8 Regional forests

A number of sites has been selected in the COST Action PROFOUND for which a wide range of forest models can be rather easily initialized. To get access to this PROFOUND Database, please contact reyer@pik-potsdam.de.

1) **Management:** The modeling experiments mostly encompass managed forests. The standard management ("histsoc") during the historical period is the observed management as defined by the data available for each site (e.g. reduction in stem numbers) and, after the observations end, missing management information is to be substituted with generic future management guidelines from Table 16-Table 18. This future management (2005soc) corresponds best to "intensive even-aged forestry" as defined by Duncker et al. 2012. After harvesting the stands (c.f. Table 16 and Table 17), 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. A "natural reference run (nosoc)" without any management will help assessing the influence of forest management. Additionally, site-specific, future management guidelines are presented in **Table 19**.

2) **Calibration:** Some of the 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the model calibration or development is driven by an improvement of the model after a comparison to data that were originally made available in ISIMIP for model evaluation, a part of those data should be kept aside for model evaluation and not used for calibration.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.

8.1 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 17**).
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 17**).
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**).
rcp26soc	Future forests are assumed to be managed towards maximizing mitigation benefits (e.g. by changing the tree species or the silvicultural regime). Depending on the region and forest stand, this could mean focusing on species and management measures to maximize (1) the production of wood for bioenergy (highly productive species, short rotations), (2) high in situ carbon stocks, or (3) production of harvested wood products with a long lifetime (sawntimber, veneer…). Specific scenarios to be defined in the FORMASAM project.
rcp60soc	Future forest are assumed to require adaptive management (such as "assisted migration" or reduction of disturbance damage) where present-day forests are managed according to current practices until final harvest and then new, more adapted forests are established (e.g. with management focusing on increasing the stability of the stand or on replacing tree species that would be the natural vegetation under the projected climate change according to

	Hanewinkel et al. (2012)). Specific scenarios to be defined in the FORMASAM project.
2100rcp26soc	This scenario means managing future forests according to rcp26soc guidelines.
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.

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**
II	RCP2.6 climate & CO_2	Climate & CO_2	not simulated	**historical**	**rcp26**	**rcp26**
	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 (forest management for mitigation)	Human & LU			**rcp26soc**	**2100rcp26soc**
V	no climate change, pre-industrial CO_2	Climate & CO_2	not simulated	Experiment I	**picontrol**	
	varying management (forest management for adaptation)	Human & LU			**rcp60soc**	
VI	RCP2.6 climate & CO_2	Climate & CO_2	not simulated	Experiment II	**rcp26**	**rcp26**
	varying management (forest management for mitigation)	Human & LU			**rcp26soc**	**2100rcp26soc**
VII	RCP6.0 climate & CO_2	Climate & CO_2	not simulated	Experiment II	**rcp60**	
	varying management (forest management for adaptation)	Human & LU			**rcp60soc**	
VIII	RCP8.5 climate & CO_2	Climate & CO_2	Experiment I	Experiment II	**rcp85**	not simulated
	varying management (forest management for adaptation)	Human & LU			**2005soc**	
IX	Optional: RCP6.0 climate & CO_2 with **improved bias-correction and statistical downscaling** of climate variables (ewembi-	Climate & CO_2	**picontrol**	**historical**	**rcp60**	not simulated

	improved)					
	fixed present-day management	Human & LU	**1860soc**	**histsoc**	**2005soc**	

The regional forest simulations as described above are carried out once using the ISIMIP2b climate of the grid cell in which the forest sites are located and once using locally bias-adjusted data based on locally observed meteorological data.

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**
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**
IIIa	RCP6.0 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	Experiment I	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	RCP8.5 climate, CO_2 after 2005 fixed at 2005 levels	Climate & CO_2	Experiment I	Experiment II	**rcp85, 2005co2**	not simulated
	LU & human influences fixed at 1860 levels	Human & LU			**2005soc**	
IVa	no climate change, pre-industrial CO_2	Climate & CO_2	not simulated	Experiment I	**picontrol**	**picontrol**
	varying management (forest management for mitigation)	Human & LU			**nosoc**	**nosoc**

Table 18 Generic future management scenarios for the different tree species. For past simulations and depending on the model, modellers should use the observed stem numbers from the time series of stand and tree level data to mimick stand management. Future management should then be added according to the generic management guidelines outlined below. E.g., The last management for the Peitz site can be infered from the tree data is taking place in 2011, hence the next management would then happen in 2026 according to **Table 17**.

Species	Thinning regime	Intensity [% of basal area]	Interval [yr]	Stand age for final harvest	Remarks
pisy	below	20	15	140	Pukkala et al. 1998; Fuerstenau et al. 2007; Gonzales et al-2005; Lasch et al. 2005
piab	below	30	15	120	Pape 2008; Pukkala et al. 1998; Hanewinkel and Pretzsch-2000; Sterba 1986; Laehde et al. 2010
fasy	above	30	15	140	Schuetz 2006; Mund et al. 2004; Hein and Dhote 2006; Cescatti and Piutti 1998
quro/qupe	above	15	15	200	Hein and Dhote 2006; Fuerstenau et al. 2007; Štefančík 2012; Kerr 1996; Gutsch et al. 2011

pipi	below	20	10	45	Management after Loustau et al. 2005 & Thivolle-Cazat et al. 2013

Table 19 Management schedules for the sites included in the simulation experiments. 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 generic management rules from **Table 16** are being used (FM). harvest and planting are marked in bold. Note that depending on how models represent the planting/regeneration information in Table 20, the overall stand- age maybe slightly higher than in Table 18 (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).

Name	Ini	HM	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FMX	FMX	FMX	FMX	FMX	Remarks
bily-kriz	1997	1998-2015^{T}	2030^{T}	2045^{T}	2060^{T}	2075^{T}	2090^{T}	**2101^{H}**	**2102^{P}**	2117^{T}	...	**2222^{H}**	**2223^{P}**	2238^{T}	...	
collelongo	1992	1997-2012^{T}	2027^{T}	**2032^{H}**	**2033^{P}**	2048^{T}	2063^{T}	2078^{T}	2093^{T}	...	**2173^{H}**	**2174^{P}**	2189^{T}	...	...	
hyytiala*	1995	1996-2011^{T}	2026^{T}	2041^{T}	2056^{T}	2071^{T}	2086^{T}	**2101^{H}**	**2102^{P}**	2117^{T}	...	**2242^{H}**	**2243^{P}**	2258^{T}	...	***
kroof*	1997	1999-2010^{T}	2025^{T}	2040^{T}	2055^{T}	2070^{T}	2085^{T}	2100^{T}	**2101^{H}**	**2102^{P}**	2117^{T}	...	**2222^{H}**	**2223^{P}**	...	****
le-bray	1986	1987-2009^{T}	**2015^{H}**	**2016^{P}**	2026^{T}	2036^{T}	2046^{T}	2056^{T}	**2061^{H}**	**2062^{P}**	2072^{T}	...	**2107^{H}**	**2108^{P}**	2118^{T}	
peitz	1948**	1952-2011^{T}	2026^{T}	**2040^{H}**	**2041^{P}**	2056^{T}	2071^{T}	2086^{T}	2101^{T}	...	**2181^{H}**	**2182^{P}**	2197^{T}	...	...	
solling-beech*	1967	1968-2014^{T}	**2015^{H}**	**2016^{P}**	2031^{T}	2046^{T}	2061^{T}	2076^{T}	2091^{T}	...	**2156^{H}**	**2157^{P}**	2172^{T}	...	**2297^{H}**	
solling-spruce*	1967	1968-2014^{T}	**2024^{H}**	**2025^{P}**	2040^{T}	2055^{T}	2070^{T}	2085^{T}	2100^{T}	...	**2145^{H}**	**2146^{P}**	2161^{T}	...	**2266^{H}**	
soro	1944**	1945-2005^{T}	2020^{T}	2035^{T}	2050^{T}	**2061^{H}**	**2062^{P}**	2077^{T}	2092^{T}	...	**2202^{H}**	**2203^{P}**	2218^{T}	...	...	

Ini = Initialization data, HM = Historic Management, FM = Future Management, T=Thinning, H= Harvest, P=Planting, *=maximum age extended a bit to match local management during observed period or avoid harvesting just before the end of the simulation, **= the GCM data only starts in 1950, hence for future runs (Experiment 2a), you have to initialize these forests at the first time step after 1949 (i.e. 1952 for Peitz and 1950 for Soro). For the historical validation runs (Experiment 1a) you can start with the first available stand initialization.***= Only simulate pine and spruce (no hard-woods) **and regenerate as pure pine stand. ****= Harvest all species at the same time (i.e. 120 years).**

Table 20 Planting information for the sites included in the simulation experiments. DBH is defined as diameter at breast height of 1.30m. The numbers in brackest indicate plausible ranges.

Name	Density ha^{-1}	Age years	Height m	DBH cm	age when DBH is reached years	Remarks
bily-kriz	4500	4	0.5	na	9	Historical planting density was 5000/ha but current practices are 4500/ha only
collelongo	10000	4	1.3	0.1	**4**	Only a rough approximation, usually natural regeneration is the regeneration method.
hyytiala	2250 (2000-2500)	2	0.25 (0.2-0.3)	na	6 (5-7)	Regenerate as pure pine stand
kroof (beech)	6000 (5000-7000)	2	0.6 (0.5-0.7)	0.5	5	The planting density is for single-species stands, hence when regenerating the 2-species-stand KROOF, the planting density of each species should be halved
kroof (spruce)	2250 (2000-2500)	2	0.35 (0.3-0.4)	0.5	7	See above
le-bray	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. ➔ modelers could mimic this by "planting" trees with DBH of 7.5cm and 6m height in 1978 with a density of 1250 trees/ha
peitz	9000 (8000-10000)	2	0.175 (0.1-0.25)	0.1	**5**	The “age when DBH is reached = 5” is an estimate
solling-beech	8500 (7000-10000)	2	0.3 (0.2-0.4)	0.5	4	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
solling-spruce	3000 (2500-3500)	2	0.35 (0.25-0.5)	0.5	3	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

soro	6000	4	0.82	na	6	Planted in 1921, stem count in 288 ha-1 in 2010, (Wu et al. 2013)

8.2 Output data

Table 21 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>**	m^3 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. (=intercept + esoil + trans)
Evaporation from Canopy (interception)	**intercept-<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 22 Codes for species, disturbance names and dbh classes as used in protocol (species, dist-name, dbhclass).

Long name	Short name
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
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

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