9 Forest Models (Regional, Forest stand-level models)

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9.1 Introduction to multi-model simulations in ISIMIP2a and PROFOUND

This is an overview document to support multi-model simulations of forest stand models for both model evaluation with observed data. A number of sites has been selected in the COST Action PROFOUND (http://cost-profound.eu/site/) for which a) a wide range of forest models can be rather easily initialized, b) observational data is available for model evaluation and b) additional local driving datasets are available such as N-deposition or locally observed climate (**Table** 20). To get access to this PROFOUND Database, please contact reyer@pik-potsdam.de. A few important particularities for the forest simulations are listed below.

1) **Management:** The modeling experiments mostly encompass managed forests. The standard management ("varsoc") during the historical period is the observed management as defined by the data available for each site (please only use the reduction in stem numbers to design the management).

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the model calibration or development is driven by an improvement of the model after a comparison to data that were originally made available in ISIMIP for model evaluation, a part of those data should be kept aside for model evaluation and not used for calibration.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 (e.g. 1971-2000 for ISIMIP2A) but since we have sometimes data for model initialization and validation going back even further in time, 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. Similarly, if the model runs only start later than, e.g. 1971, the reporting period is shorter. If the data for model initialization is only available very late (e.g. KROOF starts in 1998 only, you do not need to run your model for those climatic datasets which end early (e.g. Watch ending in 2001 already).

9.2 Experiments

Table 19 provides an overview of all experiments to be run with regional forest models in ISIMIP. This table is for your reference only; please read chapters 1-5 of the general ISIMIP protocol and this whole section carefully before beginning with the experiments. In case of any questions please contact info@isimip.org. Please note that aside from harmonized climate, stand, management and soil input, the default settings of your model should be used. Also note that for output data files the **file name is all lower case**!

Table 19: Experiment summary for regional forest models. Each experiment is to be carried out for each site named in **Table** 20**.** For management scenarios see **Table** 21 - 23.

	Climate Data	Scenario	Management	Other settings (sens-scenario)	# runs
Historical runs without disturbances (Experiment 1a)	Observations from local meteorological station or likewise	hist	1. Observed management (varsoc) 2. Natural reference run (nosoc)	historical CO_2 without disturbances (co2), EMEP-N-deposition	2
	WATCH-WFDEI	hist	1. Observed management (varsoc) 2. Natural reference run (nosoc)	historical CO_2 without disturbances (co2), EMEP-N-deposition	2
	GSWP3-W5E5	hist	1. Observed management (varsoc) 2. Natural reference run (nosoc)	historical CO_2 without disturbances (co2), EMEP-N-deposition	2
	GSWP3-EWEMBI	hist	1. Observed management (varsoc)	historical CO_2 without disturbances	2

			2. Natural reference run (nosoc)	(co2), EMEP-N-deposition	
	GSWP3	hist	1. Observed management (varsoc) 2. Natural reference run (nosoc)	historical CO_2 without disturbances (co2), EMEP-N-deposition	2
	PGMFD v.2 (Princeton)	hist	1. Observed management (varsoc) 2. Natural reference run (nosoc)	historical CO_2 without disturbances (co2), EMEP-N-deposition	2
	WATCH (WFD)	hist	1. Observed management (varsoc) 2. Natural reference run (nosoc)	historical CO_2 without disturbances (co2), EMEP-N-deposition	2

Please note: these tables do not include all necessary information and should be used as a reference only once the sector-specific and cross-sectoral protocol has been read in full.

9.3 Sector-specific input

The input and evaluation data is provided through the PROFOUND database including an R-package to explore the database. Until the database is officially released, please get in touch with Christopher Reyer (reyer@pik-potsdam.de) to access it.

Table 20: Overview of the forest stands to be simulated in ISIMIP/PROFOUND.

Site name (for filenames)	Lat	Lon	Country	Forest type	Species	Thinning during historical time period	Comments
hyytiala	61.8475	24.295	FI	Even-aged conifer	pisy, piab with some deciduous mix	below	Note that an experimental plot of pine contains a lot of data while footprint of flux tower is larger. Please note that the deciduous admixtures only appear in the data at a later stage and hence do not need to be simulated. Only simulate pine and spruce (no hard-woods) and regenerate as pure pine stand
peitz	51.9166	14.35	DE	Even-aged conifer	pisy	below	Managed using a weak thinning from below.
solling-beech	51.77	9.57	DE	Even-aged deciduous	fasy	above	

solling-spruce	51.77	9.57	DE	Even-aged conifer	piab	below	
soro	55.485844	11.644616	DK	Even-aged deciduous	fasy	above	
kroof	48.25	11.4	DE	Mixed deciduous and conifers	fasy, piab, acpl, lade, pisy, quro	below	Unmanaged/ thinning from below in past 20 years for all species.
le-bray	44.71711	-0.7693	FR	Even-aged conifer	pipi	below	
collelongo	41.8494	13.5881	IT	Even-aged deciduous	fasy	above	
bily-kriz	49.3	18.32	CZ	Even-aged conifer	piab	below	

Table 21: Planting information for the sites included in the simulation experiments. DBH is defined as diameter at breast height of 1.30m. The numbers in brackets 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.
hyytala	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)	na	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)	na	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, October, 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)	na	5	The “age when DBH is reached = 5” is an estimate
solling-beech	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
solling-spruce	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
soro	6000	4	0.82	na	6	Planted in 1921, stem count in 288 ha-1 in 2010 (Wu, et al., 2013)

9.4 Output data

Table 22: Variables to be reported by forest models. Abbreviations are provided in **Table** 23. Variables should be reported as documented in Section 5.

Variable (long name)	Variable name	Units (NetCDF format)		Resolution	DBH class resolution	Comment
Essential outputs						
Mean DBH	**dbh-<species/total>**	cm	per species and stand total	annual	None	
Mean DBH of 100 highest trees	**dbhdomhei**	cm	stand total	annual	None	100 highest trees per hectare.
Stand Height	**hei-<species/total>**	m	per species and stand total	annual	None	For models including natural regeneration this variable may not make sense, please report domhei.
Dominant Height	**domhei**	m	stand total	annual	None	Mean height of the 100 highest trees per hectare.
Stand Density	**density-<species/total>**	ha-1	per species and stand total	annual	None	
Basal Area	**ba-<species/total>**	m2 ha-1	per species and stand total	annual	None	
Volume of Dead Trees	**mort-<species/total>**	m3 ha-1	per species and stand total	annual	None	

Harvest by dbh-class	**harv-<species/total>**	m3 ha-1	per species and stand total and dbh-class	annual	Either dbh classes or total	See Section 5.1.5
Remaining stem number after disturbance and management by dbh class	**stemno-<species/total**	ha-1	per species and stand total and dbh-class	annual	Either dbh classes or total	See Section 5.1.5
Stand Volume	**vol-<species/total>**	m3 ha-1	per species and stand total	annual	None	
Carbon Mass in Vegetation biomass	**cveg-<species/total>**	kg m-2	per species and stand total	annual	None	As kg carbon*m^{-2}
*Carbon Mass in aboveground vegetation biomass	**cvegag-<species/total>**	kg m-2	per species and stand total	annual	None	As kg carbon*m^{-2}
*Carbon Mass in belowground vegetation biomass	**cvegbg-<species/total>**	kg m-2	per species and stand total	annual	None	As kg carbon*m^{-2}
Carbon Mass in Litter Pool	**clitter-<species/total>**	kg m-2	per species and stand total	annual	None	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	None	As kg carbon*m^{-2}, Info for each individual soil layer
Tree age by dbh class	**age-<species/total**	yr	per species and stand total and dbh-class	annual	Either dbh classes or total	See Section 5.1.5
Gross Primary Production	**gpp-<species/total>**	kg m-2 s-1	per species and stand total	daily	None	As kg carbon*m^{-2}*s^{-1}
Net Primary Production	**npp-<species/total>**	kg m-2 s-1	per species and stand total	daily	None	As kg carbon*m^{-2}*s^{-1}
Autotrophic (Plant) Respiration	**ra-<species/total>**	kg m-2 s-1	per species and stand total	daily	None	As kg carbon*m^{-2}*s^{-1}
Heterotrophic Respiration	**rh-< total>**	kg m-2 s-1	stand total	daily	None	As kg carbon*m^{-2}*s^{-1}
Net Ecosystem Exchange	**nee-<total>**	kg m-2 s-1	per stand	daily	None	As kg carbon*m^{-2}*s^{-1}
Mean Annual Increment	**mai-<species/total>**	m3 ha-1	per species and stand	annual	None	

			total			
Fraction of absorbed photosynthetically active radiation	**fapar-<species/total>**	%	per species and stand total	daily	None	Value between 0 and 100.
Leaf Area Index	**lai-<species/total>**	m2 m-2	per species and stand total	monthly	None	
Species composition	**species-<species>**	%	per ha	annual (or once if static)	None	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	None	sum of transpiration, evaporation, interception and sublimation. (=intercept + esoil + trans)
Evaporation from Canopy (interception)	**intercep-<species/total>**	kg m-2 s-1	per species and stand total	daily	None	the canopy evaporation + sublimation (if present in model).
Water Evaporation from Soil	**esoil**	kg m-2 s-1	per stand	daily	None	includes sublimation.
Transpiration	**trans-<species/total>**	kg m-2 s-1	per species and stand total	daily	None	
Soil Moisture	**soilmoist**	kg m-2	per stand	daily	None	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>**	ha-1	per species and stand total and dbh-class	annual	Either dbh classes or total	As trees per hectare. See Section 5.1.5
Removed stem numbers by size class by management	**harvstemno-<species/total>**	ha-1	per species and stand total and dbh-class	annual	Either dbh classes or total	As trees per hectare. See Section 5.1.5
Volume of disturbance damage	**dist-<dist-name>**	m3 ha-1	per species and stand total	annual	None	
Nitrogen of annual Litter	**nlit-<species/total>**	g m-2 a-1	per species and stand total	annual	None	As g Nitrogen m^{-2} a^{-1}
Nitrogen in Soil	**nsoil-<total>**	g m-2 a-1	stand total	annual	None	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	None	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	None	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	None	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	None	As kg carbon*m^{-2}*s^{-1}
Root autotrophic respiration	**rr-<species/total>**	kg m-2 s-1	per species and stand total	daily	None	As kg carbon*m^{-2}*s^{-1}
Carbon Mass in Leaves	**cleaf-<species>**	kg m-2	per species and stand total	annual	None	
Carbon Mass in Wood	**cwood-<species>**	kg m-2	per species and stand total	annual	None	including sapwood and hardwood
Carbon Mass in Roots	**croot-<species>**	kg m-2	per species and stand total	annual	None	including fine and coarse roots
Temperature of Soil	**tsl**	K	per stand	daily	None	Temperature of each soil layer

Note: If you cannot provide the data at the temporal or spatial resolution specified, please provide it the highest possible resolution of your model. Please contact the coordination team (info@isimip.org) to for any further clarification, or to discuss the equivalent variable in your model.

Table 23: 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

*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.

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