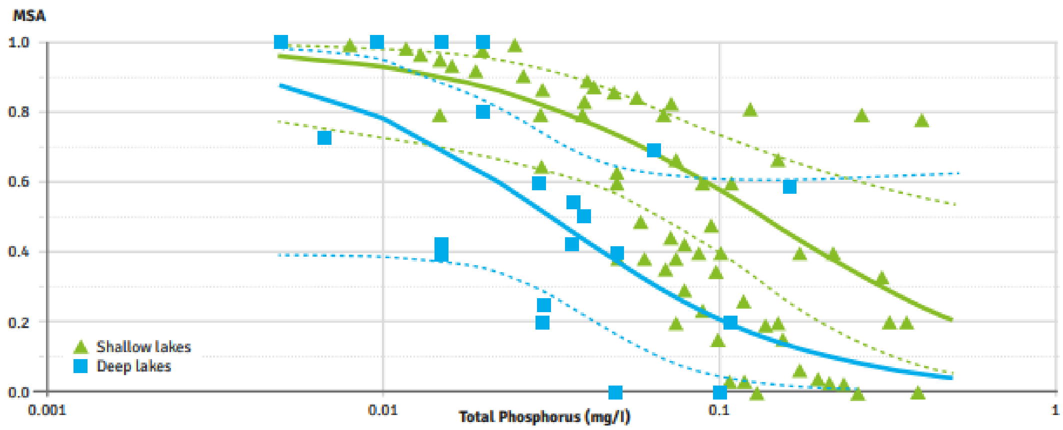

Figure 18:MSA in deep and shallow lakes in relation to nutrient concentrations: regression lines (solid lines) and 95% intervals (dashed lines) (J. H. Janse et al. 2015)

B GLOBIO-IMAGE SCENARIO

A limiting factor rule is used locally by the GLOBIO-IMAGE scenario to determine which compound, P or N, is predominant. Then, only this category's concentration is considered to compute the impact due to eutrophication in the freshwater body.

The Global Nutrient Model (Beusen 2014) estimates nitrogen (N) and phosphorus (P) leaching and runoff to surface water based on agricultural area, the application of fertilizers and manure, precipitations and spatial characteristics of slope, soil texture and groundwater characteristics. To these emissions are added the modelled urban nutrient emissions based on population, GDP, sanitation and the use of detergents.

7.2 Default assessment – Dimensioning the impact

As for other impacts, in the GBS, the default assessment of the extent of the impact of the Nutrient emissions pressure is not based on a direct cause-effect relationship applied to pressure data. Instead, due to a lack of pressure data in appropriate format (we would need to know the concentration of N and P for all the lakes in the world), we rely on the assessments made in the GLOBIO-IMAGE scenario to dimension the impacts.

7.3 Default assessment – Attributing the impact

A GENERAL LAYOUT

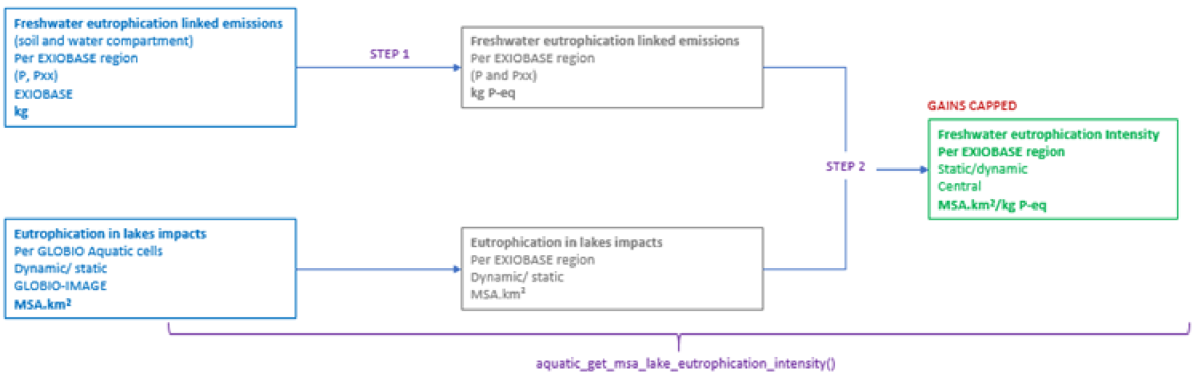

Figure 19: General layout for nutrient emissions default assessment

B "P COMPOUNDS ONLY" ASSUMPTION

For complexity reasons, in the first version of the GBS we assume that only P compounds are responsible for lakes eutrophication. Indeed, we do not have access to the data that would allow us to know which of the N or P compounds was used to compute the impacts of eutrophication for each lake, and it is very complex to compute it directly. Rather than using wobbly proxies, we decided to use a simpler and more transparent approach comforted by the fact than numerous ecotoxicity models, including EUSE, only consider P compounds for lakes.

C EMISSION VERSUS CONCENTRATION

The GLOBIO-Aquatic cause-effect relationships for lakes eutrophication link concentration level (P or N) to an average MSA% value. Therefore, the most rigorous approach to link an economic activity to a eutrophication impact would be to evaluate its contribution to the compound concentration in impacted lakes. The cause-effect relationships are not linear, meaning that a variation in concentration will have a different MSA% impact depending on the start and end absolute concentration levels. Thus, ideally, we would need to determine both initial and final concentration levels in each lake. The non-linearity between compound concentration and biodiversity impacts also poses allocation problems for lakes where impacts come from multiple activities. In this frequent situation, a rule would need to be set to determine the initial concentration for each activity as it will affect the corresponding contribution to the MSA% level of the lake and, therefore, their associated impact. These difficulties can be overcome but the main reason for us not to use intensities based on concentrations is the difficulty to evaluate which part of an emission will actually end up in the lake. In the GLOBIO-IMAGE scenario, this evaluation is done using multiple models taking into account the quality of soils, their capacity to stock N or P, the hydrological network, rainfalls… At a macro level, GLOBIO-IMAGE provides a good enough picture of the dynamics at play and the resulting expected eutrophication for lakes in a given region. However, for a given lake and even more for a given emission, the uncertainty of the underlying models is too high to provide an accurate evaluation. Another option which was considered was to use fate models from the ecotoxicity world such as Simplebox model (Hollander, Schoorl, and van de Meent 2016). Their functioning is well documented and transparent but their parametrization to account for regional specifications is very complex.

Finally, we decided that the simpler and most accurate approach was to use directly emissions and compute intensities based on emissions at reasonably large regional level. For sure, within the geographical region, emissions can have very different diffusion patterns and, therefore, impacts in terms of lakes eutrophication. Yet, the reasoning here is that it is too complex to evaluate systematically and is anyhow most probably not known nor considered by the emitters themselves. Therefore, associating an average regional fate and impact to emissions within a region seems both the most pragmatic and fair approach available at the moment. That being said, for specific refined assessments where concentration levels are available, it is still possible to use directly concentrations based GLOBIO-Aquatic cause-effect relationships consistently with our stepwise approach.

D IMPLEMENTATION

We use the emission account of EXIOBASE environmental extensions to determine the emissions of P compounds. The emission account documents emissions of P and P compounds (noted Pxx) in soil and water compartments per region and industry. Consequently, the spatial granularity is limited to that of EXIOBASE regions.

(STEP 1) The difference of impact potentials between P and Pxx compounds in the different emission compartments is accounted Following those 2 rules:

- P-equivalent quantities are computed based on P relative weight in the molecule. We use molar masses and P relative weight in phosphate (PO_4) for Pxx;

- A 10% factor is applied for emissions in the soil compartment consistently with ReCiPe where 10% is used as the default P fraction transferred from soil to freshwater.

(STEP 2) From there, the intensity computation is straightforward: for each EXIOBASE region the intensity is the ratio of the total impact due to eutrophication (static and dynamic) by the total P compounds emissions expressed in kg P-eq. It is therefore expressed in MSAkm²/kg P-eq and **falls into the** data quality tier 2.

As for the Hydrological disturbance impact due to direct water consumption and withdrawal, the fact that only emission data are available means that it is a static impact which is primarily assessed. An average change in eutrophication by EXIOBASE region can however be associated to emissions in each region: this is what the dynamic impact intensity represents (see section 5.2C for more explanations on the differences between the static and dynamic intensities, in the case of Hydrological disturbance).

For the sake of clarity, let's take a fictive numeric example. Let's assume that in GLOBIO-IMAGE scenario data, for France, the total dynamic impact for freshwater eutrophication pressure is 100 MSA.km² over the assessed period while the static impact is 10 000 MSA.km² at the beginning of the period assessed. Over the period, EXIOBASE's P compounds emissions are as presented in *Table* 1.

Compound	Water (kg)	Soil (kg)
P	1 000	500
Pxx	5 000	2 000

Table 1: Fictive emissions in France during the assessed period

To compute dynamic intensity related to freshwater eutrophication for France, P-equivalent emissions quantities are computed following the two rules described above. For instance, 2000 kg of Pxx emitted in the soil compartment are equivalent to 10% * 2000 * 31 / (31 * 4 * 16) = 65 kg P-eq (assuming Pxx is PO_4, a P molar mass of 31 and an O molar mass of 16). In this example, total emissions for France are worth 2747 kg P-eq.

Dynamic intensity for water eutrophication in France is therefore 100 / 2747 = 0.036 MSA.km²/kg P-eq. Similarly, static impact intensity is 10 000 / 2747 = 3.6 MSA.km²/kg P-eq. It means that, if a company reports for instance an emission of 100 kg P-eq during the same assessed period, then its dynamic impact due to freshwater eutrophication is evaluated at 0.036 * 100 = 3.6 MSA.km² and its static impact is 360 MSA.km².

7.4 Refined assessment

A DIMENSIONING THE IMPACT

When the difference in P or N concentration in a lake due to an economic activity can be measured, the cause-effect relationship can be used to assess the impact in MSA%. This impact has to be multiplied by the surface of the lake to get an impact expressed in MSA.km².

B ATTRIBUTING THE IMPACT

Refined assessments of this pressure are conducted only when the lakes are owned by the business assessed. In these cases, 100% of the impacts dimensioned is attributed to the business.

7.5 Limits and future developments

Instead of only considering P compounds, an allocation between P and N compounds is clearly identified as one possible update for the next version of the tool. Once again this could be easily done if we get access to GLOBIO-IMAGE scenario's intermediary computation data.

8 Algal blooms

In the GLOBIO-IMAGE scenario, the occurrence of harmful algal blooms (primarily cyanobacteria) is included as an indicator of the ecological status of lakes complementary to the MSA. Algal blooms are indeed often used as a disturbance indicator as phytoplankton dominance excludes other native species. There is however no cause-effect relationship linking algal bloom intensity to a biodiversity impact expressed in MSA in the model. Algal bloom is used by the PBL as a control indicator to reinforce the model analyses on lakes. They observe that algal blooms are negatively correlated to MSA in lakes, which was expected as algal blooms and MSA react to the same drivers: temperature increase and nutrient excess (J. H. Janse et al. 2015). Algal bloom complementary indicator is not used in GBS as it does not fit within the framework of the tool focusing on a single aggregated metric. Yet, given the high negative correlation between algal blooms and MSA in lakes, we can consider that GBS captures the drivers at play for that pressure.

9 Summary of available default assessment intensities

Table 2summarizes the available default biodiversity intensities related to pressure on aquatic biodiversity. As a reminder, these intensities all fall into the data quality tier 2 or tier 1 when they are global.

Pressure	Spatial scale	Static/ dynamic	Computation mode	Unit
Land use in catchement for rivers	Basin Country EXIOBASE Region	Static and dynamic Static and dynamic Static and dynamic	Average Average/ conservative Average/ conservative	MSA.km² per km² of human land use type
Land use in catchement for wetlands	Basin Country EXIOBASE Region	Static and dynamic Static and dynamic Static and dynamic	Average Average/ conservative Average/ conservative	MSA.km² per km² of intensity weighted area
Hydrological disturbance from Climate change	Global	Static only	Average	MSAkm² per ton of CO2eq (GWP20 or GWP100)
Hydrological disturbance from direct water use Water withdrawal	Basin Country EXIOBASE Region	Static and dynamic Static and dynamic Static and dynamic	Average Average/ conservative Average/ conservative	MSA.km² per m³ of water withdrawal
Hydrological disturbance from direct water use Water consumption	Basin Country EXIOBASE Region	Static and dynamic Static and dynamic Static and dynamic	Average Average/ conservative Average/ conservative	MSA.km² per m³ of water consumption
Wetland conversion	Country EXIOBASE Region	Static and dynamic Static and dynamic	Average Average	MSAkm² per km² of agricultural land
Eutrophication	EXIOBASE Region	Static and dynamic	Average	MSAkm² per kg of Peq

Table 2:Summary of available default assessment intensities

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