ISIMIP2b Simulation Protocol

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5   The simulation protocol describes the simulation scenarios, input data sets and output variables necessary to participate in the ISIMIP2b simulation round. The scientific rationale and more detailed information about the pre-processing of input data can be found in the accompanying description paper Frieler et al. 2017 *Assessing the impacts of 1.5 °C global warming – simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b),* Geoscientific Model Development. 10, 4321–4345 doi.org/10.5194/gmd-10-4321-2017.

Contents

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1   Scenario design

The simulation scenarios are divided into three groups, depicted in **Figure 1** and **Figure 2**, directed at addressing distinct scientific questions:

- Quantification of pure climate-change effects of the historical warming compared to pre-industrial reference levels (Group 1).
- Future impact projections accounting for low (RCP2.6) and high (RCP6.0) greenhouse gas emissions assuming present day socio-economic conditions (Group 2).
- Future impact projections accounting for low (RCP2.6) and high (RCP6.0) greenhouse gas emissions assuming dynamic future socio-economic conditions according to SSP2 (Group 3).

In the sector-specific sections below, we provide a more detailed description of the sector-specific simulations. The grey, red, and blue background colours of the different entries in the tables there indicate Group 1, 2, 3 runs, respectively. Runs marked in violet represent additional sector-specific sensitivity experiments. Each simulation run has a name (Experiment I to VII) that is consistent across sectors, i.e. runs from the individual experiments could be combined for a consistent cross-sectoral analysis. Since human influences represented in individual sectors may depend on the RCPs (such as land-use changes), while human influences relevant for other sectors may only depend on the SSP, the number of experiments differs from sector to sector.
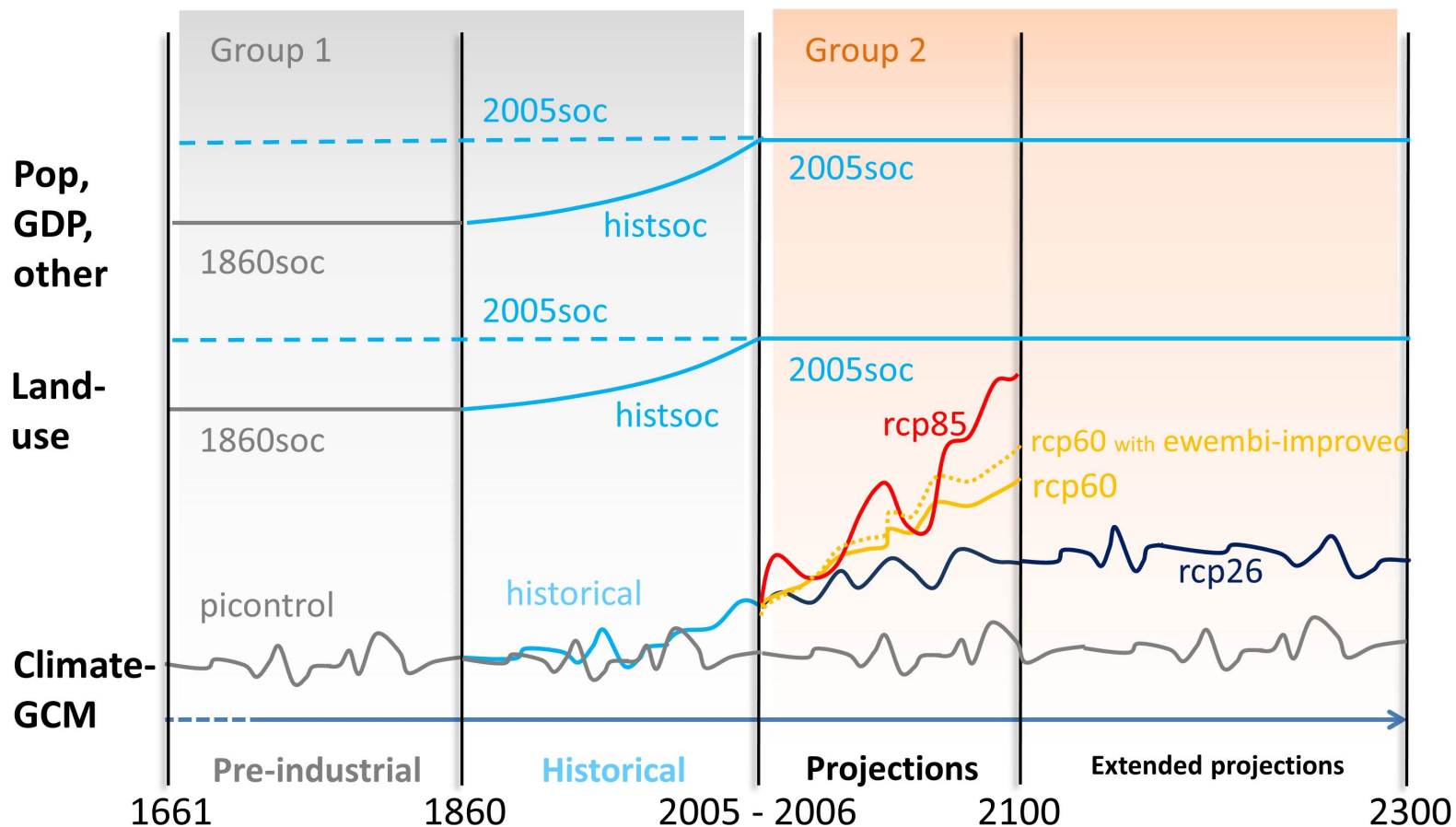
Figure 1 Schematic representation of the scenario design for ISIMIP2b **Group 1** and **Group 2** runs. "Other" includes other non-climatic anthropogenic forcing factors and management, such as irrigation, fertilizer input, selection of crop varieties, flood protection levels, dams and reservoirs, water abstraction for human use, fishing effort, atmospheric nitrogen deposition, etc. **Group 1** consists of model runs to separate the pure effect of the historical climate change from other human influences. Models that cannot account for changes in a particular forcing factor are asked to hold that forcing factor at 2005 levels (2005soc, dashed lines). **Group 2** consists of model runs to estimate the pure effect of the future climate change assuming fixed year 2005 levels of population, economic development, land use and management (2005soc). The yellow dashed line represents an optional sensitivity run with RCP6.0 climate forcing using statistical downscaling and improved bias-correction (ewembi-isimip3basd). This run, as well as the RCP8.5 run (red line) were introduced in February 2019.
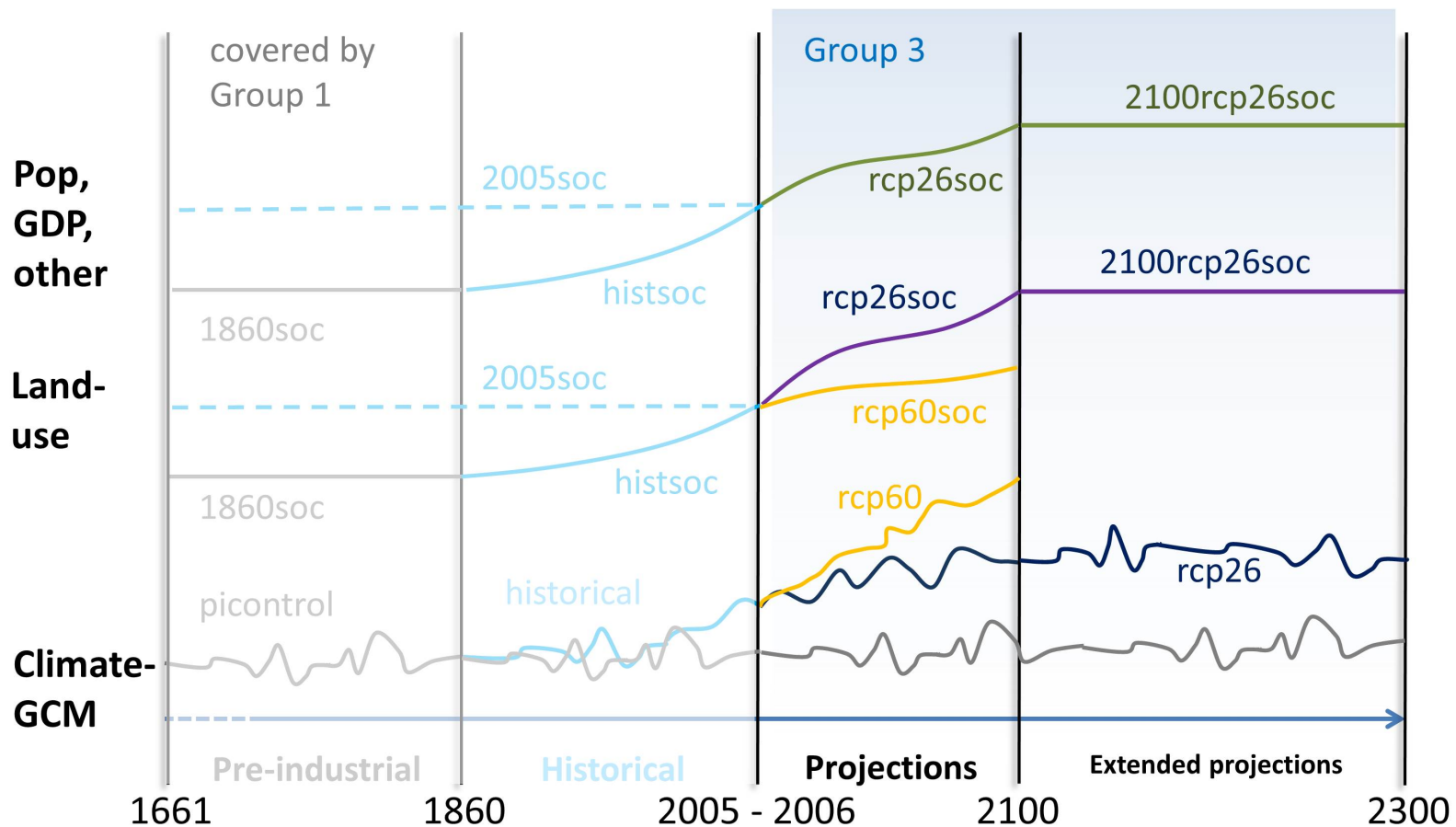
Figure 2 Schematic representation of the scenario design for **Group 3** runs. Group 3 consists of model runs to quantify the effects of the land use changes, and changes in population, GDP, and management from 2005 onwards associated with RCP6.0 (no mitigation scenario under SSP2) and RCP2.6 (strong mitigation scenario under SSP2). Forcing factors for which no future scenarios exist (e.g. dams/reservoirs) are held constant after 2005.

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2   Input data

- Information about how to access ISIMIP Input Data can be found here:

  www.isimip.org/gettingstarted/downloading-input-data

- A full list of ISIMIP input-data sets can be found here:
5   www.isimip.org/gettingstarted/#input-data-bias-correction

2.1   Climate input data

- Bias-corrected to the EWEMBI data set at daily temporal and 0.5° horizontal resolution using two updated versions of Fast-Track methods. The first of these two methods was used to bias-correct the bulk of the climate input data and is applied to climate model output data that was first spatially interpolated to 0.5° spatial resolution. This method is described in Frieler et al. (2017, doi:10.5194/gmd-10-4321-2017, section 3) and Lange (2019, doi: 10.5194/gmd-2019-36). The second method comes with many new features compared to the
10   first method including trend preservation in all quantiles, the robust adjustment of extremes, and the explicit statistical downscaling from the spatial resolution of the climate model to that of the observation. This method is described in Lange (2018, doi:tba) and is deemed to be used for all bias corrections in ISIMIP3. It was only applied RCP6.0 climate projections for sensitivity analyses that are not officially part of the protocol. This data will be made available upon request. For some locations, additional climate input data is available where climate model data was bias-corrected to local weather station data (see sector-specific chapters).
- Daily time step, 0.5° horizontal resolution
15 - Pre-industrial (1661-1860), historical (1861-2005) and future (RCP2.6 and RCP6.0) conditions provided based on CMIP5 output of GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR and MIROC5. Output from two GCMs (GFDL-ESM2M and IPSL-CM5A-LR) includes the physical and biogeochemical ocean data required by the marine ecosystem sector of ISIMIP (see FISH-MIP, www.isimip.org/gettingstarted/marine-ecosystems-fisheries/).
- For some GCMs, it was necessary to recycle pre-industrial control climate data in order to fill the entire 1661-2299 period (for more information see, Frieler et al. 2017).
- Priorization of climate models (from highest to lowest):
20   1   IPSL-CM5A-LR
       2   GFDL-ESM2M
       3   MIROC5
       4   HadGEM2-ES

25 **Table 1** Bias-corrected climate variables.

Variable	Short name	Unit
Near-Surface Relative Humidity	hurs	%

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Near-Surface Specific Humidity	huss	kg kg^{-1}
Precipitation (rainfall + snowfall)	pr	kg m^{-2} s^{-1}
Snowfall Flux	prsn	kg m^{-2} s^{-1}
Sea-level Air Pressure	ps	Pa
Surface Air Pressure	psl	Pa
Surface Downwelling Longwave Radiation	rlds	W m^{-2}
Surface Downwelling Shortwave Radiation	rsds	W m^{-2}
Near-Surface Wind Speed	sfcWind	m s^{-1}
Near-Surface Air Temperature	tas	K
Daily Maximum Near-Surface Air Temperature	tasmax	K
Daily Minimum Near-Surface Air Temperature	tasmin	K

Table 2 Variables provided without bias correction.

Variable	Short name	Unit	Temporal resolution
Ocean variables (for marine ecosystems & fisheries sector)			
Sea Water X Velocity	uo	m s^{-1}	monthly
Sea Water Y Velocity	vo	m s^{-1}	monthly
Sea Water Z Velocity	wo	m s^{-1}	monthly
Sea Water Temperature	to	K	monthly
Dissolved Oxygen Concentration	o2	mol m^{-3}	monthly

Total Primary Organic Carbon Production (by all types of phytoplankton) [calculated as sum of lpp + spp (IPSL) or sum of lpp + spp + dpp (GFDL)]	intpp	mol C m^{-2} s^{-1}	monthly
Small Phytoplankton Productivity	spp	mol C m^{-3} s^{-1}	monthly
Large Phytoplankton Productivity	lpp	mol C m^{-3} s^{-1}	monthly
Diazotroph Primary Productivity	dpp	mol C m^{-3} s^{-1}	monthly
Total Phytoplankton Carbon Concentration [sum of lphy + sphy (IPSL) or lphy + sphy + dphy (GFDL)]	phy	mol C m^{-3}	monthly
Small Phytoplankton Carbon Concentration	sphy	mol C m^{-3}	monthly
Large Phytoplankton Carbon Concentration	lphy	mol C m^{-3}	monthly
Diazotroph Carbon Concentration	dphy [diaz]	mol C m^{-3}	monthly
Total Zooplankton Carbon Concentration [sum of lzoo + szoo]	zooc	mol C m^{-3}	monthly
Small Zooplankton Carbon Concentration	szoo	mol C m^{-3}	monthly
Large Zooplankton Carbon Concentration	lzoo	mol C m^{-3}	monthly
pH	ph	1	monthly
Sea Water Salinity	so	psu	monthly
Sea Ice Fraction	sic	%	monthly
Large size-class particulate organic carbon pool	goc	mmol C m^{-3}	monthly
Photosynthetically-active radiation	Par	Einstein m^{-2} day^{-1}	monthly
Ocean variables (for tropical cyclones)			
Depth-resolved monthly mean Sea Water Potential Temperature	thetao	K	monthly
Sea Surface Temperature	tos	K	monthly
Atmospheric variables (for tropical cyclones)			
Air Temperature at all atmospheric model levels	ta	K	monthly
Specific Humidity at all atmospheric model levels	hus	kg kg^{-1}	monthly
Eastward Wind at 250 and 850 hPa levels	ua	m s^{-1}	daily
Northward Wind at 250 and 850 hPa levels	va	m s^{-1}	daily

Atmospheric variables (for coastal systems)			
Sea Level Pressure	psl	Pa	3-hourly
Eastward Near-Surface Wind	uas	m s^{-1}	3-hourly
Northward Near-Surface Wind	vas	m s^{-1}	3-hourly

2.2   Land-use patterns

The following land-use data are provided and described in detail in **Table 4**:

- Historical land-use (LU) changes from the HYDE3.2 data (Klein Goldewijk et al., 2017) (see **Figure 3**). Three, consistently generated disaggregation levels are provided:
    - Rainfed crop land, irrigated crop land, pastures and total crop land (the sum of rainfed and irrigated) – filename includes "landuse-totals";
    - As above, with crop land divided into 5 functional crop types (LUH2) – filename includes "landuse-5crops";
    - As above, with crop land divided into 15 individual crops or crop groups (based on (Monfreda et al., 2008)) – filename includes "landuse-15crops";
- Transient, future LU patterns generated by the LU model MAgPIE (Popp et al., 2014; Stevanović et al., 2016), assuming population growth and economic development as described in SSP2, for climate-change scenarios using RCP2.6 and RCP6.0 (see **Figure 3**). These scenarios should be referred to as "landuse_ISIMIP2b_ssp2_rcp26" and "landuse_ISIMIP2b_ssp2_rcp60" respectively. Note that while these data sets cover the period 2006-2100, the period 2006-2014 are taken from historical data.

The transition from historical to future LU patterns requires a harmonisation between the land-use classes and areas between the different data sets.

Table 3 Agricultural land-use categories

Land-use type	Historical reconstruction	Future projections	Disaggregation into functional crop types (LUH2)	Individual crops or crop groups
Irrigated crops	HYDE	MAgPIE	Total cropland disaggregated into: C_3 annual, C_3 nitrogen-fixing, C_3 perennial, C_4 annual, C_4 perennial (contains only sugarcane)	C_3 annual disaggregated into: rapeseed, rice, temperate cereals, temperate roots, tropical roots, sunflower, others C_3 annual C_3 perennial: (no further disaggregation) C_3 nitrogen-fixing disaggregated into: groundnut, pulses, soybean, others C_3 nitrogen-fixing C_4 annual disaggregated into: maize, tropical cereals C_4 perennial: sugarcane
Rainfed crops	HYDE	MAgPIE	Total cropland disaggregated into: C_3 annual, C_3 nitrogen-fixing, C_3 perennial, C_4 annual, C_4 perennial (contains only sugarcane)	C_3 annual disaggregated into: rapeseed, rice, temperate cereals, temperate roots, tropical roots, sunflower, others C_3 annual C_3 perennial: (no further disaggregation) C3 nitrogen-fixing disaggregated into: groundnut, pulses, soybean, others C_3 nitrogen-fixing C_4 annual disaggregated into: maize, tropical cereals C_4 perennial: sugarcane
Pastures	HYDE	MAgPIE	Total pastures are provided.	In addition, pastures are split into managed pastures and (natural) rangelands
bioenergy production (rainfed grass)	-	MAgPIE		e.g., miscanthus (if you use a different bioenergy crop, please indicate this in the model description)

bioenergy production (rainfed trees)	-	MAgPIE		e.g., poplar (temperate), eucalyptus (tropical) (if you use a different bioenergy crop, please indicate this in the model description)
Urban	HYDE	constant (HYDE)		
Other (natural vegetation etc.)	1 - everything else	1 - everything else	The LUH2 data set includes additional natural land classes, which are consistent with the historical LU data provided here, and could be provided upon request.	(to be specified)
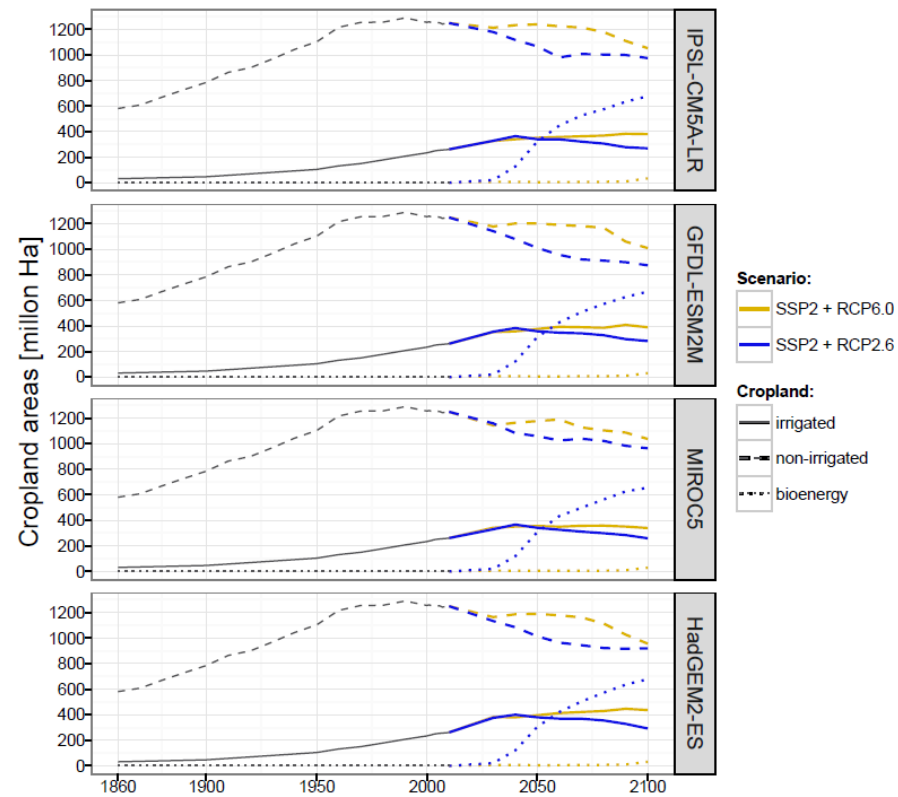
Figure 3 Time series of total crop land (irrigated (solid lines) and non-irrigated (dashed lines)) as reconstructed for the historical period (1860 - 2015) based on HYDE3.2 (Klein Goldewijk et al., 2017) and projected under SSP2 (2016-2100) assuming no explicit mitigation of greenhouse gas emissions (RCP6.0, yellow line) and strong mitigation (RCP2.6, dark blue line) as suggested by MAgPIE. Future projections also include land areas for second generation bioenergy production (not included in "total crop land") for the demand generated from the Integrated Assessment Modelling Framework REMIND/MAgPIE, as implemented in the SSP exercise (dotted lines). Global data were linearly interpolated between the historical data set and the projections.

2.3   Sea-level rise patterns

Table 4 Information on sea-level-rise data.

Driver	Historical reconstruction	Future projections	Long-term projections
Sea-level rise	Observed time series up to 2000	From 2000 onwards, spatial patterns derived from GCMs. Regional variation of sea-level rise from glaciers and the large ice sheets are scaled from their respective gravitational patterns.	Constrained extrapolations have been extended to 2299.
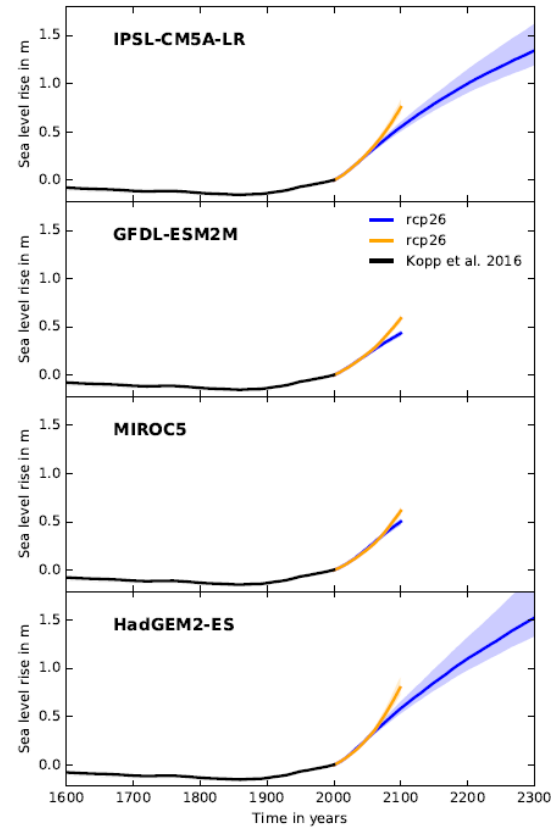
Figure 4 Time series of global total sea-level rise based on observations (Kopp et al., 2016, black line) until year 2000 and global-mean-temperature change from IPSL-CM5A-LR (panel 1), GFDL-ESM2M (panel 2), MIROC5 (panel 3) and HadGEM2-ES (panel 4) after year 2000: solid lines: Median projections, shaded areas: uncertainty range between the 5th and 95th percentile of the uncertainty distribution associated with the ice components. Blue: RCP2.6, yellow: RCP6.0. All time series relative to year 2000. Non-climate-driven contribution from glaciers and land water storage are added to the projections.

2.4 Population patterns and economic output (Gross Domestic Product, GDP)
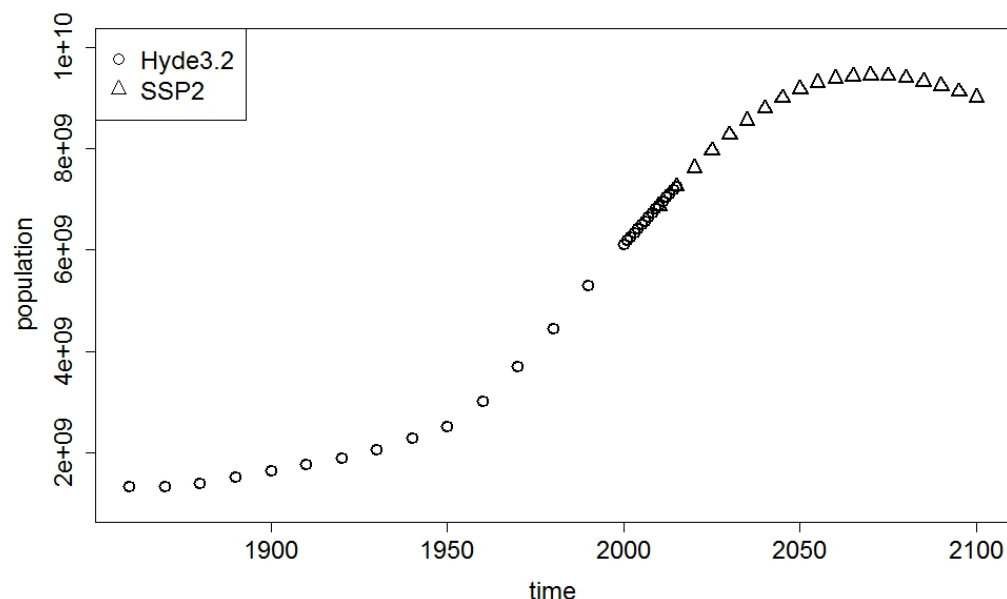
Figure 5 Time series of global population for the historical period (dots) and future projections following the SSP2 storyline (triangles).

5 **Table 5** Socio-economic input data corresponding to SSP2.

Driver	Historical reconstruction	Future projections
GDP	• Annual country-level data derived from the Maddison project (Bolt and van Zanden, 2014, www.ggdc.net/maddison/maddison-project/home.htm) and extended by Penn World Tables 9.0 and World Development Indicators (1861-2005). • Annual data on 0.5° grid corresponding to SSP2 (1861-2005).	• Annual country-level data based on OECD projections from the SSP database (Dellink et al., 2015, https://secure.iiasa.ac.at/web-apps/ene/SspDb/) corresponding to SSP2 (2006-2299). • Annual data on 0.5° grid based on downscaling of country-level data (Murakami and Yamagata, 2016) (2006-2299).
Population	• Annual data on a 0.5° and 5'grid based on the HYDE3.2 database (Klein Goldewijk et al., 2017) (1861-2005).	• Annual data on a 0.5° grid based on the national SSP2 population projections as described in Samir and Lutz, (2014) (2006-2299).

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	Annual country-level, age-specific population data based on the HYDE3.2 database (Klein Goldewijk et al., 2017) (1861-2005).	Annual country-level, age-specific data in 5-year age groups and all-age mortality rates in 5-year time (2006-2299). Also includes rural/urban division.

2.5   Other human influences

For all of these input variables, we describe reconstructions to be used for the historical **histsoc** simulations (see **Table 6**). For models that do not allow for time-varying human influences across the historical period, human influences should be fixed at present-day (**2005soc**) levels (see dashed line in **Figure 1**, Group 1). Beyond 2005 all human influences should be held constant (Group 2) or varied according to SSP2 if associated projections are available (**Figure 2**, Group 3). As ISIMIP2b Group 3 only considers SSP2 and no other socio-economic storylines, the SSP scenario is not explicitly mentioned in the file names, although the changes in land-use patterns, etc. certainly not only depend on the RCP (due to the accounting for associated climate impacts of, e.g., crop yields), but also on the SSP. Within ISIMIP2b projections are provided for future irrigation-water extraction, fertilizer application rates and nitrogen deposition (see **Table 6**).

Table 6 Data sets representing "other human influences" for the historical simulations (**histsoc**, Group 1) and the future projections accounting for changes in socio-economic drivers (**rcp26soc/rcp60soc**, Group 3).

Driver	Historical reconstruction	Future projections
Reservoirs & dams • **location** • **upstream area** • **capacity** • **construction/commissioning year**	Global data on 0.5° grid based on GranD database and the DDm30 routing network. Documentation: http://www.gwsp.org/products/grand‐database.html **Note**: Simple interpolation can result in inconsistencies between the GranD database and the DDM30 routing network (wrong upstream area due to misaligned dam/reservoir location). A file is provided with locations of all larger dams/reservoirs adapted to DDM30 so as to best match reported upstream areas.	No future data sets are provided. Held fixed at year 2005 levels in all simulations.

Water abstraction for domestic and industrial uses	Generated by each modelling group individually (e.g. following the varsoc scenario in ISIMIP2a). For modelling groups that do not have their own representation, we provide files containing the multi-model mean domestic and industrial water withdrawal and consumption generated from the ISIMIP2a varsoc runs of WaterGAP, PCR-GLOBWB, and H08. This data is available from 1901 until 2005.	Generated by each modelling group individually. For modelling groups that do not have their own representation, we provide files containing the multi-model mean (from the global water models WaterGAP, PCRGLOBWB, and H08) domestic and industrial water withdrawal and consumption under SSP2 from the Water Futures and Solutions (WFaS) (Wada et al., 2016) project. This data is available from 2006 until 2050. The values should be kept constant from 2050 onwards. The data provided for rcp26soc and rcp60soc are identical and both are taken from simulations based on RCP6.0. The combination SSP2–RCP2.6 was not considered in WFaS; the difference is expected to be small since the choice of RCP only affects cooling water demand in one of the three models.
Irrigation water abstraction	Individually derived from the land-use and irrigation patterns provided. Water directly used for livestock (e.g. animal husbandry and drinking), except for indirect uses by irrigation of feed crops, is expected to be very low (Müller Schmied et al., 2016) and could be set to zero if not directly represented in the individual models.	Derived from future land-use and irrigation patterns provided based on output from the MAgPIE model (see section 0). Land-use projections are provided for: • SSP2+RCP6.0 • SSP2+RCP2.6; Direct water use for livestock should be ignored (i.e. can be set to zero).

N fertilizer use (kg per ha of cropland)	Annual crop-specific input per ha of crop land for C_3 and C_4 annual, C_3 and C_4 perennial and C_3 Nitrogen fixing. This data set is part of the LUH2 dataset developed for CMIP6 (Hurtt et al.) based on HYDE3.2.	Crop group-specific inorganic N fertilizer use per area of cropland provided by the LUH2-ISIMIP2b dataset, which differs for SSP2CRCP2.6 and SSP2CRCP6.0. To allow for the allcrops model set-up this information is extrapolated to all land cells using a nearest neighbor algorithm.
Nitrogen (NH_X and NO_Y) deposition	Annual and monthly, 0.5° gridded data for 1850-2005 derived by taking the average of three atmospheric chemistry models (GISS-E2-R, CCSM-CAM3.5, and GFDL-AM3) in the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) (0.5° x 0.5°) (Lamarque et al., 2013a, 2013b). GISS-E2-R provided monthly data; CCSM-CAM3.5 provided monthly data in each decade from 1850s to the 2000s; and GFDL-AM3 provided monthly data for 1850-1860, 1871-1950, 1961-1980, 1991-2000 and 2001-2010. Annual deposition rates calculated by aggregating the monthly data, and deposition rates in years without model output were calculated according to spline interpolation (CCSM-CAM3.5) or linear interpolation (for GFDL). The original deposition data was downscaled to spatial resolution of half degree (90° N to 90° S, 180° W to 180° E) by applying the nearest interpolation.	As per historical reconstruction for 2006-2099 following RCP2.6 and RCP6.0.
Fishing intensity	Depending on model construction, one of: Fishing effort from the Sea Around Us Project (SAUP); catch data from the Regional Fisheries Management Organizations (RFMOs) local fisheries agencies; exponential fishing technology increase and SAUP economic reconstructions. Given that the SAUP historical reconstruction starts in 1950, fishing effort should be held at a constant 1950 value from 1860-1950.	Held constant after 2005 (**2005soc**)
Forest management	Based on observed stem numbers (see Table 17-Table 18)	Based on generic future management practices (see **Table 16**-**Table 18**)

2.6 Focus Regions

Simulation data are welcome for all world regions. Even single model simulations for specific sites will help to generate a more comprehensive picture of climate change impacts and potentially allow for constraining global models. However, to allow for model intercomparisons simulations should also be provided for the sector specific focus regions shown in **Figure 6** and defined in **Table 7**, if feasible with your model. For regions not defined in the protocol, please contact the ISIMIP Team to agree on appropriate naming and define the location of the region in the metadata of your output files.
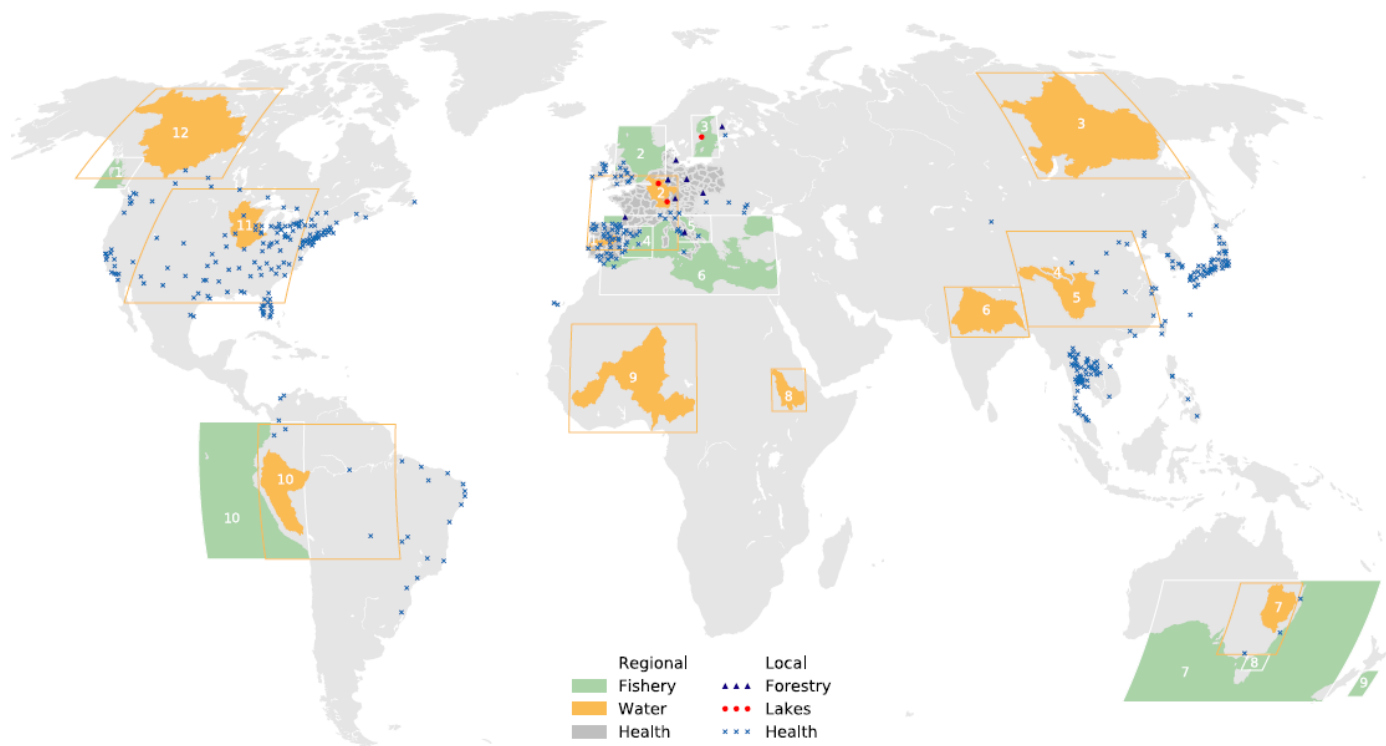
Figure 6 ISIMIP focus regions. See **Table 7** for region definitions.

2.7 Lake specifications

Grid-scale lake fraction is provided based on the Global Lake and Wetland Database (GLWD; Lehner and Döll, 2004) and available on the DKRZ input data repository (/work/bb0820/ISIMIP/ISIMIP2b/InputData/lakes/pctlake.nc4; Subin et al., 2012).

Since a 0.5°x0.5° pixel potentially contains multiple lakes with different characteristics (e.g. in terms of bathymetry, transparency, fetch), it is not possible to fully represent this subgrid-scale heterogeneity. Instead, the global-scale lake simulations should represent a 'representative lake' for a given pixel. Consequently, no stringent requirement is imposed with respect to lake depth, light extinction coefficient or initial conditions. However, lake depth, modellers are encouraged to use the data from the Global Lake Data Base (GLDB). A regridded lake-depth field based on GLDBv1 (Kourzeneva, 2010) is available at 0.5°x0.5° resolution on the DKRZ input data repository (/work/bb0820/ISIMIP/ISIMIP2b/InputData/lakes/lakedepth.nc4); this field was aggregated from 30 arc sec to 1.9°x2.5° and then interpolated again to 0.5°x0.5°; Subin et al., 2012). Alternatively, modellers may choose to use the more recent GLDBv2 available at 30 arc sec (http://www.flake.igb-berlin.de/ep-data.shtml, Choulga et al., 2014).

An up-to-date list of lakes that are analysed in the ISIMIP Lake sector can be found under https://docs.google.com/spreadsheets/d/1UY_KSR02o7LtmNoOs6jOgOxdcFEKrf7MmhR2BYDlm-Q/edit#gid=555498854.

Table 7 List of ISIMIP focus regions as shown in **Figure 6**.

Focus region (shortname) Number refers to **Figure 6**	Zonal extent (longitude)	Meridional extent (latitude)	River basin(s) or Region (shortname).
Regional water simulations			
North America (11) (nam)	114°0'W– 77°30'W	28°30'N–50°0'N	Mississippi (Mississippi)
Western Europe (1, 2) (weu)	9°30'W–12°0'E	38°30'N–52°30'N	Tagus und Rhine (rhine)
West Africa (9) (waf)	12°0'W–16°0'E	4°0'N–24°30'N	Niger (niger)
South Asia (6) (sas)	73°0'E–90°30'E	22°0'N–31°30'N	Ganges (ganges)
China (4, 5) (chi)	90°30'E–120°30'E	24°0'N–42°0'N	Yellow (yellow), Yangtze (Yangtze)
Australia (7) (aus)	138°30'E–152°30'E	38°0'S –24°30'S	Murray Darling (murrydarling)
Amazon (10) (ama)	80°0'W–50°0'W	20°0'S–5°30'N	Amazon (amazon)
Blue Nile (8) (blu)	32°30'E–40°0'E	8°0'N–16°0'N	Blue Nile (bluenile)
Lena (3) (len)	103°0'E–141°30'E	52°0'N–72°0'N	Lena (lena)
Canada (12)	140°0'W– 103°0'W	52°0'N–69°0'N	Mackenzie (mackenzie)
Regional forest simulations			
bily-kriz	18.32	49.300	-
collelongo	13.588	41.849	

soro	11.645	55.486	
hyytiala	24.295	61.848	
kroof	11.400	48.250	
solling-beech	9.570	51.770	
solling-spruce	9.570	51.770	
peitz	14.350	51.917	
le-bray	-0.769	44.717	
Ocean regions			
North-west Pacific (1) (pacific-nw)		134°**30′**W–125°**30′**W	49°**30′**N–56°**30′**N
North Sea (2) (north-sea)		4°**30′**W–9°**30′**E	50°**30′**N–62°**30′**N
Baltic Sea (3)		15°**30′**E–23°**30′**E	55°**30′**N–64°**30′**N
North-west Meditteranean (4) (med-nw)		1°**30′**W–6°**30′**E	36°**30′**N–43°**30′**N
Adriatic Sea (5) (adriatic-sea)		11°**30′**E–20°**30′**E	39°**30′**N–45°**30′**N
Meditteranean Sea (6) (med-glob)		6°**30′**W–35°**30′**E	29°**30′**N–45°**30′**N
Australia (7) (australia)		120°**30′**E–170°**30′**E	47°**30′**S–23°**30′**S
Eastern Bass Strait (8) (eastern-bass-strait)		145°**30′**E–151°**30′**E	41°**30′**S–37°**30′**S
Cook Strait (9) (cook-strait)		174°**30′**E–179°**30′**E	46°**30′**S–40°**30′**S
(10) (psp)		90°**30′**W–30°**30′**E	48°**30′**N–70°**30′**N
(11) (mat)		90°**30′**W–30°**30′**E	35°**30′**N–49°**30′**N
(12) (med-atl)		90°**30′**W–30°**30′**E	17°**30′**N–36°**30′**N
(13) (tst)		90°**30′**W–30°**30′**E	0°**30′**S–18°**30′**N
North Humboldt Sea (14) (Humboldt-n)		93°**30′**W–69°**30′**W	20°**30′**S–6°**30′**N

3 Conventions for File Names and Formats

3.1 General Notes

It is important that you comply precisely with the formatting specified below, in order to facilitate the analysis of your simulation results in the ISIMIP framework. Incorrect formatting can seriously delay the analysis. The ISIMIP Team will be glad to assist with the preparation of these files if necessary.

5 For questions or clarifications, please contact info@isimip.org or the data manager directly (buechner@pik-potsdam.de) before submitting files.

3.1.1 Time slices for individual files

For time slices holding global daily data, files should cover 10 years starting in the second year of a decade and end in the first year of the next decade (e.g. 1991-2000). If the time period starts after the second year of the decade, or ends before the first year of the new decade, the start or end year of the time period should be used as the start or end year of the file respectively. Data on a lower than daily temporal resolution or non-global data should be submitted for the entire simulation period in single files per variable.

10

Examples of time slices for individual files with global daily data:

Pre-industrial: 1661_1670, 1671_1680, ..., 1851_1860
Historical: 1861_1870, 1871_1880, ..., 2001_2005
Future: 2006_2010, 2011_2020, ..., 2081_2090, 2091_2099
15 Extended future: 2100_2100, 2101_2110, ..., 2281_2290, 2291_2299

Time slices for individual files with non-global or non-daily data:

Pre-industrial: 1661_1860
Historical: 1861_2005
20 Future: 2006_2099
Extended future: 2100_2299

3.1.2 File names

File names consist of a series of identifiers, separated by underscores; see examples below. Things to note:

25 • Report **one** variable per file

- In filenames, use **lowercase** letters only
- Use underscore ("_") to separate identifiers
- Variable names consist of a single word without hyphens or underscores
- Use hyphens ("-") to separate strings within an identifier, e.g. in a model name
- NetCDF file extension is .nc4

The file name format is:

<modelname>_<gcm>_<bias-correction>_<climate-scenario>_<soc-scenario>_<co2sens-scenarios>_<variable>_<region>_<timestep>_<start-year>_<end-year>.nc4

The identifiers in brackets should be replaced with the appropriate identifiers from **Table 8**. Identifiers may be dependent on the sector. The identifiers <variable> might also contain information about the plant functional type (in the biomes and permafrost sectors). The pft naming is model-specific and hence has to be reported in the impact-model database entries for each model (www.isimip.org/impactmodels). In the forest sector, the identifier <variable> might contain information about the tree species. The species names codes are listed in **Table 20**.

Examples:

lpjml_ipsl-cm5a-lr_ewembi_historical_histsoc_co2_qtot_global_annual_1861_1870.nc4

lpjml_ipsl-cm5a-lr_ewembi_rcp26_rcp26soc_2005co2_yield-mai-noirr_global_annual_2006_2010.nc4

Table 8 Identifiers for file naming convention.

Item	Possible identifiers	Description
<modelname>		Model name
<gcm>	hadgem2-es, ipsl-cm5a-lr, miroc5, gfdl-esm2m	Name of the General Circulation Model (global climate model) from which climate-forcing data was used.
<bias-correction>	nobc, localbc, ewembi, ewembi-isimip3basd	The target observed climate data used for the bias correction. nobc Indicates that no bias correction was performed on the climate data (e.g. ocean data). localbc refers to local data from weather stations used for the bias-correction in e.g. the forest sector. ewembi refers to EWEMBI data used for the bias-correction globally on a 0.5° grid. ewembi-isimip3basd refers to EWEMBI data used for the bias-correction globally on a 0.5° grid, using improved bias-correction methods (Lange 2018, doi: 10.5194/esd-9-627-2018),

		and with statistical downscaling (instead of interpolation) of GCM data to the 0.5° grid prior to bias-correction.
<climate-scenario>	picontrol, historical, rcp26, rcp60, rcp85	Climate & CO2 concentration scenario (RCP). Note: even though "picontrol" uses fixed co2-levels, it should come with the <co2sens-scenario> qualifier "co2" (see below)
<soc -scenario>	nosoc, 1860soc, histsoc, 2005soc, rcp26soc, rcp60soc, 2100rcp26soc	Scenario describing other human influences, such as land use and land management.
<co2sens-scenario>	co2, 2005co2	'co2' for all experiments other than the sensitivity experiments for which 2005co2 is explicitly written. Note: even models in which CO2 has no effect should use the co2 identifier relevant to the experiment.
<variable>		Output variable names – see sector-specific tables.
<region>	global, [region/basin/sites]	Region, basin or site names given in Section 2.6. Where simulations are provided for a single station within a river basin, the tag should have the format [basin]-[station].
<timestep>	3hr, daily, monthly, annual	The temporal resolution of your output data files.
<start-year>_<end-year>	e.g. 1861_1870	Files should be uploaded in 10-year pieces. For the transition from the historical to the future period (2005-2006), files should be separated, i.e. the identifiers would be 2001_2005 and 2006_2010. For the forest simulations, no time slices are needed and the full simulation period can be covered in one file.

For further instructions on file naming and formatting, please also refer to our website: https://www.isimip.org/protocol/isimip2b-files/#file-formats-and-meta-data

4 Water (hydrological models)

4.1 Scenarios

Climate & CO$_2$ concentration scenarios	
picontrol	Pre-industrial climate and 286ppm CO$_2$ concentration. The climate data for the entire period (1661-2299) are unique – no (or little) recycling of data has taken place.
historical	Historical climate and CO$_2$ concentration.
rcp26	Future climate and CO$_2$ concentration from RCP2.6.
rcp60	Future climate and CO$_2$ concentration from RCP6.0.
rcp85	Future climate and CO$_2$ concentration from RCP8.5.
Human influence and land use	
1860soc	Pre-industrial human influences. Given the small effect of dams & reservoirs before 1900, modellers may apply the 1901 dam/reservoir configuration during the pre-industrial period and the 1861-1900 part of the historical period if that is significantly easier than applying the 1861 configuration. Please indicate in the metadata of the file and the model description on the ISIMIP website which option you used.
histsoc	Varying historical land use and other human influences.
2005soc	Fixed year-2005 land use and other human influences.
nosoc	No direct human influences on the water cycle. This is only for models that do not represent any water abstraction. Such model simulations should be labeled "nosoc" even if human land-use is represented.
rcp26soc	Varying water abstraction and land use according to SSP2 and RCP2.6; fixed year-2005 dams and reservoirs. For models using fixed LU types, varying irrigation areas can also be considered as varying land use.
rcp60soc	Varying water abstraction and land use according to SSP2 and RCP6.0, fixed year-2005 dams and reservoirs. For models using fixed LU types, varying irrigation areas can also be considered as varying land use.

2100rcp26soc	Human influences and land use fixed at year 2100 levels according to RCP2.6.

For the historical period, groups that have limited computational capacities may choose to report only part of the full period but including at least 1961-2005. All other periods should be reported completely.

For the purpose of the global water sector, "**human influences**" is defined as human interference directly with the hydrological fluxes of the water cycle for the purposes of any one or several
5   of: water management (e.g. dams/reservoirs), irrigation, domestic water use, manufacturing and livestock production. I.e. human land use alone does not represent a human: influence.

For those models that do not represent *changes* in human influences, those influences should be held fixed at 2005 levels throughout all Group 1 (cf. **2005soc** marked as dashed blue lines in Fig. 1) and Group 2 simulations. Group 3 will be identical to Group 2 for these models and thus does not require additional simulations. Models that do not include any human influences *at all* (as defined above) should nevertheless run the Group 1 and Group 2 simulation, since these simulations will still allow for an exploration of the effects of climate change compare to pre-industrial climate, and will also allow for a better assessment of the relative importance of human impacts versus climate impacts. These runs should be named as **nosoc** simulations (even if
10   human land use is included).

The regional-scale simulations are performed for 12 large river basins. In six river basins (Tagus, Niger, Blue Nile, Ganges, Upper Yangtze and Darling) water management (dams/reservoirs, water abstraction) should be implemented. In the other six river basins, human influences such as LU changes, dams and reservoirs, and water abstraction is not relevant (Upper Yellow, Upper Amazon) or negligible (Rhine, Lena, Upper Mississippi), and can be ignored. Apart from this, regional water simulations should follow the global water simulations to allow for a cross-scale comparison of the simulations. The focus lakes for the local lake models are located within the focus river basins and listed in section 5.2.

15   **Table 9** ISIMIP2b scenarios for global and regional water simulations. *Option 2 only if option 1 not possible. Option 3 only if neither option 1 nor option 2 are possible. Simulations must follow a single row for each experiment; mixing of different options is not possible! **If you can only run simulations with 2005soc, then it is sufficient to provide only 200 years worth of picontrol climate (1661-1860).

	Experiment	Input	pre-industrial 1661-1860	historical 1861-2005	future 2006-2099	extended future 2100-2299
I	no climate change, pre-industrial CO_2	Climate & CO_2	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU	Option 1: **1860soc**	Option 1: **histsoc**	Option 1: **2005soc**	Option 1: **2005soc**
			Option 2*: **2005soc**	Option 2*: **2005soc****	Option 2*: **2005soc****	Option 2*: **2005soc****
			Option 3*: **nosoc**	Option 3*: **nosoc**	Option 3*: **nosoc**	Option 3*: **nosoc**

II	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I		**historical**	**rcp26**	**rcp26**
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			Option 1: **histsoc** / Option 2*: **2005soc**	Option 1/2*: **2005soc**	Option 1/2*: **2005soc**
					Option 3*: **nosoc**	Option 3*: **nosoc**	Option 3*: **nosoc**
III	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	not simulated
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			Option 1/2*: **2005soc** / Option 3*: **nosoc**	
IV	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	Experiment I	Experiment I	**picontrol**	**picontrol**
	varying human influences & LU up to 2100 (RCP2.6), then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**
V	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	Experiment I	Experiment I	**picontrol**	not simulated
	varying human influences & LU (RCP6.0)	Human & LU			**rcp60soc**	
VI	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp26**	**rcp26**
	varying human influences & LU up to 2100 (RCP2.6), then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**
VII	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	not simulated

	varying human influences & LU (RCP6.0)	Human & LU			**rcp60soc**	
VIII	RCP8.5 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp85**	not simulated
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			Option 1/2*: **2005soc**	
					Option 3*: **nosoc**	

4.2   Global and regional hydrological models

Variable names are chosen to comply, where feasible, with the ALMA convention (www.lmd.jussieu.fr/~polcher/ALMA/convention_output_3.html) and the names used in WATCH/WaterMIP. All variables are to be reported as time-averages with the indicated resolution; do not report instantaneous values ('snapshots'). Exceptions are **maxdis** and **mindis**, which are the maximum and minimum daily-average discharge in a given month, respectively, to be reported on a monthly basis (see below).

4.2.1   Output data

Table 10 Output variables to be reported by water sector models. Variables highlighted in orange are requested from both global and regional models; discharge at gauge level (highlighted in purple) is requested only from regional models; other (i.e. not shaded) variables are requested only from global models. Variables marked by * are also relevant for the permafrost sector and also listed there. Variables marked by ** are **only** relevant for the permafrost sector.

Variable (long name)	Variable name	Unit (NetCDF format)	Resolution	Comments
Hydrological Variables				
*Runoff	**qtot**	kg m-2 s-1	daily (0.5°x0.5°)	total (surface + subsurface) runoff (qtot = qs + qsb). If daily resolution not possible, please provide monthly.
Surface runoff	**qs**	kg m-2 s-1	monthly (0.5°x0.5°)	Water that leaves the surface layer (top soil layer) e.g. as overland flow / fast runoff

Subsurface runoff	**qsb**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of water that flows out from subsurface layer(s) including the groundwater layer (if present). Equals qg in case of a groundwater layer below only one soil layer
Groundwater recharge	**qr**	kg m-2 s-1	monthly (0.5°x0.5°)	Water that percolates through the soil layer(s) into the groundwater layer. In case seepage is simulated but no groundwater layer is present, report seepage as qr and qg.
Groundwater runoff	**qg**	kg m-2 s-1	monthly (0.5°x0.5°)	Water that leaves the groundwater layer. In case seepage is simulated but no groundwater layer is present, report seepage as qr and qg.
Discharge (gridded)	**dis**	m3 s-1	daily (0.5°x0.5°)	If daily resolution not possible, please provide monthly
Discharge (gauge level)	**dis**	m3 s-1	daily (see website for gauge locations)	If daily resolution not possible, please provide monthly
Monthly maximum of daily discharge	**maxdis**	m3 s-1	monthly (0.5°x0.5°)	Reporting this variable is not mandatory, but desirable particularly if daily discharge data is unfeasible
Monthly minimum of daily discharge	**mindis**	m3 s-1	monthly (0.5°x0.5°)	Reporting this variable is not mandatory, but desirable particularly if daily discharge data is unfeasible
Evapotranspiration	**evap**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of transpiration, evaporation, interception losses, and sublimation.
Evapotranspiration	**evap**	kg m-2 s-1	monthly (average for basin until gauge location)	Sum of transpiration, evaporation, interception losses, and sublimation.
Potential Evapotranspiration	**potevap**	kg m-2 s-1	monthly (0.5°x0.5°)	as for *evap*, but with all resistances set to zero, except the aerodynamic resistance.
*Soil moisture (= soil water storage)	**soilmoist**	kg m-2	monthly (0.5°x0.5°)	provide soil moisture for all depth layers (i.e. 3D-field), and indicate depth in m.

Soil moisture, root zone	rootmoist	kg m-2	monthly (0.5°x0.5°)	Total simulated soil moisture available for evapotranspiration. If simulated by the model. Please indicate the depth of the root zone for each vegetation type in your model
**Frozen soil moisture for each layer	soilmoistfroz	kg m-2	monthly (0.5°x0.5°)	water content of frozen soil
**Temperature of Soil	tsl	K	daily (0.5°x0.5°)	Temperature of each soil layer. Reported as "missing" for grid cells occupied entirely by "sea". Also need depths in meters. Daily would be great, but otherwise monthly would work. **if daily resolution not possible, please provide monthly
**Snow depth	snd	m	monthly (0.5°x0.5°)	Grid cell mean depth of snowpack.
*Snow water equivalent (= snow water storage)	swe	kg m-2	monthly (0.5°x0.5°)	Total water mass of the snowpack (liquid or frozen), averaged over a grid cell.
Total water storage	tws	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in all compartments. Please indicate in the netcdf metadata which storage compartments are considered.
Canopy water storage	canopystor	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in the canopy.
Glacier storage	glacierstor	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in glaciers.
Groundwater storage	groundwstor	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in groundwater layer.
Lake storage	lakestor	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in lakes (except reservoirs).
Wetland storage	wetlandstor	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in wetlands.
Reservoir storage	reservoirstor	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in reservoirs.

River storage	**riverstor**	kg m-2	monthly (0.5°x0.5°)	Mean monthly water storage in rivers.
*Annual maximum daily thaw depth	**thawdepth**	m	annual (0.5°x0.5°)	calculated from daily thaw depths, which do not need to be submitted themselves.
Rainfall	**rainf**	kg m-2 s-1	monthly (0.5°x0.5°)	These variables are required for test purposes only. If you need to reduce output data volumes, please provide these variables only once, with the first (test) data set you submit, e.g. for the first decade of each experiment. NOTE: rainf + snowf = total precipitation
Snowfall	**snowf**	kg m-2 s-1	monthly (0.5°x0.5°)	
Water management variables (for models that consider water management/human impacts)				
Irrigation water demand (=potential irrigation water Withdrawal)	**pirrww**	kg m-2 s-1	monthly (0.5°x0.5°)	Irrigation water withdrawal, assuming unlimited water supply
Actual irrigation water withdrawal	**airrww**	kg m-2 s-1	monthly (0.5°x0.5°)	Irrigation water withdrawal, taking water availability into account; please provide if computed
Potential irrigation water consumption	**pirruse**	kg m-2 s-1	monthly (0.5°x0.5°)	portion of withdrawal that is evapo-transpired, assuming unlimited water supply
Actual irrigation water consumption	**airruse**	kg m-2 s-1	monthly (0.5°x0.5°)	portion of withdrawal that is evapotranspired, taking water availability into account; if computed
Actual green water consumption on irrigated cropland	**airrusegreen**	kg m-2 s-1	monthly (0.5°x0.5°)	actual evapotranspiration from rain water over irrigated cropland; if computed
Potential green water consumption on irrigated cropland	**pirrusegreen**	kg m-2 s-1	monthly (0.5°x0.5°)	potential evapotranspiration from rain water over irrigated cropland; if computed and different from airrusegreen

Actual green water consumption on rainfed cropland	**arainfusegreen**	kg m-2 s-1	monthly (0.5°x0.5°)	actual evapotranspiration from rain water over rainfed cropland; if computed
Actual domestic water withdrawal	**adomww**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Actual domestic water consumption	**adomuse**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Actual manufacturing water withdrawal	**amanww**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Actual Manufacturing water consumption	**amanuse**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Actual electricity water withdrawal	**aelecww**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Actual electricity water consumption	**aelecuse**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Actual livestock water withdrawal	**aliveww**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Actual livestock water consumption	**aliveuse**	kg m-2 s-1	monthly (0.5°x0.5°)	if computed
Total (all sectors) actual water consumption	**Atotuse**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of actual water consumption from all sectors. Please indicate in metadata which sectors are included
Total (all sectors) actual water withdrawal	**Atotww**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of actual water withdrawal from all sectors. Please indicate in metadata which sectors are included
Total (all sectors) water demand (=potential water withdrawal)	**ptotww**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of potential (i.e. assuming unlimited water supply) water withdrawal from all sectors. Please indicate in metadata which sectors are included

Total (all sectors) potential water consumption	**ptotuse**	kg m-2 s-1	monthly (0.5°x0.5°)	Sum of potential (i.e. assuming unlimited water supply) water consumption from all sectors. Please indicate in metadata which sectors are included
Static output				
Soil types	**Soil**		static (0.5°x0.5°)	Soil types or texture classes as used by your model. Please include a description of each type or class, especially if these are different from the standard HSWD and GSWP3 soil types. Please also include a description of the parameters and values associated with these soil types (parameter values could be submitted as spatial fields where appropriate).
Leaf Area Index	**lai**	1	static (0.5°x0.5°) or monthly (0.5°x0.5°) where appropriate	if used by, or computed by the model
Agricultural variables (optional output for all water models that also simulate crop yields)				
Crop yields	**yield-<crop>-<irrigation setting>**	dry matter (t ha-1 per growing season)	per growing season (0.5°x0.5°)	irrigation setting = "cirr" for "constraint irrigation" or "noirr" for rainfed
Actual planting dates	**plantday-<crop>-<irrigation setting>**	Day of year	per growing season (0.5°x0.5°)	Julian dates
Actual planting year	**plantyear-<crop>-<irrigation setting>**	Year of planting	per growing season (0.5°x0.5°)	Attention: This is an additional output compared to the ISIMIP2a reporting. It allows for clear identification of planting that is also easy to follow for potential users from outside the project.

Anthesis dates	**Anthday-\<crop\>-\<irrigation setting\>**	Day of year of anthesis	per growing season (0.5°x0.5°)	Attention: This has changed compared to the ISIMIP2a reporting where we asked for the "day from planting date". Together with the year of anthesis added to the list of outputs (see below) it allows for clear identification of anthesis that is also easy to follow for potential users from outside the project.
Year of anthesis	**anthyear-\<crop\>-\<irrigation setting\>**	year of anthesis	per growing season (0.5°x0.5°)	Attention: This is an additional output compared to the ISIMIP2a reporting. It allows for clear identification of anthesis that is also easy to follow for potential users from outside the project.
Maturity dates	**matyday-\<crop\>-\<irrigation setting\>**	Day of year of maturity	per growing season (0.5°x0.5°)	Attention: This has changed compared to the ISIMIP2a reporting where we asked for the "day from planting date". Together with the year of maturity added to the list of outputs (see below) it allows for clear identification of maturity that is also easy to follow for potential users from outside the project.
Year of maturity	**matyyear-\<crop\>-\<irrigation setting\>**	year of maturity	per growing season (0.5°x0.5°)	Attention: This is an additional output compared to the ISIMIP2a reporting. It allows for clear identification of maturity that is also easy to follow for potential users from outside the project.
Nitrogen application rate	**initr-\<crop\>-\<irrigation setting\>**	kg ha-1 per growing season	per growing season (0.5°x0.5°)	Total nitrogen application rate. If organic and inorganic amendments are applied, rate should be reported as inorganic nitrogen equivalent (ignoring residues).
Biomass yields	**biom-\<crop\>-\<irrigation setting\>**	Dry matter (t ha-1 per growing season)	per growing season (0.5°x0.5°)	

Soil carbon emissions	**sco2-\<crop\>-\<irrigation setting\>**	kg C ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.
Nitrous oxide emissions	**sn2o-\<crop\>-\<irrigation setting\>**	kg N2O-N ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.
Nitrogen application rate	**initr-\<crop\>-\<irrigation setting\>**	kg ha-1 per growing season	per growing season (0.5°x0.5°)	Total nitrogen application rate. If organic and inorganic amendments are applied, rate should be reported as inorganic nitrogen equivalent (ignoring residues).

Comments related to the optional agricultural outputs

Simulations should be provided for the four major crops (wheat, maize, soy, and rice) but output for other crops and also bioenergy crops is highly welcome, too. For each crop, yields should be reported separately for irrigated land (cirr for "constraint irrigation") and rainfed conditions (noirr). This complements the full irrigation (firr) pure crop runs requested in the agriculture part of the protocol (section 10). Yields simulations provided in the water sector should account for irrigation water constraints and have to be labeled by the "cirr" to highlight the difference.

5 The reporting of the crop yield-related outputs differs from the reporting of other variables in the water sector, as it is not done according to time but according to growing seasons to resolve potential multiple harvests. The unit of the time dimension of the NetCDF v4 output file is thus "growing seasons since YYYY-01-01 00:00:00". The first season in the file (with value time=1) is then the first complete growing season of the time period provided by the input data without any assumed spin-up data, which equates to the growing season with the first planting after this date. To ensure that data can be matched to individual years in post-processing, it is essential to also provide the actual planting dates (as day of the year), actual planting years (year), anthesis dates (as day of the year), year of anthesis (year), maturity dates (day of the year), and year of maturity (year). This procedure is identical to the GGCMI convention (Elliott et al. 2015: The

10 Global Gridded Crop Model intercomparison: data and modelling protocols for Phase 1) and part of this agricultural protocol (section 10).

Those models that cannot simulate time varying management/human impacts/fertilizer input should keep these fixed at year 2005 levels throughout the simulations ("2005soc" scenario in Group 1 (dashed line in **Figure 1**) and "2005soc" scenario in Group 2). They only need to run the first preindustrial period of Experiment I (1661-1860). Group 3 runs refer to models that are able to represent future changes in human management (varying crop varieties or fertilizer input). Assumptions about historical (Group 1) and future (Group 3) fertilizer inputs are harmonized and centrally provided within ISIMIP2b (Frieler et al., GMD, 2017).

15

5   Lakes

Simulations of climate-change effects on lakes will be made using coupled lake-hydrodynamic and water-quality models. Models can operate on the global scale (uncalibrated) or on a number of case-study lakes (calibrated). Both global and local models will conduct the same set of scenarios.

Global lake models

5 Global-scale simulations should be performed either assuming a lake present in every pixel or using grid-scale lake fraction based on the Global Lake and Wetland Database (GLWD; Lehner and Döll, 2004) and available on the DKRZ input data repository (/work/bb0820/ISIMIP/ISIMIP2b/InputData/lakes/pctlake.nc4; Subin et al., 2012). Bias-corrected meteorolögical forcing is available at the global scale (that is, do not use the land-only forcing models). Since a 0.5°x0.5° pixel potentially contains multiple lakes with different characteristics (e.g. in terms of bathymetry, transparency, fetch), it is not possible to fully represent this subgrid-scale heterogeneity. Instead, the global-scale lake simulations should represent a 'representative lake' for a given pixel. Consequently, no stringent requirement is imposed with respect to lake depth, light extinction coefficient or initial conditions.

10 For lake depth, modellers are encouraged to use the data from the Global Lake Data Base (GLDB). A regridded lake depth field based on GLDBv1 (Kourzeneva, 2010) is available at 0.5°x0.5° resolution on the DKRZ input data repository (/work/bb0820/ISIMIP/ISIMIP2b/InputData/lakes/lakedepth.nc4; this field was aggregated from 30 arc sec to 1.9°x2.5° and then interpolated again to 0.5°x0.5°; Subin et al., 2012), but modellers may choose to use the more recent GLDBv2 available at 30 arc sec (http://www.flake.igb-berlin.de/ep-data.shtml, Choulga et al., 2014). Modellers are requested to document their approach regarding lake depth, light extinction coefficient and initial conditions in the ISIMIP Impact Model Database (www.isimip.org/impactmodels). In case the lake model has no built-in calculation of the light extinction coefficient, modellers may consider using the parameterisation proposed by Shatwell

15 (unpubl.): extcoeff = 5.681 * max(depth,1) ^(-0.795), derived from a collection of 1258 lakes, or the parameterisation proposed by Hakanson (1995, Aquatic sciences): extcoeff = 1.1925 * max(lakedepth,1)^(-0.424), derived from 88 Swedish glacial lakes. Yet it should be noted that modellers are free to decide how to represent extinction coefficient.

Local lake models

Simulations will be made for case-study lakes selected based on the availability of high-quality meteorological and limnological observations, thereby aiming for a good spread across climates and lake types. Model inputs consist of the meteorological variables given in **Table 1**, water inputs from hydrological model simulations, and nutrient loads estimated using simple loading

20 function (Haith and Shoemaker., 1987; Schneiderman et al., 2002) or statistical estimation procedures. In addition, site-specific data will be needed such as lake bathymetry data. Climate-change effects on lakes will be proportioned according to the ISIMP2b experiments (**Table 10**). Direct climate effects on lakes that influence factors such as water temperature stratification period, mixing depth etc. will be simulated using climate scenarios shown in **Table 11** and water inflows from hydrologic model simulations based on the **Table 9** experiments. Lake water quality simulations, which affect factors such as phytoplankton and nutrient levels, will also need to include simple nutrient loading inputs linked to the hydrologic model simulations.

Reporting

25 All variables are to be reported as time-averages with the indicated resolution.

For depth-varying variables, data should be provided either as fully-resolved vertical profiles, or, if that is not possible, as a mean of the epilimnion or mixed layer ("mean epi"), and mean of the hypolimnion ("mean hypo"). When the lake is simulated as completely mixed or isothermal, the mean of the entire water column is assigned to the epilimnion, and the hyolimnion concentration is set to a missing value.

Diagnostic for lake stratification

As density is a non-linear function of temperature and a global analysis requires examination of a wide range of lake temperatures it is preferable to use a density-derived definition of stratification to a purely temperature-related definition, as follows:

Calculate density (ρ) from temperature using the formula (Millero & Poisson, 1981):

5 $\rho = 999.842594 + (6.793952 \times 10^{-2}\, t) - (9.095290 \times 10^{-3}\, t2) + (1.001685 \times 10^{-4}\, t3) - (1.120083 \times 10^{-6}\, t4) + (6.536336 \times 10^{-9}\, t5)$,

where t is water temperature of the lake layer in °C.

Define the lake to be stratified whenever the density difference between the surface and the bottom of the lake is greater than 0.1 kg m-3. Note this definition does not distinguish between 'normal' and 'reverse' stratification. Reverse stratification means that the surface is colder than the bottom, but the surface water density is less than the maximum density of water, found particularly under ice. While a separate step can be used to distinguish these events by assessing whether the surface temperature is greater than or less than 3.98 °C, this separation is not 10 requested by the protocol.

Note that the range of model outputs will vary from model to model. Below are generic outputs that capture the basic information provided by most lake-eutrophication models. Modelling groups whose models do not provide all information listed here are invited to report on the reduced set of variables implemented in their models.

5.1 Scenarios

Climate & CO_2 concentration scenarios	
picontrol	Pre-industrial climate and 286ppm CO_2 concentration. The climate data for the entire period (1661-2299) are unique – no (or little) recycling of data has taken place.
historical	Historical climate and CO_2 concentration.
rcp26	Future climate and CO_2 concentration from RCP2.6.
rcp60	Future climate and CO_2 concentration from RCP6.0.
rcp85	Future climate and CO_2 concentration from RCP8.5.
Human influence and land-use scenarios	
1860soc	Pre-industrial land use and other human influences. Given the small effect of dams & reservoirs before 1900, modellers may apply the 1901 dam/reservoir configuration during the pre-industrial period and the 1861-1900 part of the historical period if that is significantly easier than applying the 1861 configuration.

histsoc	Varying historical land use and other human influences.
2005soc	Fixed year-2005 land use and other human influences.
nosoc	No direct human influences on the water cycle. This is only for models that do not represent any water abstraction. Such model simulations should be labeled "nosoc" even if human land-use is represented.
rcp26soc	Varying land use ((e.g. point source inputs of nutrients and operational changes of reservoirs), water abstraction and other human influences according to SSP2 and RCP2.6; fixed year-2005 dams and reservoirs. For models using fixed LU types, varying irrigation areas can also be considered as varying land use.
rcp60soc	Varying land use, water abstraction and other human influences according to SSP2 and RCP6.0, fixed year-2005 dams and reservoirs. For models using fixed LU types, varying irrigation areas can also be considered as varying land use.
2100rcp26soc	Land use and other human influences fixed at year 2100 levels according to RCP2.6.

For the historical period, groups that have limited computational capacities may choose to report only part of the full period but including at least 1961-2005. All other periods should be reported completely. For those models that do not represent *changes* in human influences, those influences should be held fixed at 2005 levels throughout all Group 1 (cf. **2005soc** marked as dashed blue lines in Fig. 1) and Group 2 simulations. Group 3 will be identical to Group 2 for these models and thus does not require additional simulations. Models that do not include human
5 influences *at all* should nevertheless run the Group 1 and Group 2 simulation, since these simulations will still allow for an exploration of the effects of climate change compare to pre-industrial climate, and will also allow for a better assessment of the relative importance of human impacts versus climate impacts. These runs should be named as **nosoc** simulations.

Table 11 ISIMIP2b scenarios for lakes simulations**. *Option 2 only if option 1 not possible. **If you can only run simulations with 2005soc, then it is sufficient to provide 200 years worth of picontrol climate (1661-1860).

	Experiment	Input	pre-industrial 1661-1860	historical 1861-2005	future 2006-2099	extended future 2100-2299
I	no climate change, pre-industrial CO_2	Climate & CO_2	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	varying LU and other human influences according to RCP2.6 + SSP2 up to 2100, then fixed at 2100 levels thereafter	Human & LU	Option 1: **1860soc**	Option 1: **histsoc**	Option 1*: **2005soc**	Option 1*: **2005soc**
			Option 2*: **2005soc**	Option 2*: **2005soc**	Option 2*: **2005soc**	Option 2*: **2005soc**

			Option 3*: **nosoc**	Option 3*: **nosoc**	Option 3*: **nosoc**	Option 3*: **nosoc**
II	RCP2.6 climate & CO_2	Climate & CO_2	Experiment I	**historical**	**rcp26**	**rcp26**
	varying LU and other human influences according to RCP2.6 + SSP2 up to 2100, then fixed at 2100 levels thereafter	Human & LU		Option 1: **histsoc** Option 2*: **2005soc**	**2005soc**	**2005soc**
IIa	RCP2.6 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	Experiment I	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**
	LU & human influences fixed at 2005 levels after 2005	Human & LU			**2005soc**	**2005soc**
III	RCP6.0 climate & CO_2	Climate & CO_2	Experiment I	Experiment II	**rcp60**	not simulated
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	
IV	no climate change, pre-industrial CO_2	Climate & CO_2	Experiment I	Experiment I	**picontrol**	**picontrol**
	varying LU and other human influences according to RCP2.6 + SSP2 up to 2100, then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**
V	no climate change, pre-industrial CO_2	Climate & CO_2	Experiment I	Experiment I	**picontrol**	not simulated
	varying human influences & LU (RCP6.0)	Human & LU			**rcp60soc**	
VI	RCP2.6 climate & CO_2	Climate & CO_2	Experiment I	Experiment II	**rcp26**	**rcp26**
	varying human influences & LU up to 2100 (RCP2.6), then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**

	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	not simulated
VII						
	varying human influences & LU (RCP6.0)	Human & LU			**rcp60soc**	
	RCP8.5 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp85**	not simulated
VIII						
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	

5.1.1   Output data

Table 12 Output variables to be reported by lake models.

Variable (long name)	Variable name	Unit (NetCDF format)	Spatial Resolution	Temporal Resolution	Depth Resolution	Comments
Hydrothermal Variables						
Thermal stratification	**strat**	*unitless*	Representative lake associated with grid cell	Daily	None	1 if lake grid cell is thermally stratified 0 if lake grid cell is not thermally stratified
Depth of Thermocline	**thermodepth**	m	Representative lake associated with grid cell	Daily	None	Depth corresponding the maximum water density gradient
Water temperature	**watertemp**	K	Representative lake associated with grid cell	Daily	Full Profile	Simulated water temperature. Layer averages and full profiles

Surface temperature	**surftemp**	K	Representative lake associated with grid cell	Daily (monthly)	None	Average of the upper layer in case not simulated directly.
Bottom temperature	**bottemp**	K	Representative lake associated with grid cell	Daily (monthly)	None	Average of the lowest layer in case not simulated directly.
Lake ice cover	**ice**	*unitless*	Representative lake associated with grid cell	Daily	None	1 if ice cover is present in lake grid cell 0 if no ice cover is present in lake grid cell
Lake layer ice mass fraction	**lakeicefrac**	*unitless*	Representative lake associated with grid cell	Daily (monthly)	Mean Epi	Fraction of mass of a given layer taken up by ice
Ice thickness	**icethick**	m	Representative lake associated with grid cell	Daily (monthly)	None	
Snow thickness	**snowthick**	m	Representative lake associated with grid cell	Daily (monthly)	None	
Temperature at the ice upper surface	**icetemp**	K	Representative lake associated with grid cell	Monthly	None	

Temperature at the snow upper surface	**snowtemp**	K	Representative lake associated with grid cell	Monthly	None	
Sensible heat flux at the lake-atmosphere interface	**sensheatf**	W m-2	Representative lake associated with grid cell	Daily (monthly)	None	At the surface of snow, ice or water depending on the layer in contact with the atmosphere. positive if upwards.
Latent heat flux at the lake-atmosphere interface	**latentheatf**	W m-2	Representative lake associated with grid cell	Daily (monthly)	None	See sensible heat flux
Momentum flux at the lake-atmosphere interface	**momf**	kg m-1 s-2	Representative lake associated with grid cell	Daily (monthly)	None	See sensible heat flux
Upward shortwave radiation flux at the lake-atmosphere interface	**swup**	W m-2	Representative lake associated with grid cell	Daily (monthly)	None	See sensible heat flux. Not to be confused with net shortwave radiation
Upward longwave radiation flux at the lake-atmosphere interface	**lwup**	W m-2	Representative lake associated with grid cell	Daily (monthly)	None	See sensible heat flux. Not to be confused with net longwave radiation

Downward heat flux at the lake-atmosphere interface	**lakeheatf**	W m-2	Representative lake associated with grid cell	Daily (monthly)	None	See sensible heat flux the residual term of the surface energy balance, i.e. the net amount of energy that enters the lake on daily time scale: lakeheatf = swdown - swup + lwdown - lwup - sensheatf - latenheatf (terms defined positive when directed upwards)
Turbulent diffusivity of heat	**turbdiffheat**	m2 s-1	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	only if computed by the model
Surface albedo	**albedo**	*unitless*	Representative lake associated with grid cell	Daily (monthly)	None	Albedo of the surface interacting with the atmosphere (water, ice or snow)
Light extinction coefficient	**extcoeff**	m-1	Representative lake associated with grid cell	Constant	None	only to be reported for global models, local models should use extcoeff as input
Sediment upward heat flux at the lake-sediment interface	**sedheatf**	W m-2	Representative lake associated with grid cell	Daily (monthly)	None	Positive if upwards. Only if computed by the model.
Water Quality Variables						

Chlorophyll Concentration	chl	g-3 m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	Total water chlorophyll concentration – indicator of phytoplankton
Phytoplankton Functional group biomass	phytobio	mole m-3 as carbon	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	Different models will have different numbers of functional groups so that the reporting of these will vary by model
Zoo plankton biomass	zoobio	mole m-3 as carbon	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	Total simulated Zooplankton biomass
Total Phosphorus	tp	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	
Particulate Phosphorus	pp	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	
Total Dissolved Phosphorus	tpd	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	Some models may also output data for soluable reactive phosphorus (SRP)

Total Nitrogen	**tn**	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	
Particulate Nitrogen	**pn**	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	
Total Dissolved Nitrogen	**tdn**	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	Some models may also output data for Nitrate (N02) nitrite (NO3) and ammonium (NH4)
Dissolved Oxygen	**do**	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	
Dissolved Organic Carbon	**doc**	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	Not always available
Dissolved Silica	**si**	mole m-3	Representative lake associated with grid cell	Daily (monthly)	Either full profile, or mean epi and mean hypo	Not always available

6 Biomes

6.1 Scenarios

Since the pre-industrial simulations are an important part of the experiments, the spin-up has to finish before the pre-industrial simulations start. The spin-up should be using pre-industrial climate (**picontrol**) and year 1860 levels of "other human influences". For this reason, the pre-industrial climate data should be replicated as often as required. The precise implementation of the spin up will be model specific, the description of which will be part of the reporting process.

5

Climate & CO$_2$ scenarios	
picontrol	Pre-industrial climate and 286ppm CO$_2$ concentration. The climate data for the entire period (1661-2299) are unique – no (or little) recycling of data has taken place.
historical	Historical climate and CO$_2$ concentration.
rcp26	Future climate and CO$_2$ concentration from RCP2.6.
rcp60	Future climate and CO$_2$ concentration from RCP6.0.
rcp85	Future climate and CO$_2$ concentration from RCP8.5.
2005co2	CO2 concentration fixed at 2005 levels at 378.81ppm.
Human influence and land-use scenarios	
1860soc	Constant pre-industrial (1860) land use, nitrogen deposition, and fertilizer input.
histsoc	Varying historical land use, nitrogen deposition and fertilizer input.
2005soc	Fixed year-2005 land use, nitrogen deposition and fertilizer input.
rcp26soc	Varying land use, water abstraction, nitrogen deposition and fertilizer input according to SSP2 and RCP2.6.
rcp60soc	Varying land use, water abstraction, nitrogen deposition and fertilizer input according to SSP2 and RCP6.0.

			2100rcp26soc	Land use, nitrogen deposition and fertilizer input fixed at year 2100 levels according to RCP2.6 in 2100.

Table 13 ISIMIP2b scenarios for the global biomes simulations.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299
I	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU	**1860soc**	**histsoc**	**2005soc**	**2005soc**
II	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I	**historical**	**rcp26**	**rcp26**
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU		**histsoc**	**2005soc**	**2005soc**
IIa	RCP2.6 climate, CO$_2$ after 2005 fixed at 2005 levels	Climate & CO$_2$	Experiment I	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	**2005soc**
III	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	not simulated
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	
IV	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	Experiment I	Experiment I	**picontrol**	**picontrol**
	varying human influences & LU up to 2100 (RCP2.6), then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**

			Pre-industrial	Historical	Future	Extended future
V	no climate change, pre-industrial CO_2	Climate & CO_2	Experiment I	Experiment I	**picontrol**	not simulated
	varying human influences & LU (RCP6.0)	Human & LU			**rcp60soc**	
VI	RCP2.6 climate & CO_2	Climate & CO_2	Experiment I	Experiment II	**rcp26**	**rcp26**
	varying human influences & LU up to 2100 (RCP2.6), then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**
VII	RCP6.0 climate & CO_2	Climate & CO_2	Experiment I	Experiment II	**rcp60**	not simulated
	varying human influences & LU (RCP6.0)	Human & LU			**rcp60soc**	
VIII	RCP8.5 climate & CO_2	Climate & CO_2	Experiment I	Experiment II	**rcp85**	not simulated
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	

Table 14 Additional sector-specific simulations for the biome sector.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299
Ia	no climate change, pre-industrial CO_2	Climate & CO_2	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	LU & human influences fixed at 1860 levels	Human & LU	**1860soc**	**1860soc**	**1860soc**	**1860soc**
IIb	RCP2.6 climate & CO_2	Climate & CO_2	Experiment I	**historical**	**rcp26**	**rcp26**
	LU & human influences fixed at 1860 levels	Human & LU		**1860soc**	**1860soc**	**1860soc**

IIIa	RCP6.0 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	Experiment I	Experiment II	**rcp60, 2005co2**	not simulated
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	
IIIb	RCP6.0 climate & CO_2	Climate & CO_2	Experiment I	Experiment II	**rcp60**	not simulated
	LU & human influences fixed at 1860 levels	Human & LU			**1860soc**	
IIIc	RCP8.5 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	Experiment I	Experiment II	**rcp85, 2005co2**	not simulated
	varying LU & human influences up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	

6.2 Output data

Table 15 Variables to be reported by biomes models. Variables marked by * are also relevant for the permafrost sector and also listed in **Table 21**. **Note**: If you cannot provide the data at the temporal or spatial resolution specified, please provide it the highest possible resolution of your model.

Variable (long name)	Variable name	Unit (NetCDF name)		Resolution	Comment
Essential outputs					
Pools					
*Carbon Mass in Vegetation biomass	**cveg-<pft>**	kg m-2	per pft and gridcell total	annual	Gridcell total cveg is essential. Per PFT information is desirable.

*Carbon Mass in aboveground vegetation biomass	**cvegag-\<pft\>**	kg m-2	per pft and gridcell total	annual	Gridcell total cvegag is essential. Per PFT information is desirable.
*Carbon Mass in belowground vegetation biomass	**cvegbg-\<pft\>**	kg m-2	per pft and gridcell total	annual	Gridcell total cvegbg is essential. Per PFT information is desirable.
*Carbon Mass in Litter Pool	**clitter**	kg m-2	per gridcell total	annual	Info for each individual pool.
*Carbon Mass in Soil Pool	**csoil**	kg m-2	per gridcell total	annual	Info for each individual pool.
*Total Carbon Mass in Soil Pool	**soilc**	kg m-2	per gridcell total	annual	Integrated over the entire soil depth
Fluxes					
*Carbon Mass Flux out of atmosphere due to Gross Primary Production on Land	**gpp**	kg m-2 s-1	gridcell total	daily (monthly)	
*Carbon Mass Flux out of atmosphere due to Gross Primary Production on Land	**gpp-\<pft\>**	kg m-2 s-1	per pft	annual	
*Carbon Mass Flux into atmosphere due to Autotrophic (Plant) Respiration on Land	**ra**	kg m-2 s-1	gridcell total	daily (monthly)	
*Carbon Mass Flux out of atmosphere due to Net Primary Production on Land	**npp**	kg m-2 s-1	gridcell total	daily (monthly)	
*Carbon Mass Flux out of atmosphere due to Net Primary Production on Land	**npp-\<pft\>**	kg m-2 s-1	per pft	annual	
*Carbon Mass Flux into atmosphere due to Heterotrophic Respiration on Land	**rh**	kg m-2 s-1	gridcell total	daily (monthly)	
*Carbon Mass Flux into atmosphere due to total Carbon emissions from Fire	**fireint**	kg m-2 s-1	gridcell total	daily (monthly)	

*Carbon loss due to peat burning	**somcfire**	kg m-2 s-1	gridcell total	monthly	
*Carbon Mass Flux out of Atmosphere due to Net biome Production on Land (NBP)	**ecoatmflux**	kg m-2 s-1	gridcell total	daily (monthly)	This is the net mass flux of carbon between land and atmosphere calculated as photosynthesis MINUS the sum of plant and soil respiration, carbon fluxes from fire, harvest, grazing and land use change. Positive flux is into the land.
Structure					
*Leaf Area Index	**lai-<pft>**	1	per pft	annual	
*Leaf Area Index	**lai**	1	gridcell average	daily (monthly)	
*Plant Functional Type Grid Fraction	**pft-<pft>**	%	per gridcell	annual (or once if static)	The categories may differ from model to model, depending on their PFT definitions. This may include natural PFTs, anthropogenic PFTs, bare soil, lakes, urban areas, etc. Sum of all should equal the fraction of the grid-cell that is land. Value between 0 and 100.
Hydrological variables					
Total Evapo-Transpiration	**evap**	kg m-2 s-1	gridcell total	daily (monthly)	
Evaporation from Canopy (interception)	**intercept-<pft>**	kg m-2 s-1	gridcell total	daily (monthly)	the canopy evaporation+sublimation (if present in model). Provide at pft-level if available in the model
Water Evaporation from Soil	**esoil-<pft>**	kg m-2 s-1	per gridcell	daily (monthly)	includes sublimation. Provide at pft-level if available in the model
Transpiration	**trans-<pft>**	kg m-2 s-1	per gridcell	daily (monthly)	Provide at pft-level if available in the model

*Runoff	qtot	kg m-2 s-1	per gridcell	daily** (monthly)	total (surface + subsurface) runoff (qtot = qs + qsb).
					** especially for models also participating in the water sector
					If daily resolution not possible, please provide monthly. If storage issues keep you from reporting daily data, please contact the ISIMIP team to discuss potential solutions.
*Soil Moisture	soilmoist	kg m-2	per gridcell	daily (monthly)	If possible, please provide soil moisture for all depth layers (i.e. 3D-field), and indicate depth in m. Otherwise, provide soil moisture of entire column.
Surface Runoff	qs	kg m-2 s-1	per gridcell	daily (monthly)	Total surface runoff leaving the land portion of the grid cell.
*Frozen soil moisture for each layer	soilmoistfroz	kg m-2	per gridcell	monthly	Please provide soil moisture for all depth levels and indicate depth in m.
*Snow depth	snd	m	per gridcell	monthly	Grid cell mean depth of snowpack.
*Snow water equivalent	swe	kg m-2	per gridcell	monthly	Total water mass of the snowpack (liquid or frozen), averaged over a grid cell.
*Annual maximum thaw depth	thawdepth	m	per gridcell	annual	calculated from daily thaw depths
					Please provide for purposes of permafrost sector.
Other outputs					

*Temperature of Soil	tsl	K	per gridcell	daily (monthly)	Temperature of each soil layer. Reported as "missing" for grid cells occupied entirely by "sea". Also needs depths in meters. Daily would be great, but otherwise monthly would work.
Burnt Area Fraction	burntarea	%	per gridcell	daily (monthly)	Area percentage of grid cell that has burned at any time of the given day/month/year (for daily/monthly/annual resolution)
Albedo	albedo	1	per gridcell	monthly	average of pfts, snow cover, bare ground and water surfaces, range between 0-1
*N_2O emissions into atmosphere	n2o	kg m-2 s-1	gridcell total	monthly	From land, not from industrial fossil fuel emissions and transport
*CH4 emissions into atmosphere	ch4	kg m-2 s-1	gridcell total	monthly	From land, not from industrial fossil fuel emissions and transport

7 Regional forests

Several sites for which a wide range of forest models can be rather easily initialized have been selected for carrying out ISIMIP regional forest simulations. The PROFOUND Database is available as Reyer et al. (2019), please contact reyer@pik-potsdam.de for further questions. The management scenarios were prepared by the FORMASAM project with contributions of the following persons: Christopher Reyer, Mart-Jan Schelhaas, Annikki Mäkelä, Mikko Peltoniemi, Martin Gutsch, Mats Mahnken, Denis Loustau, Simon Martel, Katarína Merganičová, Henning Meesenburg, Thomas Rötzer, Michael Heym, Alessio Collalti, Ettore D'Andrea, Giorgio Matteucci, Andreas Ibrom, Vivian Kvist Johannsen.

1) **Climate and other data:** For the FORMASAM Management scenarios, please use the ISIMIP2BLBC climate data available in the PROFOUND database as a first priority and then the ISIMIP2B data from the grid cell as available in the PROFOUND DB. Please use historical CO_2 data and then switch to RCP CO_2 concentrations in 2005. Please use the future N deposition (NDEPOSITION_ISIMIP2B data files in PROFOUND DB) and also the tree, stand and soil data (TREE, STAND, SOIL data files in PROFOUND DB) provided by the PROFOUND database.

2) **Calibration:** Some models may require some kind of calibration or model development before they can contribute to ISIMIP. Such alterations of the model can influence the results of a model comparison and "model calibration" is understood differently by different modelers. All alterations to the model in the framework of this exercise should be reported in the model experiment documentation provided together with the upload of the simulations. Whenever the model calibration or development is driven by an improvement of the model after a comparison to data that were originally made available in ISIMIP for model evaluation, a part of those data should be kept aside for model evaluation and not used for calibration.

    a. Model development needed to run a model at specific sites is welcomed and needs to be transparent/ properly documented (e.g. adjustment of phenology model to include chilling effects). This is also applicable for more general calibration (i.e. fixing parameters once but not changing afterwards) for example to include a new tree species in a model.

    b. Manual or automatic site-specific "tuning" of species-specific and process-specific parameters should be avoided. The same "model" (i.e. also with the same parameter values) should be used in all simulations. If needed, any tuning needs to be documented in a transparent way and should be backed up by existing data (e.g. from TRY-database). If your model contains genetic processes where the change in parameters is part of the model processes, this is naturally part of "your model approach" and should be clearly spelled out as part of the documentation of your model. In this specific case, please contact the sectoral coordinators to discuss if it makes sense to include a "genetic adaptation" and a "parameter-fixed, control" run.

3) **Reporting Period**: Each phase of ISIMIP has its own reporting period but you should always start your reporting period for the first time step for which stand data is available (e.g. 1948 for the Peitz stand) and run your model until the last point in time where climate data is available.

4) Management 1: DBH is defined as diameter at breast height of 1.30m. The first available data point is used for model initialization (Ini). Following data points are used to mimick historic management (HM). When no more observed data is available, the management rules from **Table 18**-**Table 36** need to be used (FM). Note that depending on how models represent the planting/regeneration information from **Table 18**-**Table 36**, the overall stand- age maybe slightly higher than in **Table 18**-**Table 36** (e.g. seedlings planted with an age of 2 in 2033 will be harvested at an age of 142 after 140 years of rotation in 2173).

5) Management 2: Le Bray has two bioenergy scenarios, Solling-Beech has two adaptation scenarios and no HWP scenario, Solling-Spruce has no HWP scenario.

6) Management 3: The use of socioeconomic identifiers such as rcp26soca and rcp60soca are for the purpose of keeping consistency with ISIMIP naming conventions, the underlying management is identical.

7) Management 4: The transition from historical management to future managements start in 2020. E.g. Bily Kriz is 34 years old in 2015, hence theoretically in 2016 at age 35 the first thinning from the new management should start (15% BA under current site specific management guidelines). Yet, because this is before 2020, it is not included but only the next thinning in 2026 at age 45 (10% BA under current site specific management guidelines is modelled). Exceptions exist for Le-bray and Solling-beech for the current generic scenarios.

8) Management 5: When harvesting and planting are scheduled in the same year, i.e. in a sheltercut system, the new stand age starts counting from the planting year. In the subsequent management intervention, usually, the harvesting then takes place and refers to trees still present from the old rotation. The Thinning intensity then refers to the trees of the new rotation. E.g. in Collelongo in 2126, the 95 year old trees are thinned (TB15 under the maximize bioenergy scenario) and at the same time new trees are planted according to the plantation guidelines. Then, in 2141, the 120 year old remaining trees are harvested and the newly planted, 15-year old trees are thinned (TB35).

9) Management 6: If models are unable to simulate natural regeneration as a continuous process as required for the Bily Kriz MFA management, the suggestion is to mimic continuous natural regeneration by simulating plantings every 5 years depending on how the model works).

7.1   Scenarios

Climate scenarios	
picontrol	Pre-industrial climate and 286ppm CO_2 concentration. The climate data for the entire period (1661-2299) are unique – no (or little) recycling of data has taken place. The regional forest simulation should start at the first point in time for which initialisation data is available (**Table 18**-**Table 36**).
historical	Historical climate and CO_2 concentration.
rcp26	Future climate and CO_2 concentration from RCP2.6.
rcp60	Future climate and CO_2 concentration from RCP6.0.
rcp85	Future climate and CO_2 concentration from RCP8.5.
2005co2	CO2 concentration fixed at 2005 levels at 378.81ppm.
Human influences scenarios	
histsoc	Manage forests according to historical management guidelines without species change and keeping the same rotation length and thinning types (see **Table 18**-**Table 36**). The standard management ("histsoc") during the historical period is the observed management as defined by the data available for each site (Please only use the, species information, thinning type and reduction in stem numbers from the PROFOUND DB to mimic management, no other information (such as dbh or height should be used))
2005soc	Manage future forests according to present-day generic management guidelines without species change and keeping the same rotation length and thinning types (see **Table 18 – Table 20**). This generic management (2005soc) corresponds best to "intensive even-aged forestry" as defined by Duncker et al. 2012. After harvesting the stands (c.f. **Table 18**-**Table 36**), please proceed after harvest as your model usually does, e.g. plant the same tree species again or allow for regeneration of the same species according to the regeneration guidelines outlined in **Table 18**-**Table 36**.
2005socsite	Manage future forests according to present-day site-specific management guidelines (see **Table 18**-**Table 36**).

rcp26soc	Future forest can be managed either to maximize bioenergy (**rcp26socbe**), harvested wood products (**rcp26sochwp**) or a multifunctional, adapted forest (**rcp26soca**) as described in **Table 18**-**Table 36**. For some sites, further subscenarios exist, 1) a bioenergy-biomass (**rcp26socbeb**) scenario in leBray, 2) a multifunctional, adapted scenario in Solling-beech with focus on admixing native species (**rcp26socam**).	
rcp60soc	Future forest can be managed either to maximize bioenergy (**rcp60socbe**), harvested wood products (**rcp60sochwp**) or a multifunctional, adapted forest (**rcp60soca**) as described in **Table 18**-**Table 36**. For some sites, further subscenarios exist, 1) a bioenergy-biomass (**rcp60socbeb**) scenario in leBray, 2) a multifunctional, adapted scenario in Solling-beech with focus on admixing native species (**rcp60socam**). The managements under rcp60soc are the same as in rcp26soc.	
rcp85soc	Future forest can be managed either to maximize bioenergy (**rcp85socbe**), harvested wood products (**rcp85sochwp**) or a multifunctional, adapted forest (**rcp85soca**) as described in **Table 18**-**Table 36**. For some sites, further subscenarios exist, 1) a bioenergy-biomass (**rcp85socbeb**) scenario in leBray, 2) a multifunctional, adapted scenario in Solling-beech with focus on admixing native species (**rcp85socam**). The managements under rcp85soc are the same as in rcp26soc..	
2100rcp26soc	This scenario means managing future forests according to rcp26soc guidelines. **NOTE:** Not really applicable for the forest sector as the rcp26socs, rcp60socs and rcp85socs are all designed until 2300.	
nosoc	No forest management (but nitrogen deposition should be included). If your model includes natural regeneration, please only regeneration those species previously present on the plot. A "natural reference run (nosoc)" without any management will help assessing the influence of forest management.	

Table 16: ISIMIP2b scenarios for the regional forest simulations.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2100	Extended future 2101-2299
I	no climate change, pre-industrial CO_2	Climate & CO_2	not simulated	**picontrol**	**picontrol**	**picontrol**
	varying LU & human influences up to 2005, fixed present-day management afterwards	Human & LU		**histsoc**	**2005soc**	**2005soc**
	RCP2.6 climate & CO_2	Climate & CO_2	not simulated	**historical**	**rcp26**	**rcp26**

II	varying LU & human influences up to 2005, fixed present-day management afterwards	Human & LU		**histsoc**	**2005soc**	**2005soc**
IIa	RCP2.6 climate, CO$_2$ fixed after 2005	Climate & CO$_2$	not simulated	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**
	fixed present-day management after 2005	Human & LU			**2005soc**	**2005soc**
III	RCP6.0 climate & CO$_2$	Climate & CO$_2$	not simulated	Experiment II	**rcp60**	not simulated
	fixed present-day management after 2005	Human & LU			**2005soc**	
IV	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	not simulated	Experiment I	**Picontrol**	**picontrol**
	varying management	Human & LU			**rcp26soc (i.e. rcp26socbe, rcp26sochwp, rcp26soca)**	
V	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	not simulated	Experiment I	**Experiment IV**	not simulated
	varying management	Human & LU				
VI	RCP2.6 climate & CO$_2$	Climate & CO$_2$	not simulated	Experiment II	**rcp26**	**rcp26**
	varying management	Human & LU			**rcp26soc (i.e. rcp26socbe, rcp26sochwp, rcp26soca)**	
VII	RCP6.0 climate & CO$_2$	Climate & CO$_2$	not simulated	Experiment II	**rcp60**	not simulated
	varying management	Human & LU			**rcp60soc (i.e. rcp60socbe, rcp60sochwp, rcp60soca)**	

| VIII | RCP8.5 climate & CO$_2$ | Climate & CO$_2$ | Experiment I | Experiment II | rcp85 | not simulated |
| | fixed present-day management after 2005 | Human & LU | | | 2005soc | |

Table 17: Additional sector-specific simulations for the regional forest sector.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299
Ia	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	not simulated	**picontrol**	**picontrol**	**picontrol**
	No forest management	Human & LU		**nosoc**	**nosoc**	**Nosoc**
Ib	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	not simulated	Experiment I	**picontrol**	**picontrol**
	varying LU & human influences up to 2005, fixed present-day, site specific management afterwards	Human & LU			**2005socsite**	**2005socsite**
IIb	RCP2.6 climate & CO$_2$	Climate & CO$_2$	not simulated	**historical**	**rcp26**	**rcp26**
	No forest management	Human & LU		**nosoc**	**nosoc**	**Nosoc**
IIc	RCP2.6 climate, CO$_2$ fixed after 2005	Climate & CO$_2$	not simulated	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**
	No forest management	Human & LU			**nosoc**	**Nosoc**
	RCP2.6 climate & CO$_2$	Climate & CO$_2$	not simulated	Experiment II	**rcp26**	**rcp26**

IId	varying LU & human influences up to 2005, fixed present-day, site-specific management afterwards	Human & LU			**2005socsite**	**2005socsite**
IIe	RCP2.6 climate, CO_2 fixed after 2005	Climate & CO_2	not simulated	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**
	varying LU & human influences up to 2005, fixed present-day, site-specific management afterwards	Human & LU			**2005socsite**	**2005socsite**
IIIa	RCP6.0 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	not simulated	Experiment II	**rcp60, 2005co2**	not simulated
	LU & human influences fixed at 1860 levels	Human & LU			**2005soc**	
IIIb	RCP6.0 climate & CO_2	Climate & CO_2	not simulated	Experiment II	**rcp60**	not simulated
	No forest management	Human & LU			**nosoc**	
IIIc	RCP6.0 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	not simulated	Experiment II	**rcp60, 2005soc**	not simulated
	No forest management	Human & LU			**nosoc**	
IIId	RCP6.0 climate & CO_2	Climate & CO_2	not simulated	Experiment II	**rcp60**	not simulated
	fixed present-day, site-specific management after 2005	Human & LU			**2005socsite**	
IIIe	RCP6.0 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	Experiment I	Experiment II	**rcp60, 2005co2**	not simulated
	fixed present-day, site-specific management after 2005	Human & LU			**2005socsite**	
	RCP2.6 climate & CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	not simulated	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**

VIa	varying management	Human & LU			**rcp26soc (i.e. rcp26socbe, rcp26sochwp, rcp26soca)**	
VIIa	RCP6.0 climate & CO$_2$ after 2005 fixed at 2005 levels	Climate & CO$_2$	not simulated	Experiment II	**rcp60, 2005co2**	
	varying management	Human & LU			**rcp60soc (i.e. rcp60socbe, rcp60sochwp, rcp60soca)**	
VIIIa	RCP8.5 climate & CO2	Climate & CO$_2$	not simulated	Experiment II	**rcp85**	not simulated
	fixed present-day, site-specific management after 2005	Human & LU			**2005socsite**	
VIIIb	RCP8.5 climate, CO$_2$ after 2005 fixed at 2005 levels	Climate & CO$_2$	not simulated	Experiment II	**rcp85, 2005co2**	not simulated
	fixed present-day, site-specific management after 2005	Human & LU			**2005socsite**	
VIIIc	RCP8.5 climate & CO2	Climate & CO$_2$	not simulated	Experiment II	**rcp85**	not simulated
	varying management	Human & LU			**rcp85soc (i.e. rcp85socbe, rcp85sochwp, rcp85soca)**	
VIIId	RCP8.5 climate, CO$_2$ after 2005 fixed at 2005 levels	Climate & CO$_2$	not simulated	Experiment II	**rcp85, 2005co2**	not simulated
	varying management	Human & LU			**rcp85soc (i.e. rcp85socbe, rcp85sochwp, rcp85soca)**	

	RCP8.5 climate & CO2	Climate & CO_2			**rcp85**	
VIIIe			not simulated	Experiment II		not simulated
	No forest management	Human & LU			**Nosoc**	
VIIIf	RCP8.5 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	not simulated	Experiment II	**rcp85, 2005co2**	not simulated
	No forest management	Human & LU			**Nosoc**	
VIIIg	RCP8.5 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	not simulated	Experiment II	**rcp85, 2005co2**	not simulated
	Fixed present day management after 2005	Human & LU			**2005soc**	

7.1.1   Bily-Kriz

Table 18: FORMASAM management guidelines for Bily-Kriz. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario [ISIMIP-scenario-name]	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	piab	stem	below	30% BA	120	15 30 45 60 75 90 105	piab	4500	4	0.5	na	9	historical planting density was 5000/ha but current practices are 4500/ha only
No management [nosoc]	na	piab	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot

Current Site-specific [2005socsite]	even-aged clearcut	piab	stem	below	50 20 15 10 10 30 40% BA	110	15 25 35 45 60 95 105	piab + NR of fasy & abal (about 5%)	4000/ha piab + 1000/ha fasy + 500/ ha abal to mimic NR	4	0.3	na	8	fasy and abal are "allowed" in NR but not managed, only sanitary removal of dead trees, the final cut is split into two (at age 105 and age 110)
Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	even-aged clearcut	piab	stem+ branches	below	40% BA	45	20	piab	4000	4	0.3	na	8	regenerate as pure piab stand
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	even-aged clearcut	piab	stem	above	50 20 15 10 10 10 30 40% BA	120	15 25 35 45 60 80 100 110	piab	4000	4	0.3	na	8	thinning from above mimics selection of future crop trees (400 trees per hectare)
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	shelterwood transition to mixed selection forest (regenerating continuously, whenever there are gaps)	piab, fasy, abal	stem	Above Above Random Random Above_piab (Target DBH 55cm)/Random_fasy,abal,piab2 Above (Target DBH 55cm)	25 piab 10 piab 15 piab 10 piab, 5 fasy & abal 15 piab, 5 fasy & abal & piab 2nd generation 15%BA all	after transition: target DBH 55cm	40 45 55 65-75-85 95-105-115-125-135-145	during transition: planting of fasy & abal + NR of piab, after transition only NR	4000/ha piab + 1000/ha fasy + 500/ ha abal to mimic NR	4	0.3	na	8	any species, but mainly piab, fasy, abal are "allowed" in NR

								155-165…every 10 years						

Table 19: Detailed FORMASAM management schedule for Bily-Kriz. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting, T = Random Thinning

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	Remarks
Current generic	1997	1998-2015	2030	2045	2060	2075	2090	2100	2101	2116	2131	…	2221	2222	2238	…	2297					
		TB	TB30	TB30	TB30	TB30	TB30	H	P	TB30	TB30	TB30	H	P	TB30	TB30	TB30					
Current Site-specific	1997	1998-2015	2026	2041	2076	2086	2091	2092	2107	2117	2127	2137	2152	2187	2197	2202	2203	…	2313			
		TB	TB10	TB10	TB30	TB40	H	P	TB50	TB20	TB15	TB10	TB10	TB30	TB40	H	P	…	H			
Bioenergy	1997	1998-2015	2026	2027	2047	2072	2073	2093	2118	2119	2139	2164	2165	2185	2210	2211	2231	2256	2257	…	2302	
		TB	H	P	TB40	H	P	TB40	H	P	TB40	H	P	TB40	H	P	TB40	H	P		H	
HWP	1997	1998-2015	2026	2041	2061	2081	2091	2101	2102	2117	2127	2137	2147	2162	2182	2202	2212	2222	2223	…	2303	
		TB	TA10	TA10	TA10	TA30	TA40	H	P	TA50	TA20	TA15	TA10	TA10	TA10	TA30	TA40	H	P	…	TA10	
Multifunctional-Adapted	1997	1998-2015	2021	2026	2036	2046	2056	2066	2076	2086	2096	2106	2116	2126	2136	2146	2156	2166	2176	..	2306	special settings as continuous cover forestry is implemented
		TB	TA25	TA10	T15	T10			TA15, NR						TA15, NR							Spruce management
						NR			T05						TA15, NR							2nd generation Spruce management
			P			T05, NR									TA15, NR							Beech and Abies management

5

7.1.2 Collelongo

Table 20: FORMASAM management guidelines for Collelongo. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	fasy	stem	above	30% BA	140	15 30 45 60 75 90 105 120 135	fasy	10000	4	1.3	0.1	4	the planting data is only a rough approximation, usually NR is the regeneration method
No management [nosoc]	na	fasy	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	shelterwood (start regenerating at age 105)	fasy	stem	below below below below above	35% 25% 25% 25% 35% BA	120	15 35 60 85 105	fasy	NR 9000 (8000-10000)	1	0.1	0.1	5	the first thinning is precommercial, The planting data is only a rough approximation, usually NR is the regeneration method.
Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	shelterwood (start regenerating at age 105)	fasy	stem+ branches	below	35% 15% 15% 15% 15% 15% BA	120	15 35 55 75 95 105	fasy	NR 9000 (8000-10000)	1	0.1	0.1	5	the planting data is only a rough approximation, usually NR is the regeneration method.
HWP [rcp26sochwp /	shelterwood (start	fasy	stem	below below	35% 25%	160	15 35	fasy	NR 9000 (8000-10000)	1	0.1	0.1	5	the planting data is only a rough

rcp60sochwp / rcp85sochwp]	regenerating at age 140)			below below above above	25% 25% 35% 35% BA		60 85 105 140							approximation, usually NR is the regeneration method.
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	even-aged clearcut	fasy + qupu	stem	below below below below below above below below below below below above	fasy: 35% 15% 15% 15% 15% 15% BA qupu: 40% 20% 20% 20% 20% 20% BA	120	15 35 55 75 95 105 15 35 55 75 95 105	fasy + qupu	400 qupu, NR with fasy approximated using 600 samplings	3	0.5	1	5	

Table 21: Detailed FORMASAM management schedule for Collelongo. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	FM20	FM21	Remarks
Current Generic	1992	1997-2012	2027	2032	2033	2048	2063	2078	2093	...	2258	2173	2174	2189	...	2294								
		TA	TA30	H	P	TA30	TA30	TA30	TA30	TA30	TA30	H	P	TA30		TA30								
Current Site-specific	1992	1997-2012	2020	2021	2036	2056	2081	2106	2126	2141	2161	2186	2211	2231	2246	2266	2286							
		TA	H	P	TB35	TB25	TB25	TB25	TA35, P	H, TB35	TB25	TB25	TB25	TA35, P	H, TB35	TB35	TB25							
Bioenergy	1992	1997-2012	2020	2021	2036	2056	2076	2096	2116	2126	2141	2161	2181	2201	2221	2231	2246	2266	2286					
		TA	H	P	TB35	TB15	TB15	TB15	TB15	TB15, P	H, TB35	TB15	TB15	TB15	TB15	TB15, P	H, TB35	TB15	TB15					
HWP	1992	1997-2012	2032	2052	2053	2068	2088	2113	2138	2158	2193	2213*	2228	2253	2278	2298								
		TA	TA35	H	P	TB35	TB25	TB25	TB25	TA35	TA35, P	H, TB35	TB25	TB25	TB25	TA35								
Multifunctional-Adapted	1992	1997-2012	2020	2021	2036	2056	2076	2096	2116	2126	2141	2142	2157	2177	2197	2217	2237	2247	2262	2263	2278	2298	2318	
		TA	H	P	TB35, TB40	TB15, TB20	TB15, TB20	TB15, TB20	TB15, TB20	TA15, TA20	H	P	TB35, TB40	TB15, TB20	TB15, TB20	TB15, TB20	TB15, TB20	TA15, TA20	H	P	TB35, TB40	TB15, TB20	TB15, TB20	first number fasy, second qupu

*exceptionally this thinning happens at age 20 and not age 15

7.1.3 Hyytiälä

Table 22: FORMASAM management guidelines for Hyytiälä. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	pisy	stem	below	20% BA	140	15 30 45 60 75 90 105 120 135	pisy	2250 (2000-2500)	2	0.25 (0.2-0.3)	na	6 (5-7)	regenerate as pure pisy stand
No management [nosoc]	na	pisy	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	even-aged clearcut	pisy	stem	below below above	20% BA	90	20 50 70	pisy	2000	2	0.25 (0.2-0.3)	na	7 (5-7)	regenerate as pure pisy stand
Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	even-aged clearcut	pisy	stem+ branches	below	25% BA	60	20	pisy	2500	2	0.25 (0.2-0.3)	na	8 (5-7)	regenerate as pure pisy stand
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	even-aged clearcut	pisy	stem	below below above above	10% BA	120	20 50 70 110	pisy	2500	2	0.25 (0.2-0.3)	na	9 (5-7)	regenerate as pure pisy stand
Multifunctional-Adapted [rcp26soca / rcp60soca /	even-aged clearcut	pisy	stem	below below above	20% BA	80	20 40 60	pisy	2000 +NR	2	0.25 (0.2-0.3)	na	10 (5-7)	regenerate as pure pisy stand

rcp85soca]															

Table 23: Detailed FORMASAM management schedule for Hyytiälä. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	Remarks
Current generic	1995	1996-2011	2026	2041	2056	2071	2086	2101	2102	2117	...	2242	2243	2258	...							Only simulate pine and spruce (no hard-woods) and regenerate as pure pine stand.
		TB	TB20	TB20	TB20	TB20	TB20	H	P	TB20	TB20	H	P	TB20	TB20							
Current Site-specific	1995	1996-2011	2031	2051	2052	2072	2102	2122	2142	2143	2163	2193	2213	2233	2234	2254	2284	2304				
		TB	TA20	H	P	TB20	TB20	TA20	H	P	TB20	TB20	TA20	H	P	TB20	TB20	TA20				
Bioenergy	1995	1996-2011	2021	2022	2042	2082	2083	2103	2143	2144	2164	2204	2205	2225	2265	2266	2286	2326				
		TB	H	P	TB25	H	P	TB25	H	P	TB25	H	P	TB25	H	P	TB25	H				
HWP	1995	1996-2011	2031	2071	2081	2082	2102	2132	2152	2192	2202	2203	2223	2253	2273	2313						
		TB	TA10	TA10	H	P	TB10	TB10	TA10	TA10	H	P	TB10	TB10	TA10	TA10						
Multifunctional-Adapted	1995	1996-2011	2021	2041	2042	2062	2082	2102	2122	2123	2143	2163	2183	2203	2204	2224	2244	2264	2284	2285	2305	
		TB	TA20	H	P	TB20	TB20	TA20	H	P	TB20	TB20	TA20	H	P	TB20	TB20	TA20	H	P	TB20	

7.1.4 Kroof (mixed beech & spruce forest)

Table 24: FORMASAM management guidelines for Kroof (beech). Grey=already covered in ISIMIP2b, green = new FORMASAM runs,

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	fasy	stem	above	30% BA	140	15 30 45 60 75 90 105 120 135	fasy	6000 (5000-7000)	2	0.6 (0.5-0.7)	na	5	the planting density is for single-species stands, hence when regenerating the stand as a 2-species-stand (fasy, piab), the planting density of each species should be halved
No management [nosoc]	na	fasy	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	target DBH mimicked through rotation length	fasy	stem	above	15% BA	120	20 30 40 50 60 70 80 90 100 110	NR; fasy	4000 after 10 years (2500-5000)	2	0.6 (0.5-0.7)	na	7	the planting density is a 2-species-stand (fasy,piab), planting density for a single stand should be doubled
Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	target DBH mimicked through rotation length	fasy	stem + branches	above	15% BA	80	20 25 30 35 40	NR; fasy	4000 after 10 years (2500-5000)	2	0.6 (0.5-0.7)	na	7	the planting density is a 2-species-stand (fasy,piab), planting density for a single stand should be

						45 50 60 70							doubled
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	target DBH mimicked through rotation length	fasy	stem	above	10% BA	130	20 30 35 40 45 50 55 60 70 80 90 100 110 120	NR; fasy	4000 after 10 years (2500-5000)	2	0.6 (0.5-0.7)	na	7	the planting density is a 2-species-stand (fasy,piab), planting density for a single stand should be doubled
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	Same as Current Site-specific												

Table 25: FORMASAM management guidelines for Kroof (spruce). Grey=already covered in ISIMIP2b, green = new FORMASAM runs.

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	piab	stem	below	30% BA	120	15 30 45 60 75 90 105	piab	2250 (2000-2500)	2	0.35 (0.3-0.4)	na	7	the planting density is for single-species stands, hence when regenerating the stand as a 2-species-stand (fasy, piab), the planting density of each species should be halved
No management [nosoc]	na	piab	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	target DBH mimicked through rotation length	piab	stem	above	12.5% BA	90	10 25 30 35 40 45 55 65 75	piab	1500 (1000-2000)	2	0.35 (0.3-0.4)	na	5	the planting density is for single-species stands, hence when regenerating the stand as a 2-species-stand (fasy, piab), the planting density of each species should be halved, planting is delayed until beech is also planted
Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	target DBH mimicked through rotation length	piab	stem + branches	below	10% BA	50	15 25 35 45	piab	1500 (1000-2000)	2	0.35 (0.3-0.4)	na	5	the planting density is a 2-species-stand (fasy, piab), planting density for a single stand

														should be doubled, planting is delayed until beech is also planted
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	target DBH mimicked through rotation length	piab	stem	above	7.5% BA	110	10 20 30 40 50 60 70 80 90	piab	1500 (1000-2000)	2	0.35 (0.3-0.4)	na	5	the planting density is a 2-species-stand (fasy, piab), planting density for a single stand should be doubled, planting is delayed until beech is also planted
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	Same as Current Site-specific													

Table 26: Detailed FORMASAM management schedule for Kroof (beech+spruce). Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting, ***plantings are delayed until beech is also harvested to harmonize the planting dates.

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	FM20	FM21	FM22	FM23	FM24	Remarks
	1997	1999-2010	2025	2040	2055	2070	2085	2100	2101	2102	2117	...	2222	2223	2238	...											Beech part of stand, maximum age extended a bit to avoid harvesting just before the end of the simulation
		TB	TA30	TA30	TA30	TA30	TA30	TA30	H	P	TA30	TA30	H	P	TA30	TA30											
Current Generic	1997	1999-2010	2025	2040	2055	2070	2085	2100	2101	2102	2117	...	2222	2223	2238	...											Spruce part of stand, maximum age extended a bit to avoid harvesting just before the end of the simulation
		TB	TB30	TB30	TB30	TB30	TB30	TB30	H	P	TB30	TB30	H	P	TB30	TB30											
		1999-2010	2023	2033	2043	2053	2063	2064	2084	2094	2104	2114	2124	2134	2144	2154	2164	2174	2184	2185	...	2295					Beech part of stand
		TB	TA15	TA15	TA15	TA15	H	P	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	H	P	...	TA15					
Current Site-specific		1999-2010	2025	2040	2064	2074	2089	2094	2099	2104	2109	2119	2129	2139	2154	2185	...	2275									Spruce part of stand
	1997	TB	TA12.5	H	P***	TA12.5	TA12.5	TA12.5	TA12.5	TA12.5	TA12.5	TA12.5	TA12.5	TA12.5	H	P***	...	H									

Bioenergy — 1997

1999-2010	2023	2024	2044	2049	2054	2059	2064	2069	2074	2084	2094	2104	2105	...	2185	2186	...	2266	2267	...	2297	Beech part of stand
TB	H	P	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	H	P	...	H	P	...	H	P	...	TA15	

1999-2010	2020	2024	2039	2049	2059	2069	2074	2105	2120	2130	2140	2150	2155	2186	...	2236	2267	...	2292	Spruce part of stand
TB	H	P***	TB10	TB10	TB10	TB10	H	P***	TB10	TB10	TB10	TB10	H	P***	...	H	P***	...	TB10	

HWP — 1997

1999-2010	2023	2033	2043	2053	2063	2073	2074	2094	2104	2109	2114	2119	2124	2129	2134	2144	2154	2164	2174	2184	2194	2204	2205	...	Beech part of stand
TB	TA10	TA10	TA10	TA10	TA10	H	P	TA10	TA10	TA10	TA10	TA10	TA10	TA10	TA10	TA10	TA10	TA10	TA10	TA10	TA10	H	P	...	

1999-2010	2020	2030	2040	2060	2074	2084	2094	2104	2114	2124	2134	2144	2154	2164	2184	2205	...	2295	Spruce part of stand
TB	TA7.5	TA7.5	TA7.5	H	P***	TA7.5	TA7.5	TA7.5	TA7.5	TA7.5	TA7.5	TA7.5	TA7.5	TA7.5	H	P***	...	TA7.5	

7.1.5   Le-bray

Table 27: FORMASAM management guidelines for Le-bray. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	pipi	stem	below	20% BA	45	10 20 30 40	pipi	1250 (1000-14000)	1	0.2 (0.1-0.25)	na	3 (2-5)	these are the current practices (De Lary, 2015) and should be used for future regeneration. Historically, the site was seeded with 3000-5000 seedlings per ha and then cleared once or twice to reach a density of 1250/ha at 7-year old when seedlings reach the size for DBH recruitment. If a model requires to be initialised at planting for the historical simulations as well. modelers could mimic this by "planting" trees with DBH of 7.5cm and 6m height in 1978 with a density of 1250 trees/ha

No management [nosoc]	na	pipi	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	even-aged clearcut	pipi	stem	below	20% BA	45	10 20 30 40	pipi	2500	1	0.1	na	7	this is to mimic the change in managed from sowing to planting, timing of thinnings and final cut is mimicking a target-oriented harvesting schedule.
Bioenergy-flexible [rcp26socbef / rcp60socbef / rcp85socbef]	even-aged clearcut	pipi	stem+ branches+ stump	below	50% 20% 20% 20% 20% BA	45	7 12 20 30 40	pipi	2500	1	0.1	na	7	stumps only harvested after final cut, not after thinnings
Bioenergy-biomass [rcp26socbeb / rcp60socbeb / rcp85socbeb]	even-aged clearcut	pipi	stem+ branches+ stump	below	na	30	na	pipi	2500	1	0.1	na	7	stumps only harvested after final cut, not after thinnings
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	even-aged clearcut	pipi	stem	below	15% BA	60	15 30 40 50	pipi	1600	1	0.1	na	7	
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	even-aged clearcut	pipi	stem	below	30% BA	45	10 20 30 40	pipi	1250	1	0.1	na	7	

Table 28: Detailed FORMASAM management schedule for Le-bray. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	FM20	Remarks
Current generic	1986	1987-2009	2015	2016	2026	2036	2046	2056	2061	2062	2072	...	2107	2108	2118	...	2153	...	2199	...	2245	...	
		TB	H	P	TB20	TB20	TB20	TB20	H	P	TB20	TB20	H	P	TB20	TB20	H	TB20	H	TB20	H	TB20	
Current Site-specific	1986	1987-2009	2020	2021	2031	2041	2051	2061	2066	2067	2077	2087	2097	2107	2112	2113	...	2158	...	2203	...	2295	
		TB	H	P	TB20	TB20	TB20	TB20	H	P	TB20	TB20	TB20	TB20	H	P	...	H	...	H	...	H	
Bioenergy-flexible	1986	1987-2009	2020	2021	2028	2033	2041	2051	2061	2066	2067	2074	2079	2087	2097	2107	2112	2113	...	2158	...	2295	
		TB	H	P	TB50	TB20	TB20	TB20	TB20	H	P	TB50	TB20	TB20	TB20	TB20	H	P	...	H	...	H	
Bioenergy-biomass	1986	1987-2009	2020	2021	2051	2052	2082	2083	2113	2114	2144	2145	2175	2176	2206	2207	2237	2238	2268	...	2300		
		TB	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H	P	H		P		
HWP	1986	1987-2009	2020	2030	2031	2046	2061	2071	2081	2091	2092	2107	2122	2132	2142	2152	2153	...	2274	2275	...	2305	
		TB	TB15	H	P	TB15	TB15	TB15	TB15	H	P	TB15	TB15	TB15	TB15	H	P		H	P	...	TB15	
Multifunctional-Adapted	1986	1987-2009	2020	2021	2031	2041	2051	2061	2066	2067	2077	2087	2097	2107	2112	2213	...	2258	2259	...	2304		
		TB	H	P	TB30	TB30	TB30	TB30	H	P	TB30	TB30	TB30	TB30	H	P	...	H	P	...	H		

7.1.6 Peitz

Table 29: FORMASAM management guidelines for Peitz. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	pisy	stem	below	20% BA	140	15 30 45 60 75 90 105 120 135	pisy	9000 (8000-10000)	2	0.175 (0.1-0.25)	na	5	The "age when DBH is reached = 5" is an estimate
No management [nosoc]	na	pisy	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	even-aged clearcut	pisy	stem	below below above	10% 20% 20% BA	120	55 75 95	pisy	9000	2	0.175 (0.1-0.25)	na	5	regenerate as pure pisy stand
Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	even-aged clearcut	pisy	stem+ branches	below (pulp+ bioenergy)	25% BA	95	55	pisy	7000	2	0.175 (0.1-0.25)	na	5	regenerate as pure pisy stand
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	even-aged clearcut	pisy	stem	below below above above	10% BA	120	20 50 70 110	pisy	9000	2	0.175 (0.1-0.25)	na	5	regenerate as pure pisy stand
Multifunctional-Adapted [rcp26soca /	even-aged clearcut with few remaining	pisy	stem	below below above	15% BA	100	40 60 80	pisy, quro/qupe, bepe in NR	4000 (pisya) +1500 (qupe/qupo)	2	0.175 (0.1-0.25)	na	5	qupe/quro, fasy, rops, bepe allowed in NR

rcp60soca / rcp85soca]	seed trees											+1500 (bepe)					

Table 30: Detailed FORMASAM management schedule for Peitz. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting. **= some GCM data only starts in 1950, hence for future runs, you have to initialize these forests at the first time step after 1949 (i.e. 1952 for Peitz). For the historical validation runs you can start with the first available stand initialization.

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	Remarks
Current Generic	1948**	1952-2011	2026	2040	2041	2056	2071	2086	2101	...	2181	2182	2197	...				
		TB	TB20	H	P	TB20	TB20	TB20	TB20	TB20	H	P	TB20	TB20				
Current Site-specific	1948**	1952-2011	2020	2021	2076	2096	2116	2141	2142	2197	2217	2237	2262	2263	2318			
		TB	H	P	TB10	TB20	TA20	H	P	TB10	TB20	TA20	H	P	TB10			
Bioenergy	1948**	1952-2011	2020	2021	2076	2116	2117	2172	2212	2213	2268	2308						
		TB	H	P	TB25	H	P	TB25	H	P	TB25	H						
HWP	1948**	1952-2011	2020	2021	2041	2071	2091	2131	2141	2142	2162	2192	2212	2252	2262	2263	2283	
		TB	H	P	TB10	TB10	TA10	TA10	H	P	TB10	TB10	TA10	TA10	H	P	TB10	
Multifunctional-Adapted	1948**	1952-2011	2020	2021	2061	2081	2101	2121	2122	2162	2182	2202	2222	2223P	2263	2283	2303	
		TB	H	P	TB15	TB15	TA15	H	P	TB15	TB15	TA15	H	P	TB15	TB15	TA15	

7.1.7 Solling-beech

Table 31: FORMASAM management guidelines for Solling-beech. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	fasy	stem	above	30% BA	140	15 30 45 60 75 90 105 120 135	fasy	6000 (5000-7000)	2	0.6 (0.5-0.7)	na	5	The actual stand was established in 1847 from natural regeneration. Until begin of measurements in 1966, the stand was regularly thinned. All figures in table are estimates. Natural regeneration is the recommended regeneration method of stand establishment; stem count in 2014: 130
No management [nosoc]	na	fasy	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	even-aged clearcut	fasy	stem	above above above above above above above above	20% BA	120	5 10 15 20 25 30 35 50	fasy	8500 (7000-10000)	2	0.3 (0.2-0.4)	na	4	

				above above below below			65 80 95 110							
Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	even-aged clearcut	fasy	stem+ branches	below	30% BA	90	45	fasy	8500 (7000-10000)	2	0.3 (0.2-0.4)	na	4	
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	same as Current Site-specific													
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	even-aged clearcut transition to mixed forest with psme	fasy (40%) + psme (60%)	stem	above above above above above above above above below below	20% BA	90	5 10 15 20 25 30 35 50 65 80	fasy + psme	4000 (3500-4500) fasy + 6000 (5000-7000) psme	2	0.3 (0.2-0.4)	na	4	
Multifunctional-Adapted [rcp26socam / rcp60socam / rcp85socam]	even-aged clearcut transition to mixed forest with piab, bepe and soau	Fasy, piab, bepe, soau	stem	above above above above above above above above above above below below	20% BA	120	5 10 15 20 25 30 35 50 65 80 95 110	Fasy + NR 30% piab, 5% bepe, 3% soau	6200 + natural regeneration (3000 piab, 500 bepe 300 soau)	2	0.35 (0.25-0.5)	0.6	3	

Table 32: Detailed FORMASAM management schedule for Solling-beech. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	FM20	FM21	Remarks
Current Generic	1967	1968-2014	2015	2016	2031	2046	2061	2076	2091	…	2156	2157	2172	…	2297	2298								maximum age extended a bit to match local management during observed period
		TA	H	P	TA30	TA30	TA30	TA30	TA30	TA30	H	P	TA30	TA30	H	P								
Current Site-specific	1967	1968-2014	2020	2021	2026	2031	2036	2041	2046	2051	2056	2071	2086	2101	2116	2131	2141	2142	…	2262	2263	…	2298	
		TA	H	P	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TB20	TB20	H	P		H	P		TA20	
Bioenergy	1967	1968-2014	2020	2021	2066	2111	2112	2157	2202	2203	2248	2293	2294	2339										
		TA	H	P	TB30	H	P	TB30	H	P	TB30	H	P	TB30										
HWP	Same as Current Site Specific																							
Multifunctional-Adapted	1967	1968-2014	2020	2021	2026	2031	2036	2041	2046	2051	2056	2071	2086	2101	2111	2112	…	2202	2203	…	2293	…	2304	management for fasy & psme
		TA	H	P	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TB20	TB20	H	P	…	H	P	…	H	…	TA20	
Multifunctional-Adapted	1967	1968-2014	2020	2021	2026	2031	2036	2041	2046	2051	2056	2071	2086	2101	2116	2131	2141	2142	…	2262	2263	…	2298	Management for piab, fasy, bepe, soau
		TA	H	P	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TA20	TB20	TB20	H	P	…	H	P	…	TA20	

7.1.8 Solling-spruce

Table 33: FORMASAM management guidelines for Solling-spruce. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	piab	stem	below	30% BA	120	15 30 45 60 75 90 105	piab	2250 (2000-2500)	2	0.35 (0.3-0.4)	na	7	The actual stand was planted in 1891 on a former meadow. Until begin of measurements in 1966, the stand was regularly thinned. All figures in table are estimates.; stem count in 2014: 290
No management [nosoc]	na	piab	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	even-aged clearcut	piab	stem	above above above above above above above above above above above below below	15% BA	120	5 10 15 20 25 30 35 50 65 80 95 110	piab	3000 (2500-3500)	2	0.35 (0.25-0.5)	0.6	3	

Bioenergy [rcp26socbe / rcp60socbe / rcp85socbe]	even-aged clearcut	piab	stem+ branches	below	25% BA	60	30	piab	3000 (2500-3500)	2	0.35 (0.25-0.5)	0.6	3	
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	same as Current Site-specific													
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	even-aged clearcut transition to mixed forest with fasy, bepe and soau	piab, fasy, bepe, soau	stem	above above above above above above above above above below below	15% BA	120	5 10 15 20 25 30 35 50 65 80 95 110	piab + NR 12% fasy, 5% bepe, 3% soau	2400 + NR (360 fasy, 150 bepe, 90 soau)	2	0.35 (0.25-0.5)	0.6	3	

Table 34: Detailed FORMASAM management schedule for Solling-spruce. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	FM20	Remarks
Current Generic	1967	1968-2014	2024	2025	2040	2055	2070	2085	...	2145	2146	2161	...	2266	2267	...							maximum age extended a bit to match local management during observed period
		TB	H	P	TB30	TB30	TB30	TB30	TB30	H	P	TB30	TB30	H	P	TB30							
Current Site-specific	1967	1968-2014	2020	2021	2026	2031	2036	2041	2046	2051	2056	2071	2086	2101	2116	2131	2141	2142	...	2262	...	2298	
		TB	H	P	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TB15	TB15	H	P	...	H	...	TA15	
Bioenergy	1967	1968-2014	2020	2021P	2051	2081	2082	2112	2142	2143	2173	2203	2204	2234	2264	2265	2295	2325					
		TB	H	P	TB25	H	P	TB25	H	P	TB25	H	P	TB25	H	P	TB25	H					
HWP	Same as Current Site-specific																						
Multifunctional-Adapted	1967	1968-2014	2020	2021	2026	2031	2036	2041	2046	2051	2056	2071	2086	2101	2116	2131	2141	2142	...	2262	...	2298	piab, fasy, bepe, soau
		TB	H	P	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TA15	TB15	TA15	H	P	...	H	...	TA15	

7.1.9 Soro

Table 35: FORMASAM management guidelines for Soro. Grey=already covered in ISIMIP2b, green = new FORMASAM runs

Scenario	Silvicultural system	Species	Harvest type (stem / branches)	Thinning type	Intensity	Rotation length [years]	Thinning frequency	Replanting species	Planting density	Planting age [years]	Planting seedling height [m]	Planting DBH [cm]	Age when DBH is reached [years]	Remarks
Current generic ISIMIP [2005soc]	even-aged clearcut	fasy	stem	above	30% BA	140	15 30 45 60 75 90 105 120 135	fasy	6000	4	0.82	na	6	Planted in 1921, stem count in 288 ha-1 in 2010, (Wu et al. 2013)
No management [nosoc]	na	fasy	na	na	na	na	na	na	na	na	na	na	na	allow any NR of species formerly present on plot
Current Site-specific [2005socsite]	sheltercut with NR	fasy	stem	below below below below below below below below below above above above above	20% 20% 20% 20% 20% 10% 10% 10% 10% 10% 10% 10% 10% BA	140 (keep a few shelter trees until age 160, if possible)	15 20 25 30 35 45 50 60 70 80 90 105 120	fasy	6000 from NR	2	0.4	na	7	at age 70 move to Future crop tree management, models could simulate as thinning from above because all trees have similar size anyway, overall this is a strategy to manage for high quality timber (veneer)
Bioenergy [rcp26socbe /	even-aged clearcut	fasy	stem+ branches	below	20% BA	100	15 30	fasy	5000	2	0.4	na	7	

rcp60socbe / rcp85socbe]							45 60 75 90							
HWP [rcp26sochwp / rcp60sochwp / rcp85sochwp]	even-aged clearcut	fasy	stem	below below below below below below below below below above above above	20% 20% 20% 20% 20% 10% 10% 10% 10% 10% 10% 10% BA	120	15 20 25 30 35 45 50 60 70 80 90 105	fasy	6000	2	0.4	na	7	planting for quality
Multifunctional-Adapted [rcp26soca / rcp60soca / rcp85soca]	even-aged clearcut	fasy + psme	stem	below below below below below below below below below above above above above	20% 20% 20% 20% 20% 10% 10% 10% 10% 10% 10% 10% 10% BA	140	15 20 25 30 35 45 50 60 70 80 90 105 120	fasy, psme	4000 fasy, 2000 psme	fasy 2, psme 4	both 0.4	na	7	transition to mixed forest with clear-cut, Douglas-fir at age 70 move to Future crop tree management, models could simulate as thinning from above because all trees have similar size anyway

Table 36: Detailed FORMASAM management schedule for Soro. Ini = Initialization data, HM = Historic Management, FM = Future Management, TB=Thinning from below, TA = Thinning from above, H= Harvest, P=Planting. Some GCM data only starts in 1950, hence for future runs, you have to initialize these forests at the first time step after 1949 (i.e. 1950 for Soro). For the historical validation runs you can start with the first available stand initialization.

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19	FM20	FM21	Remarks
Current Generic	1944	1945-2010	2020	2035	2050	2061	2062	2077	2092	---	2202	2203	2218	...										
		TA	TA30	TA30	TA30	H	P	TA30	TA30	TA30	H	P	TA30											
Current Site-specific	1944	1945-2010	2026	2041	2061	2062	2077	2082	2087	2092	2097	2107	2112	2122	2132	2142	2152	2167	2182	2202	2203	...	2308	
		TA	TA10	TA10	H	P	TB20	TB20	TB20	TB20	TB20	TB10	TB10	TB10	TB10	TA10	TA10	TA10	TA10	H	P	...	TA10	
Bioenergy	1944	1945-2010	2021	2022	2037	2052	2067	2082	2097	2112	2122	2123	2138	2153	2168	2183	2198	2213	2223	2224	....	2314		
		TA	H	P	TB20	TB20	TB20	TB20	TB20	TB20	H	P	TB20	TB20	TB20	TB20	TB20	TB20	H	P	...	TB20		
HWP	1944	1945-2010	2026	2041	2042	2057	2062	2067	2072	2077	2087	2092	2102	2112	2122	2132	2147	2162	2163	...	2283	...	2304	
		TA	TA10	H	P	TB20	TB20	TB20	TB20	TB20	TB10	TB10	TB10	TB10	TB10	TB10	H	P	...	H	...	TB20		
Multifunctional-Adapted	1944	1945-2010	2026	2041	2061	2062	2077	2082	2087	2092	2097	2107	2112	2122	2132	2142	2152	2167	2182	2202	2203	...	2308	
		TA	TA10	TA10	H	P	TB20	TB20	TB20	TB20	TB20	TB10	TB10	TB10	TB10	TA10	TA10	TA10	TA10	H	P	...	TA10	

5

7.2 Output data

Table 37 Variables to be reported by forest models.

Variable (long name)	Variable name	Unit (NetCDF format)		Resolution	Comment
Essential outputs					
Mean DBH	**dbh-<species/total>**	cm	per species and stand total	annual	
Mean DBH of 100 highest trees	**dbhdomhei**	cm	stand total	annual	100 highest trees per hectare.
Stand Height	**hei-<species/total>**	m	per species and stand total	annual	For models including natural regeneration this variable may not make sense, please report dom_height
Dominant Height	**domhei**	m	stand total	annual	Mean height of the 100 highest trees per hectare.
Stand Density	**density-<species/total>**	ha-1	per species and stand total	annual	As trees per hectare
Basal Area	**ba-<species/total>**	m2 ha-1	per species and stand total	annual	
Volume of Dead Trees	**mort-<species/total>**	m3 ha-1	per species and stand total	annual	
Harvest by dbh-class	**harv-<species/total>-<dbhclass/total>**	m3 ha-1	per species and stand total and dbh-class	annual	
Remaining stem number after disturbance and management by dbh class	**stemno-<species/total>-<dbhclass/total>**	ha-1	per species and stand total	annual	As trees per hectare, dbhclass_name as specific in **Table 20**.

Stand Volume	**vol-\<species/total\>**	m3 ha-1	per species and stand total	annual	
Carbon Mass in Vegetation biomass	**cveg-\<species/total\>**	kg m-2	per species and stand total	annual	As kg carbon*m^{-2}
*Carbon Mass in aboveground vegetation biomass	**cvegag-\<species/total\>**	kg m-2	per species and stand total	annual	As kg carbon*m^{-2}
*Carbon Mass in belowground vegetation biomass	**cvegbg-\<species/total\>**	kg m-2	per species and stand total	annual	As kg carbon*m^{-2}
Carbon Mass in Litter Pool	**clitter-\<species/total\>**	kg m-2	per species and stand total	annual	As kg carbon*m^{-2}, Info for each individual pool.
Carbon Mass in Soil Pool	**csoil-\<species/total\>**	kg m-2	per species and stand total	annual	As kg carbon*m^{-2}, Info for each individual soil layer
Tree age by dbh class	**age-\<species/total\>-\<dbhclass/total\>**	yr	per species and stand total	annual	dbhclass_name as specified in **Table 20**.
Gross Primary Production	**gpp-\<species/total\>**	kg m-2 s-1	per species and stand total	daily	As kg carbon*m^{-2}*s^{-1}
Net Primary Production	**npp-\<species/total\>**	kg m-2 s-1	per species and stand total	daily	As kg carbon*m^{-2}*s^{-1}
Autotrophic (Plant) Respiration	**ra-\<species/total\>**	kg m-2 s-1	per species and stand total	daily	As kg carbon*m^{-2}*s^{-1}
Heterotrophic Respiration	**rh-\< total\>**	kg m-2 s-1	stand total	daily	As kg carbon*m^{-2}*s^{-1}
Net Ecosystem Exchange	**nee-\<total\>**	kg m-2 s-1	per stand	daily	As kg carbon*m^{-2}*s^{-1}
Mean Annual Increment	**mai-\<species/total\>**	m³ ha-1	per species and stand total	annual	

Fraction of absorbed photosynthetically active radiation	fapar-<species/total>	%	per species and stand total	daily	Value between 0 and 100.
Leaf Area Index	lai-<species/total>	m2 m-2	per species and stand total	monthly	
Species composition	species-<species>	%	per ha	annual (or once if static)	As % of basal area; the categories may differ from model to model, depending on their species and stand definitions.
Total Evapotranspiration	evap	kg m-2 s-1	stand total	daily	sum of transpiration, evaporation, interception and sublimation. (=intercep + esoil + trans)
Evaporation from Canopy (interception)	intercep-<species/total>	kg m-2 s-1	per species and stand total	daily	the canopy evaporation+ sublimation (if present in model).
Water Evaporation from Soil	esoil	kg m-2 s-1	per stand	daily	includes sublimation.
Transpiration	trans-<species/total>	kg m-2 s-1	per species and stand total	daily	
Soil Moisture	soilmoist	kg m-2	per stand	daily	If possible, please provide soil moisture for all depth layers (i.e. 3D-field), and indicate depth in m. Otherwise, provide soil moisture of entire column.
Optional outputs					
Removed stem numbers by size class by natural mortality	mortstemno-<species/total>-<dbhclass/total>	ha-1	per species and stand total	annual	As trees per hectare, dbhclass_name as specific in **Table 20**.
Removed stem numbers by size class by management	harvstemno-<species/total>-<dbhclass/total>	ha-1	per species and stand total	annual	As trees per hectare, dbhclass_name as specific in **Table 20**.

Volume of disturbance damage	**dist-<dist-name>**	m3 ha-1	per species and stand total	annual	dist_name as specific in **Table 20**.
Nitrogen of annual Litter	**nlit-<species/total>**	g m-2 a-1	per species and stand total	annual	As g Nitrogen m^{-2} a^{-1}
Nitrogen in Soil	**nsoil-<total>**	g m-2 a-1	stand total	annual	As g Nitrogen m^{-2} a^{-1}
Net Primary Production allocated to leaf biomass	**nppleaf-<species>**	kg m-2 s-1	per species and stand total	daily	As kg carbon$*m^{-2}*s^{-1}$
Net Primary Production allocated to fine root biomass	**npproot-<species>**	kg m-2 s-1	per species and stand total	daily	As kg carbon$*m^{-2}*s^{-1}$
Net Primary Production allocated to above ground wood biomass	**nppagwood-<species>**	kg m-2 s-1	per species and stand total	daily	As kg carbon$*m^{-2}*s^{-1}$
Net Primary Production allocated to below ground wood biomass	**nppbgwood-<species>**	kg m-2 s-1	per species and stand total	daily	As kg carbon$*m^{-2}*s^{-1}$
Root autotrophic respiration	**rr-<species/total>**	kg m-2 s-1	per species and stand total	daily	As kg carbon$*m^{-2}*s^{-1}$
Carbon Mass in Leaves	**cleaf-<species>**	kg m-2	per species and stand total	annual	
Carbon Mass in Wood	**cwood-<species>**	kg m-2	per species and stand total	annual	including sapwood and hardwood
Carbon Mass in Roots	**croot-<species>**	kg m-2	per species and stand total	annual	including fine and coarse roots
Temperature of Soil	**tsl**	K	per stand	daily	Temperature of each soil layer

Table 38 Codes for management, species, disturbance names and dbh classes as used in protocol (species, dist-name, dbhclass).

Long name	Short name
Thinning	T
Thinning from above removing XX% of Basal Area	TAXX
Thinning from below removing XX% of Basal Area	TBXX
Thinning of random individuals for structural diversity (XX of Basal Area)	TXX
Harvest	H
Planting/Regeneration	P
Natural Regeneration	NR
Fagus sylvatica	fasy
Quercus robur	quro
Quercus petraea	qupe
Pinus sylvestris	pisy
Picea abies	piab

Pinus pinaster	pipi
Larix decidua	lade
Acer platanoides	acpl
Eucalyptus globulus	eugl
Betula pendula	bepe
Betula pubescens	bepu
Robinia pseudoacacia	rops
Fraxinus excelsior	frex
Populus nigra	poni
Sorbus aucuparia	soau
Pseudotuga Menzies	psme
Quercus pubescens	qupu
Abies alba	abal
C3 grass	c3gr

hard woods	hawo
fire	fi
wind	wi
insects	ins
drought	dr
grazing	graz
diseases	dis
DBH-class_<X>-<X+5>*	dbh-c<X>
DBH-class_>140*	dbh-c140

*the boundaries of the dbh classes should be interpreted as follows: dbh-class-0-5 = 0 to<5 5 cm; dbh-class-5-10 =5 to<10 cm, etc…. the dbh class dbh-c140 includes all trees of 140cm dbh and larger.

8 Permafrost

8.1 Scenarios

The simulation scenarios for models only participating as permafrost models are described below. Assuming that for the relevant regions "other human influences" only play a minor role, i.e.
5 the regional simulations can be done as "naturalized" runs (**nosoc**). Results from permafrost modules embedded in global biomes models should be reported for the biomes model simulations specified in Section 6 and the extension beyond 2299 described below.

Since the pre-industrial simulations are an important part of the experiments, the spin-up has to finish before the pre-industrial simulations start. The spin-up should be using pre-industrial climate (**picontrol**) and year 1860 levels of "other human influences". For this reason, the pre-industrial climate data should be replicated as often as required. The precise implementation of the spin up will be model specific, the description of which will be part of the reporting process.

10 **IMPORTANT: Please contact the permafrost sector coordinators (see https://www.isimip.org/about/#contact) before starting permafrost simulations. The list of requested output variables may be added to.**

Climate & CO_2 scenarios	
picontrol	Pre-industrial climate and 286ppm CO_2 concentration. The climate data for the entire period (1661-2299) are unique – no (or little) recycling of data has taken place.
historical	Historical climate and CO_2 concentration.
rcp26	Future climate and CO_2 concentration from RCP2.6.
rcp60	Future climate and CO_2 concentration from RCP6.0.
rcp85	Future climate and CO_2 concentration from RCP8.5.
2299rcp26	Repeating climate between 2270 and 2299 for additional 200 years up to 2500 (or equilibrium if possible), CO_2 fixed at year 2299 levels.
2005co2	Fixed year 2005 CO_2 concentration.
Human influence & land-use scenarios	

nosoc	No human influences.

Table 39 ISIMIP2b scenario specification for the permafrost simulations.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299	Beyond 2299
I	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	**picontrol**	not simulated	not simulated	not simulated	not simulated
	no other human influences	Human & LU	**nosoc**				
II	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I	**historical**	**rcp26**	**rcp26**	**2299rcp26**
	no other human influences	Human & LU		**nosoc**	**nosoc**	**nosoc**	**nosoc**
IIa	RCP6.0 climate, CO$_2$ varying until 2005, then fixed at 2005 levels thereafter	Climate & CO$_2$	Experiment I	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**	**2299rcp26, 2005co2**
	no other human influences	Human & LU			**nosoc**	**nosoc**	**nosoc**
III	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	not simulated	not simulated
	no other human influences	Human & LU			**nosoc**		
IV-VII	Not simulated						
VIII	RCP8.5 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp85**	not simulated	not simulated
	no other human influences	Human & LU			**nosoc**		

8.2 Output data

Table 40 Variables to be reported by permafrost models.

Variable name (long name)	Variable name	Unit (NetCDF format)	Resolution		Comment
Essential outputs					
Temperature of Soil	**tsl**	K	per gridcell	daily (monthly)	Temperature of each soil layer. Reported as "missing" for grid cells occupied entirely by "sea". **THIS IS THE MOST IMPORTANT VARIABLE.** Also need depths in meters. Daily would be great, but otherwise monthly would work.
Pools (as Biomes output Table)					
Carbon Mass in Vegetation biomass	**cveg-<pft>**	kg m-2	per pft and gridcell total	annual	Gridcell total cveg is essential. Per PFT information is desirable.
Carbon Mass in aboveground vegetation biomass	**cvegag-<pft>**	kg m-2	per pft and gridcell total	annual	Gridcell total cvegag is essential. Per PFT information is desirable.
Carbon Mass in belowground vegetation biomass	**cvegbg-<pft>**	kg m-2	per pft and gridcell total	annual	Gridcell total cvegbg is essential. Per PFT information is desirable.
Carbon Mass in Litter Pool	**clitter**	kg m-2	per gridcell total	annual	Info for each individual pool.
Carbon Mass in Soil Pool	**csoil**	kg m-2	per gridcell total	annual	Info for each individual pool.
*Total Carbon Mass in Soil Pool	**soilc**	kg m-2	per gridcell total	annual	Integrated over the entire soil depth
Fluxes (as Biomes output Table)					

Carbon Mass Flux out of atmosphere due to Gross Primary Production on Land	**gpp**	kg m-2 s-1	gridcell total	daily (monthly)	
Carbon Mass Flux out of atmosphere due to Gross Primary Production on Land	**gpp-<pft>**	kg m-2 s-1	per pft	annual	
Carbon Mass Flux into atmosphere due to Autotrophic (Plant) Respiration on Land	**ra**	kg m-2 s-1	gridcell total	daily (monthly)	
Carbon Mass Flux out of atmosphere due to Net Primary Production on Land	**npp**	kg m-2 s-1	gridcell total	daily (monthly)	
Carbon Mass Flux out of atmosphere due to Net Primary Production on Land	**npp-<pft>**	kg m-2 s-1	per pft	annual	
Carbon Mass Flux into atmosphere due to Heterotrophic Respiration on Land	**rh**	kg m-2 s-1	gridcell total	daily (monthly)	
Carbon Mass Flux into atmosphere due to total Carbon emissions from Fire	**fireint**	kg m-2 s-1	gridcell total	daily (monthly)	
*Carbon loss due to peat burning	**somcfire**	kg m-2 s-1	gridcell total	monthly	
Carbon Mass Flux out of Atmosphere due to Net biome Production on Land (NBP)	**ecoatmflux**	kg m-2 s-1	gridcell total	daily (monthly)	This is the net mass flux of carbon between land and atmosphere calculated as photosynthesis MINUS the sum of plant and soil respiration, carbon fluxes from fire, harvest, grazing and land-use change. Positive flux is into the land.

Structure [as Biomes output Table]					
Leaf Area Index	**lai-<pft>**	1	per pft	annual	
Leaf Area Index	**lai-<pft>**	1	gridcell average	daily (monthly)	
Plant Functional Type Grid Fraction	**pft-<pft>**	%	per gridcell	annual (or once if static)	The categories may differ from model to model, depending on their PFT definitions. This may include natural PFTs, anthropogenic PFTs, bare soil, lakes, urban areas, etc.. Sum of all should equal the fraction of the grid-cell that is land.
Hydrological variables [as per Biomes output Table]					
Runoff	**qtot**	kg m-2 s-1	per gridcell	daily** (monthly)	total (surface + subsurface) runoff (qtot = qs + qsb). If daily resolution not possible, please provide monthly. If storage issues keep you from reporting daily data, please contact the ISI-MIP team to discuss potential solutions. **For those models also participating in the water simulations
Soil moisture	**soilmoist**	kg m-2	per grid cell	monthly	Please provide soil moisture for all depth layers (i.e. 3D-field), and indicate depth in m.
Frozen soil moisture for each layer	**soilmoistfroz**	kg m-2	per gridcell	monthly	Please provide frozen soil moisture for all depth levels and indicate depth in m.
Snow depth	**snd**	m	per gridcell	daily (monthly)	Grid cell mean depth of snowpack.
Snow water equivalent	**swe**	kg m-2	per gridcell	daily (monthly)	Total water mass of the snowpack (liquid or frozen), averaged over a grid cell.
Annual maximum thaw depth	**thawdepth**	m	per gridcell	annual	calculated from daily thaw depths

Other outputs					
Burnt Area Fraction	**burntarea**	%	per gridcell	daily (monthly)	fraction of entire grid cell that is covered by burnt vegetation
N_2O emissions into atmosphere	**n2o**	kg m-2 s-1	gridcell total	monthly	From land, not from industrial fossil fuel emissions and transport
CH4 emissions into atmosphere	**ch4**	kg m-2 s-1	gridcell total	monthly	From land, not from industrial fossil fuel emissions and transport

9 Agriculture (crop modelling)

9.1 Scenarios

Crop-model simulations should be provided as pure crop runs (i.e. assuming that each crop grows everywhere), so that future LU patterns can be applied in post-processing ensuring maximum flexibility. Simulations should be provided for the four major crops (wheat, maize, soy, and rice). For each crop there should be a full irrigation run (firr) and a no-irrigation run (noirr).

Those models that cannot simulate time varying management/human impacts/fertilizer input should keep these fixed at year 2005 levels throughout the simulations ("2005soc" scenario in Group 1 (dashed line in **Figure 1**) and "2005soc" scenario in Group 2). They only need to run the first preindustrial period of Experiment I (1661-1860). Group 3 runs only refer to models that are able to represent future changes in human management (varying crop varieties or fertilizer input).

To resolve potential double harvests within one year, crop yields should be reported per growing and not per calendar year. The unit of the time dimension of the NetCDF v4 output file is thus "growing seasons since YYYY-01-01 00:00:00". Cumulative growing season variables as, e.g., actual evapotranspiration or precipitation are to be accumulated over the growing season. The first season in the file (with value time=1) is then the first complete growing season of the time period provided by the input data without any assumed spin-up data, which equates to the growing season with the first planting after this date. To ensure that data can be matched to individual years in post-processing, it is essential to also provide the actual planting dates (as day of the year), actual planting years (year), anthesis dates (as day of the year), year of anthesis (year), maturity dates (day of the year), and year of maturity (year). This procedure is identical to the GGCMI convention (Elliott et al. 2015: The Global Gridded Crop Model intercomparison: data and modeling protocols for Phase 1).

Climate & CO_2 scenarios	
picontrol	Pre-industrial climate and 286ppm CO_2 concentration. The climate data for the entire period (1661-2299) are unique – no (or little) recycling of data has taken place.
historical	Historical climate and CO_2 concentration.
rcp26	Future climate and CO_2 concentration from RCP2.6.
rcp60	Future climate and CO_2 concentration from RCP6.0.
rcp85	Future climate and CO_2 concentration from RCP8.5.
2005co2	Fixed year 2005 levels of CO_2 at 378.81ppm.
Human influence & land-use scenarios	
1860soc	Pre-industrial levels of fertilizer input.

			Pre-industrial	Historical	Future	Extended future
	Experiment	**Input**	**1661-1860**	**1861-2005**	**2006-2099**	**2100-2299**
I	no climate change, pre-industrial CO_2	Climate & CO_2	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	varying management until 2005, then fixed at 2005 levels thereafter	Human & LU	Option 1*: **1860soc**	Option 1*: **histsoc**	**2005soc**	**2005soc**
			Option 2*: **2005soc**	Option 2*: **2005soc****	**2005soc****	**2005soc****
II	RCP2.6 climate & CO_2	Climate & CO_2	Experiment I	**historical**	**rcp26**	**rcp26**
	varying management until 2005, then fixed at 2005 levels thereafter	Human & LU		Option 1*: **histsoc**	**2005soc**	**2005soc**
				Option 2*: **2005soc**		
IIa	RCP2.6 climate, CO_2 after 2005 fixed at 2005 levels	Climate	Experiment I	Experiment II	**rcp26, 2005co2**	**rcp26, 2005co2**
	varying management until 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	**2005soc**

histsoc	Varying historical fertilizer input.
2005soc	Fixed year 2005 management
rcp26soc	Varying level of fertilizer input and varying varieties of the same crop associated with SSP2 and RCP2.6
rcp60soc	Varying level of fertilizer input and varying varieties of the same crop associated with SSP2 and RCP6.0
2100rcp26soc	Fertilizer input and varieties of the same crop fixed at year 2100.

Table 41 ISIMIP2b scenarios for global crop simulations. *Option 2 only if option 1 not possible. **If you can only run simulations with 2005soc, then it is sufficient 200 years worth of picontrol climate (1661-1860).

III	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	not simulated
	varying management until 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	
IV	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	Experiment I	Experiment I	**picontrol**	**picontrol**
	varying management up to 2100 (RCP2.6), then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**
V	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	Experiment I	Experiment I	**picontrol**	not simulated
	varying management (RCP6.0)	Human & LU			**rcp60soc**	
VI	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp26**	**rcp26**
	varying management up to 2100 (RCP2.6), then fixed at 2100 levels thereafter	Human & LU			**rcp26soc**	**2100rcp26soc**
VII	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	
	varying management (RCP6.0)	Human & LU			**rcp60soc**	
VIII	RCP8.5 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp85**	not simulated
	management fixed at 2005 levels	Human & LU			**2005soc**	

9.2 Output data

Table 42 Variables to be reported by crop models

Variable (long name)	Variable name	Unit (NetCDF format)	Resolution	Comments
Key model outputs				
Crop yields	yield-<crop>-<irrigation setting>	dry matter (t ha-1 per growing season)	per growing season (0.5°x0.5°)	
Irrigation water withdrawal (assuming unlimited water supply)	pirrw-<crop>-<irrigation setting>	mm per growing season	per growing season (0.5°x0.5°)	*Irrigation water withdrawn in case of optimal irrigation (in addition to rainfall), assuming no losses in conveyance and application.*
Key diagnostic variables				
Actual evapotranspiration	aet-<crop>-<irrigation setting>	mm per growing season	per growing season (0.5°x0.5°)	portion of all water (including rain) that is evapo-transpired, the water amount should be accumulated over the entire growing period (**not** the calendar year)
Nitrogen application rate	initr-<crop>-<irrigation setting>	kg ha-1 per growing season	per growing season (0.5°x0.5°)	Total nitrogen application rate. If organic and inorganic amendments are applied, rate should be reported as inorganic nitrogen equivalent (ignoring residues).
Actual planting dates	plantday-<crop>-<irrigation setting>	Day of year	per growing season (0.5°x0.5°)	Julian dates
Actual planting year	plantyear-<crop>-<irrigation setting>	Year of planting	per growing season (0.5°x0.5°)	Attention: This is an additional output compared to the ISIMIP2a reporting. It allows for clear identification of planting that is also easy to follow for potential users from outside the project.

Anthesis dates	anthday-<crop>-<irrigation setting>	Day of year of anthesis	per growing season (0.5°x0.5°)	Attention: This has changed compared to the ISIMIP2a reporting where we asked for the "day from planting date". Together with the year of anthesis added to the list of outputs (see below) it allows for clear identification of anthesis that is also easy to follow for potential users from outside the project.
Year of anthesis	anthyear-<crop>-<irrigation setting>	year of anthesis	per growing season (0.5°x0.5°)	Attention: This is an additional output compared to the ISIMIP2a reporting. It allows for clear identification of anthesis that is also easy to follow for potential users from outside the project.
Maturity dates	matyday-<crop>-<irrigation setting>	Day of year of maturity	per growing season (0.5°x0.5°)	Attention: This has changed compared to the ISIMIP2a reporting where we asked for the "day from planting date". Together with the year of maturity added to the list of outputs (see below) it allows for clear identification of maturity that is also easy to follow for potential users from outside the project.
Year of maturity	matyyear-<crop>-<irrigation setting>	year of maturity	per growing season (0.5°x0.5°)	Attention: This is an additional output compared to the ISIMIP2a reporting. It allows for clear identification of maturity that is also easy to follow for potential users from outside the project.
Additional output variables (optional)				
Biomass yields	biom-<crop>-<irrigation setting>	Dry matter (t ha-1 per growing season)	per growing season (0.5°x0.5°)	
Soil carbon emissions	sco2-<crop>-<irrigation setting>	kg C ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.

Nitrous oxide emissions	sn2o-<crop>-<irrigation setting>	kg N2O-N ha-1	per growing season (0.5°x0.5°)	Ideally should be modeled with realistic land-use history and initial carbon pools. Subject to extra study.
Total N uptake (total growing season sum)	tnup-<crop>-<irrigation setting>	kg ha -1 yr -1	monthly (0.5°x0.5°)	Nitrogen balance: uptake
Total N inputs (total growing season sum)	tnin-<crop>-<irrigation setting>	kg ha -1 yr -1	monthly (0.5°x0.5°)	Nitrogen balance: inputs
Total N losses (total growing season sum)	tnloss-<crop>-<irrigation setting>	kg ha -1 yr -1	monthly (0.5°x0.5°)	Nitrogen balance: losses

10 Energy

The Energy protocol has been removed temporarily, since it was outdated. It will be replaced by an updated version shortly.

11 Health (Temperature-related mortality)

11.1 Scenarios

The following protocol has been designed for contributions on temperature-related mortality (TRM). There are no restrictions regarding the type of empirical models (GAMs, DLNMs, log-linear, simple exponential etc.) to be used as long as the methodology has been documented in previous peer-reviewed publications. It also does not matter at which spatial scale the model operates (city-scale, regional, national, global), with the possible restrictions stemming from the input data provided.

Group 3 runs (experiments IV to VII) only refer to models that are able to represent future changes in societal conditions (demographic changes, shifts in mortality baselines, adaptation/acclimatization).

Climate	
picontrol	Pre-industrial climate (year specific for the entire period 1661-2299).
historical	Historical climate.
rcp26	Future climate from RCP2.6.
rcp60	Future climate from RCP6.0.
rcp85	Future climate from RCP8.5.
Human influence	
2005soc	Representation of fixed year 2005 society: • Present-day exposure-response functions • Present-day mortality baselines (average from observational records, or from grid based 2005 mortality data (SSP2) • 2005 population data from your observational records, or from ISIMIP grid based population data (SSP2)
ssp2soc	Varying society according to SSP2 – no adaptation • Present-day exposure-response functions • Mortality baselines according to SSP2[a] • Population data according to SSP2[b]

2100ssp2soc	Society in 2100 according to SSP2 – no adaptation
	• As ssp2soc but mortality and population data fixed at 2100 levels
ssp2soc-adapt	Varying society according to SSP2 – with adaptation
	• changing exposure-response relationships according to default adaptation assumptions[c] • mortality baselines and population according to SSP2

[a] It is also possible to neglect shifts in mortality baselines and only consider population shifts in this experiment; if changes in mortality baselines are accounted for, scaling from SSP2 national projections to city-scale/regional scale should be done as for population data (see [b])

[b] Use grid-based or national population data for 2005-2100 in 5-year intervals for 5-year age groups (0-4,5-9,…,100+), split between urban and rural population from SSP database. For mortality models working on city scale, projected national urban population growth rates should be applied to 2005 city populations (assuming that city-scale projections scale directly to nation-scale projections)

[c] Uncertainty on acclimatization/adaptation is large. Based on your available data choose the most plausible approach to incorporate acclimatization into your exposure-response functions (e.g., shift MMT, shift slope); this approach will have to be documented in detail

Additional Notes:

Definition of attributable mortality: Where applicable attributable mortality should be defined as e.g., in Gasparrini & Leone (2014); Here attributable refers to mortality attributable to excursion of ambient temperature from MMT.

Definition of climate change impacts: Additional deaths due to climate change will be derived as the difference between attributable mortality estimates based on the pre-industrial control (picontrol) and climate change scenario runs (rcp26, rcp60) or as difference between present-day reference (2010-2019) and future decades.

Local bias-correction of climate time-series: For TRM models working on a point scale (e.g., city scale) or small regional scale, a downscaling and bias correction to the local observational climate time-series will be undertaken (using ISIMIP2b bias-correction method). Other support regarding preparation of climate input data (aggregation to specific regions, conversion from netcdf to txt etc.) might be provided on demand.

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Table 43 ISIMIP2b scenarios for temperature-related mortality simulations. Option 2* only if option 1 not possible.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299
I	no climate change	Climate	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	varying society up to 2005, then fixed at 2005 levels thereafter, no adaptation	Human	Option 1: **1860soc**	Option 1: **histsoc**	**2005soc**	**2005soc**
	society fixed at 2005 levels, no adaptation		Option 2*: **2005soc**	Option 2*: **2005soc**		
II	RCP2.6 climate	Climate	Experiment I	**historical**	**rcp26**	**rcp26**
	varying society up to 2005, then fixed at 2005 levels thereafter, no adaptation	Human		Option 1*: **histsoc**	**2005soc**	**2005soc**
	society fixed at 2005 levels, no adaptation			Option 2*: **2005soc**		
III	RCP6.0 climate	Climate	Experiment I	Experiment II	**rcp60**	not simulated
	society fixed at 2005 levels, no adaptation	Human			**2005soc**	
IV	no climate change	Climate	Experiment I	Experiment II	**picontrol**	**picontrol**
	varying society (SSP2) up to 2100, then fixed at 2100 levels thereafter, no adaptation	Human			**ssp2soc**	**2100ssp2soc**
V	Not simulated					

VI	RCP2.6 climate	Climate	Experiment I	Experiment II	**rcp26**	**rcp26**
	varying society (SSP2) up to 2100, then fixed at 2100 levels thereafter, no adaptation	Human			**ssp2soc**	**2100ssp2soc**
VIa	RCP2.6 climate	Climate	Experiment I	Experiment II	**rcp26**	not simulated
	varying society (SSP2) with adaptation	Human			**ssp2soc-adapt**	
VII	RCP6.0 climate	Climate	Experiment I	Experiment II	**rcp60**	not simulated
	varying society (SSP2), no adaptation	Human			**ssp2soc**	
VIIa	RCP6.0 climate	Climate	Experiment I	Experiment II	**rcp60**	not simulated
	varying society (SSP2), with adaptation	Human			**ssp2soc-adapt**	
VIII	RCP8.5 climate	Climate	Experiment I	Experiment II	**rcp85**	not simulated
	society fixed at 2005 levels, no adaptation	Human			**2005soc**	

11.2 Output data

Table 44 *Variables to be reported by TRM models*

Note: The variable name should specify the age group x for which mortality estimates are supplied:

x = -all, -65minus, -65plus, etc.

Variable (long name)	Variable name	Unit (NetCDF format)	Spatial resolution	Temporal resolution	Comments

Number of deaths attributable to cold in age group x	**an-tot-cold-x**	Total number of deaths	Per city/region/grid cell	daily	Temperature below minimum mortality temperature (MMT)
Number of deaths attributable to heat in age group x	**an-tot-heat-x**	Total number of deaths	Per city/region/grid cell	daily	Temperature above MMT
Death rate attributable to cold in age group x	**an-rate-cold-x**	Deaths per 100 000 population	Per city/region/grid cell	daily	Temperature below MMT
Death rate attributable to heat in age group x	**an-rate-heat-x**	Deaths per 100 000 population	Per city/region/grid cell	daily	Temperature above MMT
Attributable fraction (cold) in age group x	**af-cold-x**	%	Per city/region/grid cell	daily	Temperature below MMT
Attributable fraction (heat) in age group x	**af-heat-x**	%	Per city/region/grid cell	daily	Temperature above MMT

12 Coastal Systems

12.1 Scenarios

Climate change affects coastal systems through rising mean and extreme sea levels, causing damages through temporary flooding and losses due to permanent submergence of land. To assess these impacts, climate scenarios have to be complemented by sea-level-rise projections. While the information about thermal expansion and dynamical changes of sea level is provided by the four GCMs considered, contributions from mountain glaciers and ice sheets have to be added from other sources, which introduces a further dimension of uncertainty (see section 5). The uncertainty range introduced is substantial and a least on equal footing with the climate model and scenario uncertainty (e.g. Kopp et al. 2014). To reflect this aspect we include an additional scenario dimension in the scenario design for this sector and sample this by providing projections for the median and 5th and 95th percentiles of the contributions from ice sheets and mountain glaciers to sea-level rise. One aspect specific to the coastal-systems sector is that impacts are extremely non-linear in and sensitive to adaptation. Impacts without adaptation are 2-3 orders of magnitudes higher than those with adaptation (Hinkel et al. 2014). This leads to the circumstance that the regions with the highest infrastructure damages under the scenarios without adaptation are actually the regions least vulnerable to sea-level rise, because it is highly cost-efficient and standard practise to protect those regions against sea-level rise. Scenarios including adaptation are therefore added to the protocol to provide projections of climate change risks including adaptation potentials.

Those models that do not account for varying societal conditions (population, GDP, protection levels etc.) should keep these fixed at year 2005 levels throughout the simulations (**2005soc** scenario in Group 1 (dashed line in Figure 1 a) + **rcp26soc** or **rcp60soc** scenario in Group 2). They only need to run the first pre-industrial period of Experiment I (1661-1860). Group 3 runs only refer to models that are able to represent future changes in societal conditions.

Climate & CO$_2$ scenarios	
picontrol	Pre-industrial climate (year specific for the entire period 1661-2299).
historical	Historical climate and CO$_2$ concentration.
rcp26	Future climate and CO$_2$ concentration from RCP2.6.
rcp60	Future climate and CO$_2$ concentration from RCP6.0.
rcp85	Future climate and CO$_2$ concentration from RCP8.5.
Human influence & land-use scenarios	
1860soc	Pre-industrial society and protection.
2005soc	Representation of fixed year 2005 society and protection.

ssp2soc			Varying society and protection according to SSP2.			
2100ssp2soc			Representation of fixed year 2100 society and protection according to SSP2.			

Table 45 ISIMIP2b scenario specification for the simulations of impacts on coastal systems.

	Experiment	**Input**	**Pre-industrial** **1661-1860**	**Historical** **1861-2005**	**Future** **2006-2099**	**Extended future** **2100-2299**
I	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	varying society & protection up to 2005, then fixed at 2005 levels thereafter	Human & LU	Option 1:**1860soc** Option 2*: **2005soc**	Option 1: **histsoc** Option 2*: **2005soc**	**2005soc**	**2005soc**
II	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I	**historical**	**rcp26**	**rcp26**
	varying society & protection up to 2005, then fixed at 2005 levels thereafter	Human & LU		Option 1*: **histsoc** Option 2*: **2005soc**	**2005soc**	**2005soc**
III	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	**rcp60**	not simulated
	varying society & protection up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	
IV	no climate change, pre-industrial CO$_2$	Climate & CO$_2$	Experiment I	Experiment I	**picontrol**	**picontrol**
	varying society & protection up to 2100 (SSP2), then fixed at 2100 levels thereafter	Human & LU			**ssp2soc**	**2100ssp2soc**

VI	RCP2.6 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	rcp26	rcp26
	varying society & protection up to 2100 (SSP2), then fixed at 2100 levels thereafter	Human & LU			ssp2soc	2100ssp2soc
VII	RCP6.0 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	rcp60	not simulated
	varying society & protection (SSP2)	Human & LU			ssp2soc	
VIII	RCP8.5 climate & CO$_2$	Climate & CO$_2$	Experiment I	Experiment II	rcp85	not simulated
	varying society & protection up to 2005, then fixed at 2005 levels thereafter	Human & LU			2005soc	

12.2 Output data

Table 46 Variables to be reported by coastal-systems models.

Variable (long name)	Variable name	Unit (NetCDF format)	Resolution	Comments
Expected number of people flooded annually	**par**	thousands/yr (1000 yr-1)	Time resolved grid	Par = People at risk.
Expected seaflood costs	**seafloodcost**	million dollars/yr (mio 2005US$ yr-1)		Expected annual damage caused by seafloods
Adaptation costs of building and upgrading dikes	**seadikecost**	million dollars/yr (mio 2005US$ yr-1)		Cost for building/upgrading dikes

Adaptation costs of maintaining dikes	**seadikemain**	million dollars/yr (mio 2005US$ yr-1)		Cost for maintenance of dikes build since the initial year (2000), but not cost for dikes "build" in the initialization of the model.

13 Fisheries and Marine Ecosystems

13.1 Scenarios

The fisheries and marine ecosystem models are quite diverse. Most include climate-impact models via ESM-simulated primary-production changes, and many also include impacts of changes in water temperature on ectotherm metabolic rates. A very small subset of the models includes ocean-acidification effects. Most models include fishing, either as an imposed process based on observed historical fishing effort (which start in 1950), or as an endogenous process based on simple economic factors.

Fishing effort should be held at constant 1950 levels from 1861-1950. It should then follow the standard historical reconstruction from 1950-2006 typically used by the model, using reconstructed effort or economic forcings as appropriate. Effective effort should be held constant following 2005 in all simulations. For models that include acidification effects, all simulations should include ocean acidification in accordance with the respective climate scenario.

Climate scenarios	
picontrol	Pre-industrial climate and 286ppm CO_2 concentration. The climate data for the entire period (1661-2299) are unique – no (or little) recycling of data has taken place.
historical	Historical climate and CO_2 concentration.
rcp26	Future climate and CO_2 concentration from RCP2.6.
rcp60	Future climate and CO_2 concentration from RCP6.0.
rcp85	Future climate and CO_2 concentration from RCP8.5.
Human influences scenarios	
nosoc	No fishing.
histsoc	Historical reconstruction of fishing starting in 1950.
2005soc	Fishing fixed at year 2005 levels.

Table 47 ISIMIP2b scenarios for simulations of the impacts on marine ecosystems and fisheries.

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299
I	no climate change, pre-industrial CO_2	Climate & CO_2	not simulated	**picontrol**	**picontrol**	**picontrol**
	varying fishing up to 2005, then fixed at 2005 levels thereafter	Human & LU		**histsoc**	**2005soc**	**2005soc**
II	RCP2.6 climate & CO_2	Climate & CO_2	not simulated	**historical**	**rcp26**	**rcp26**
	varying fishing up to 2005, then fixed at 2005 levels thereafter	Human & LU		**histsoc**	**2005soc**	**2005soc**
III	RCP6.0 climate & CO_2	Climate & CO_2	not simulated	Experiment II	**rcp60**	not simulated
	varying fishing up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	
IV-VII	not simulated					
VIII	RCP8.5 climate & CO_2	Climate & CO_2	not simulated	Experiment II	**rcp85**	not simulated
	varying fishing up to 2005, then fixed at 2005 levels thereafter	Human & LU			**2005soc**	

Table 48 Additional sector-specific simulations for the fisheries and marine ecosystems sector

	Experiment	Input	Pre-industrial 1661-1860	Historical 1861-2005	Future 2006-2099	Extended future 2100-2299

Ia	no climate change, pre-industrial CO_2	Climate & CO_2	not simulated	**picontrol**	**picontrol**	not simulated
	no fishing	Human & LU		**nosoc**	**nosoc**	
Ib	NPP control. All forcings except NPP at pre-industrial levels.	Climate & CO_2	not simulated	**npp-control**	**npp-control**	not simulated
	No fishing	Human & LU		**nosoc**	**nosoc**	
Ic	Temperature control. All forcings except NPP at pre-industrial levels.	Climate & CO_2	not simulated	**temperature-control**	**temperature-control**	not simulated
	no fishing	Human & LU		**nosoc**	**nosoc**	
VIIIa	RCP8.5 climate & CO2	Climate & CO_2	not simulated	**historical**	**rcp85**	not simulated
	no fishing	Human & LU		**nosoc**	**nosoc**	

13.2 Output data

Table 49 Common output variables to be provided by global and regional marine fisheries models.

Variable name (long name)	Variable name	Unit (NetCDF format)	Resolution	Comments
Essential outputs from global and regional models (provide as many as possible)				
TOTAL system biomass density	**tsb**	g C m-2	monthly	all primary producers and consumers
TOTAL consumer biomass density	**tcb**	g C m-2	monthly	all consumers (trophic level >1, vertebrates and invertebrates)

Biomass density of consumers >10cm	**b10cm**	g C m-2	monthly	if L infinity is >10 cm, include in >10 cm class
Biomass density of consumers >30cm	**b30cm**	g C m-2	Monthly	if L infinity is >30 cm, include in >30 cm class
TOTAL Catch (all commercial functional groups / size classes) where fishing included in model	**tc**	g wet biomass / m2, g m-2	monthly	catch at sea (commercial landings plus discards, fish and invertebrates)
TOTAL Landings (all commercial functional groups / size classes) where fishing included in model	**tla**	g wet biomass / m2, g m-2	monthly	commercial landings (catch without discards, fish and invertebrates)
Optional output from global and regional models				
Biomass density of commercial species where fishing included in model	**bcom**	g C m-2	monthly	Discarded species not included (Fish and invertebrates)
Biomass density (by functional group / size class) where fishing included in model	**b-<class>-<group>**	g C m-2	monthly	Provide name of each size class (<class>) and functional group (<group>) used, and provide a definition of each class/group
Catch (by functional group / size class) where fishing included in model	**c-<class>-<group>**	g wet biomass / m2,g m-2	monthly	Provide name of each size class (<class>) and functional group (<group>) used, and provide a definition of each class/group

14 Terrestrial biodiversity

The following protocol describes the contribution of global terrestrial biodiversity models to ISIMIP2b. Biodiversity is influenced by both climate and land-use change, as well as the biome changes resulting from these drivers. All of these drivers will be considered in terrestrial biodiversity simulations.

Different model types may be used to simulate terrestrial biodiversity, such as correlative species distribution models (SDMs), macroecological species-richness models (MEMs), process-based
5 biodiversity models, and others. There are no restrictions regarding the model type, as long as the methodology has been documented in previous peer-reviewed publications.

In its initial stage, this protocol focuses on correlative SDMs and MEMs; it will be amended with the needs and requirements of other model types as required.

Species distribution models are used to identify the potential climatic niche of a species and so allow to predict a species' probability of occurrence under present and future climatic conditions. Running these models for multiple species, one can aggregate the individual occurrence probabilities to a summed probability of occurrence (a proxy of species richness).

Species distribution data, in combination with the observed climate dataset "EWEMBI" provided by ISIMIP, are used for the initial model construction (i.e., model calibration). Biodiversity
10 projections are then calculated using the ISIMIP2b bias-corrected GCM data.

The effects of biome and land-use changes on biodiversity are currently not considered. In the future, biome and land-use changes may be directly used as predictor variables during model construction.

14.1 Scenarios

Climate scenarios	
picontrol	Pre-industrial climate (year specific for the entire period 1661-2299).
historical	Historical climate.
rcp26	Future climate from RCP2.6.
rcp60	Future climate from RCP6.0.
rcp85	Future climate from RCP8.5.
Human influences scenarios	
nosoc	No human influences considered.

Table 50* ISIMIP2b scenarios for global (and potentially regional) terrestrial biodiversity simulations.

	Experiment	Input	Pre-industrial 1660-1860	Historical 1861-2005[1]	Future 2006-2099[2]	Extended future 2101-2299[3]
I	pre-industrial climate	Climate	**picontrol**	**picontrol**	**picontrol**	**picontrol**
	no other human influences	Human & LU	**nosoc**	**nosoc**	**nosoc**	**nosoc**
II	RCP2.6 climate	Climate	Experiment I	**historical**	**rcp26**	**rcp26**
	no other human influences	Human & LU		**nosoc**	**nosoc**	**nosoc**
III	RCP6.0 climate	Climate	Experiment I	Experiment II	**rcp60**	not simulated
	no other human influences	Human & LU			**nosoc**	
IV-VII	not simulated					
VIII	RCP8.5 climate	Climate	Experiment I	Experiment II	**rcp85**	not simulated
	no other human influences	Human & LU			**nosoc**	

* For now, only correlative species distribution models are considered. Additional scenario combinations will be contributed from other model types in due time.

[1] For the Terrestrial biodiversity sector, "historical" refers to a 30-year period of current conditions (i.e., 1976-2005).

[2] Within these long-term time periods, biodiversity models will be run for average conditions of selected 30-year periods (2006-2035, 2036-2065, 2066-2095)and the 30-year periods centered around the 1.5°C GCM-specific Global Mean Temperature (GMT) thresholds (1996-2025, 2012-2041, 2018-2047, 2034-2063, 2038-2067, 2042-2071) provided by ISIMIP (https://www.isimip.org/protocol/temperature-thresholds-and-time-slices/) are considered.

[3] Within this extended-future time period, biodiversity models will be run for average conditions of selected 30-year periods (2086-2115, 2136-2165, 2186-2215, 2236-2265).

5

14.2 Output data

Table 51 Output variables to be reported by terrestrial biodiversity sector models.

Variable (long name)	Variable name	Unit (NetCDF format)	Resolution	Comments
Amphibian species probability of occurrence	**amphibianprob**	Probability of occurrence per cell[2]	30-year averages of selected time periods[1] (0.5°x0.5°)	Results from individual SDMs assuming full dispersal[3]
Terrestrial bird species probability of occurrence	**birdprob**			
Terrestrial mammal species probability of occurrence	**mammalprob**			
Amphibian summed probability of occurrence	**amphibiansumprob**	Summed probability of occurrence per cell[2]	30-year averages of selected time periods[1] (0.5°x0.5°)	Aggregated results from individual SDMs with different dispersal scenarios[4]
Terrestrial bird summed probability of occurrence	**birdsumprob**			
Terrestrial mammal summed probability of occurrence	**mammalsumprob**			
Summed probability of endemic amphibian species[5]	**endamphibiansumprob**			

		Estimated number of species (species richness) per cell	30-year averages of selected time periods[1] (0.5°x0.5°)	Results from macroecological richness models
Summed probability of endemic terrestrial bird species[5]	**endbirdsumprob**			
Summed probability of endemic terrestrial mammal species[5]	**endmammalsumprob**			
Summed probability of threatened amphibian species[6]	**thramphibiansumprob**			
Summed probability of threatened terrestrial bird species[6]	**thrbirdsumprob**			
Summed probability of threatened terrestrial mammal species[6]	**thrmammalsumprob**			
Amphibian species richness	**amphibiansr**			
Terrestrial bird species richness	**birdsr**			
Terrestrial mammal species richness	**mammalsr**			

[1] Currently the following 30-year periods (2006-2035, 2036-2065, 2066-2095, 2086-2115, 2136-2165) and the 30-year periods centered around the 1.5°C GCM-specific Global Mean Temperature (GMT) thresholds (1996-2025, 2012-2041, 2018-2047, 2034-2063, 2038-2067, 2042-2071) provided by ISIMIP (https://www.isimip.org/protocol/temperature-thresholds-and-time-slices/) are considered.

[2]For the Maximum Entropy (MaxEnt) model algorithm the output is not probability, but habitat suitability/relative occurrence probability. Values also range between 0 and 1.

5 [3] Probability of occurrence is projected to the currently present and all neighbouring realms of a species and so sort of represents the unlimited dispersal of a species into the future.

[4] Summed probability of occurrence is calculated for different dispersal scenarios (no dispersal, 0.5*d, 1*d, 2*d, full dispersal). Full dispersal represents the sum of the probability of occurrence output files. No dispersal assumes that species can only be present where they are actually present according to the IUCN and BirdLife range maps. The other three dispersal scenarios consider species-specific dispersal buffers added to the present range, where **d** is the largest diameter of the original range of the species.

[5] Endemic (range-restricted) species are the smallest ranging 15% of all species.

10 [6] Threatened species are all species that are (i) either critically endangered, (ii) endangered or (iii) vulnerable according to their IUCN red list status.

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