ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

ISIMIP biome sector overview

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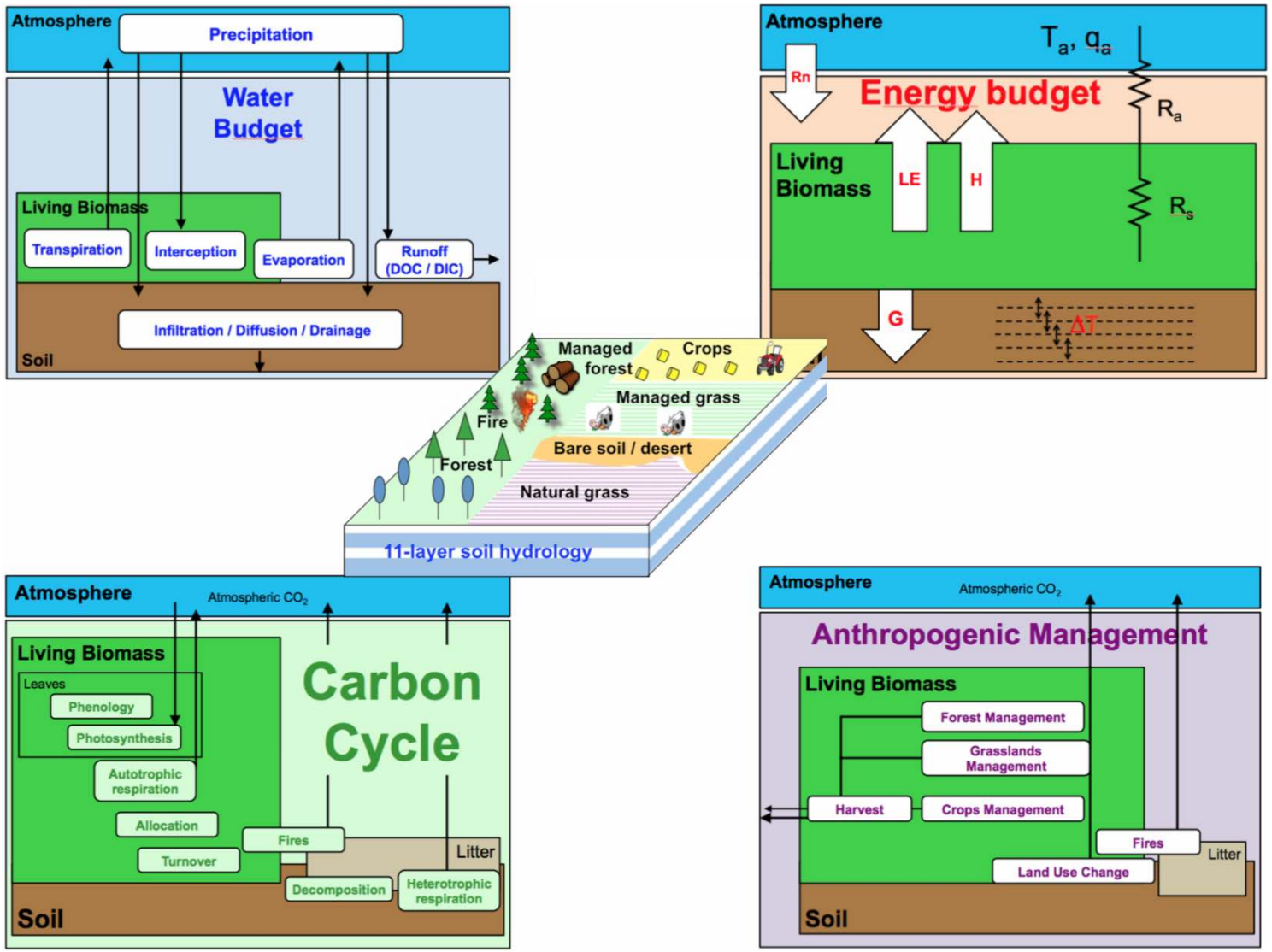
and ISIMIP biome sector contributors

ISIMIP Workshop, 23rd April 2024

Biome sector: biogeochemical cycles of terrestrial ecosystem



Source: ORCHIDEE development group at IPSL

Contributing sectors:

Agriculture

Terrestrial biodiversity

Biome

Fire

Peatland

Permafrost

Water (global)

…

ISIMIP Biome sector: Past achievements and advantages

- ISIMIP Fast Track: 7 models. Comparing projections of climate change impacts from global models
- ISIMIP2a: 8 models. Evaluation + Extreme events and variability
- ISIMIP2b: 8 models. Assessing the impacts of 1.5 ◦C global warming
- ISIMIP3a: 16 models. Evaluation + Detection and attribution of observed impacts
- ISIMIP3b: ?? models. Quantification of climate-related risks at different levels of climate change and direct human forcing
- ISIMIP4: Planned in this workshop

Advantages

- Future scenarios with changing land-use etc.
- PFT specific outputs and those are being used, e.g. to derive forest outputs for the Guo et al. paper
- ISIMIP3 has added many sectors (e.g., fire, peat) that are close to biomes and have overlap for key topics and outputs, biodiversity is still a key sector to cooperate with but needs further pushes

ISIMIP Fast Track

- Objectives: "**comparing projections of climate change impacts from global models**".
- Forcings and Scenarios: 5 GCMs from CMIP5: GFDL-ESM2M; HadGEM2-ES; IPSL-CM5A-LR; MIROC-ESM-CHEM; NorESM1-M

IMPORTANT: For all scenarios in this section, no human land-use is to be assumed.

	GCMs	RCPs (clim-scenario)	Other settings (sens-scenario)	# runs
Minimal setting: GCM1, all RCPs; sensitivity experiment; GCM 2-5, RCP8.5 + 2.6	GCM 1	2.6 (**rcp2p6**) 4.5 (**rcp4p5**) 6.0 (**rcp6p0**) 8.5 (**rcp8p5**)	**co2**	4
	GCM 1	8.5 (**rcp8p5**)	**noco2**	1
	GCM 2-5	2.6 (**rcp2p6**) 8.5 (**rcp8p5**)	**co2**	8

- Land use: not prescribed
- 7 Biome models: Hybrid, JeDi, JULES (water), LPJmL(water): Dynamic vegetation
  ORCHIDEE, SDGVM, VISIT: Prescribed vegetation (1850)

ISIMIP Fast Track Publications

- Friend *et al.*, **Carbon residence time** dominates uncertainty in terrestrial vegetation responses to future climate and atmospheric CO2. *PNAS*, 2013

NPP, cVeg

- Ito *et al.*, Impacts of future climate change on the **carbon budget** of northern high-latitude terrestrial ecosystems: An analysis using ISI-MIP data. *Polar Science*, 2016.

NPP, cVeg, cSoil

- Nishina *et al.*, Quantifying uncertainties in **soil carbon** responses to changes in global mean temperature and precipitation. *Earth System Dynamics*, 2014.

cSoil, cVeg

- Nishina *et al.*, Decomposing uncertainties in the future **terrestrial carbon budget** associated with emission scenarios, climate projections, and ecosystem simulations using the ISI-MIP results. *Earth System Dynamics*, 2015.

NPP, cSoil, cVeg

- Thurner *et al.*, Evaluation of climate-related **carbon turnover processes** in global vegetation models for boreal and temperate forests. *Global Change Biology*, 2017.

NPP, cVeg

- **Cross-sectoral analysis**:
  Warszawski *et al.*, A multi-model analysis of **risk of ecosystem shifts** under climate change. *Enivron. Res. Lett.*, 2013

NPP, Rh, fFire, cSoil, cVeg, trans, evap, qtot, soil moisture, PFT coverage

ISIMIP2a

- Objectives: "**Extreme events and variability** " - "**evaluating** the models' ability to reproduce observed historical variability, responses to extreme climatic events such as heat waves, droughts, floods, heavy rains and storms, and representation of extreme impact events"
- Forcings : 4 reconstructed historical climate forcing datasets (PGFv2, GSWP3, WATCH, WFDEI)
- Land use: **HYDE3 + MIRCA**

Table 19 Experiment summary for Biomes models

	Climate Data	Scenario	Population/GDP	Land use (LU)	Other settings (sens-scenario)	# runs
Historical runs	PGMFD v.2 (Princeton)	hist	varsoc (see **Table 18**; if varsoc not possible, please submit the presoc run)	Hyde3 + MIRCA (no LU specifier)	historical CO2 (co2)	1
	GSWP3	hist	varsoc	Hyde3 + MIRCA (no LU specifier)	historical CO2 (co2)	1
	WATCH (WFD)	hist	varsoc	Hyde3 + MIRCA (no LU specifier)	historical CO2 (co2)	1
	WATCH+WFDEI.GPCC	hist	varsoc	Hyde3 + MIRCA (no LU specifier)	historical CO2 (co2)	1

- 8 Biome models: CARAIB, DLEM, JULES (water), LPJ-GUESS, LPJmL (water), ORCHIDEE (water), VEGAS, VISIT

ISIMIP2a Publications

Environmental Research Letters special issue

- Chen *et al.*, Regional contribution to variability and trends of global **gross primary productivity**. 2017.

GPP

- Ito *et al.*, **Photosynthetic productivity** and its efficiencies in ISIMIP2a biome models: benchmarking for impact assessment studies. 2017

GPP

- García Cantú *et al.*, Evaluating changes of biomass in global vegetation models: the role of **turnover fluctuations** and ENSO events. 2018.

NPP, cVeg

- Chang *et al.*, Benchmarking **carbon fluxes** of the ISIMIP2a biome models. 2017.

NBP (including LUC)

- Wartenburger *et al.*, **Evapotranspiration** simulations in ISIMIP2a—Evaluation of spatio-temporal characteristics with a comprehensive ensemble of independent datasets, 2018

Evapotranspiration

- Pan S *et al.*, **Climate extreme** versus carbon extreme: responses of terrestrial carbon fluxes to temperature and precipitation, JGR-Biogeosciences, 2020

NPP, Rh, NEP

- **Cross-sectoral analysis**: Schewe *et al.*, State-of-the-art models underestimate impacts from **climate extremes**. *Nature communications*, *2019*

GPP

What we have learned?

	GPP	NPP	NBP	Biomass turnover
Global mean	well captured [2,3]	-	well captured [1]	-
Trends	not consistently captured [2]	-	not consistently captured [1]	-
Spatial pattern	well captured [2]	-	-	-
Seasonality	not consistently captured [2, 3]	-	-	-
Inter-annual variation	not consistently captured [2,3]	-	well captured [1]	-
ENSO	not consistently captured [3]	-	well captured [1]	not consistently captured [4]
Large volcanic eruption	not consistently captured [3]	-	-	-
Drought	magnitude not captured [5]	-	-	-
Extreme		well captured for T but not P [6]		

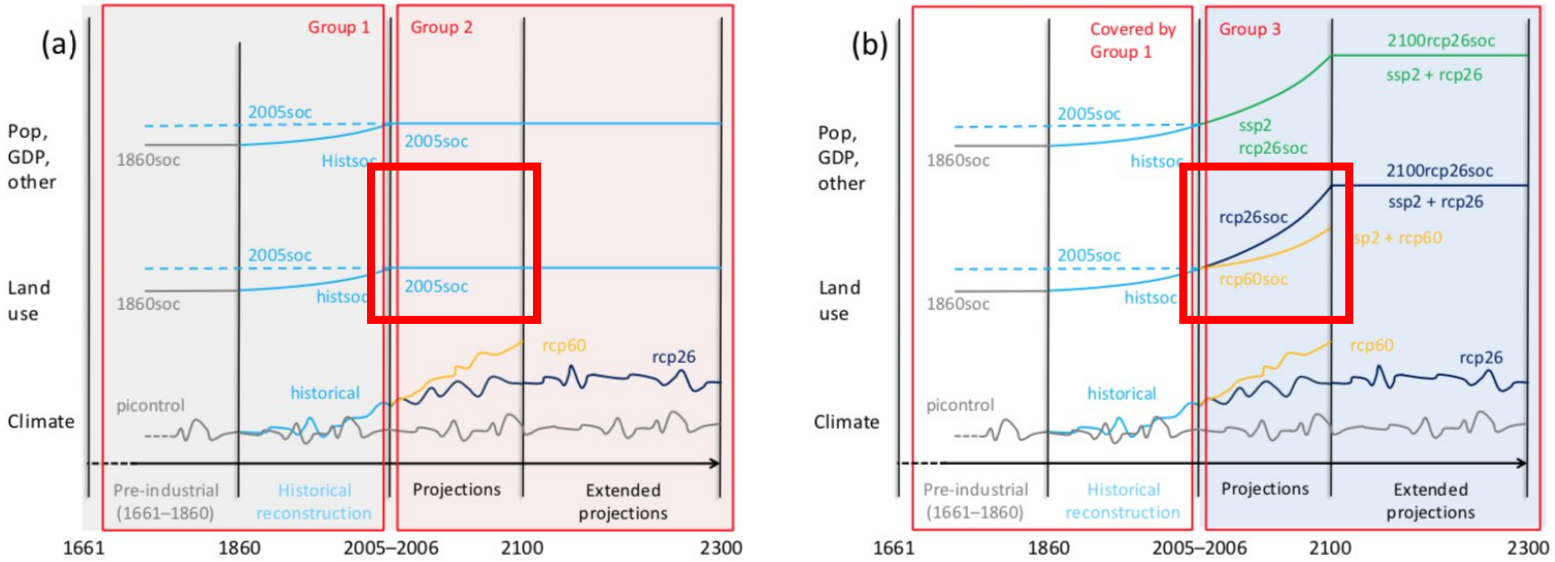
[1] Chang et al., 2017 [2] Chen et al., 2017 [3] Ito et al., 2017 [4] Carcia Cantu et al., 2018 [5] Schewe et al., 2019 [6] Pan et al,. 2020

- These findings imply that we need to improve i) parameterization of GPP in terms of seasonality [2] and radiation responsiveness [3], ii) heat and water stress effects on plants [5,6], ii) vegetation carbon turnover [4], and iii) the sensitivity of NPP and NBP to tropical temperature and precipitation variations [1,6].

ISIMIP2b

- Objectives: "**Assessing the impacts of 1.5 ◦C global warming**"
- Forcings and Scenarios: 4 bias-corrected GCM climate, IPSL-CM5A-LR; GFDL-ESM2M; MIROC5; HadGEM2-ES.
- Land use: **historical (HYDE3 + MIRCA) and future (SSP2 rcp26/rcp60 from MAgPIE)**

Effects of land use change on C budget (mainly deforestation/reforestation)



- 8 Biome models: CARAIB, CLM4.5 (water), DLEM, LPJ-GUESS, LPJmL (water), ORCHIDEE-MICT (water), VEGAS, VISIT

ISIMIP2b Publications

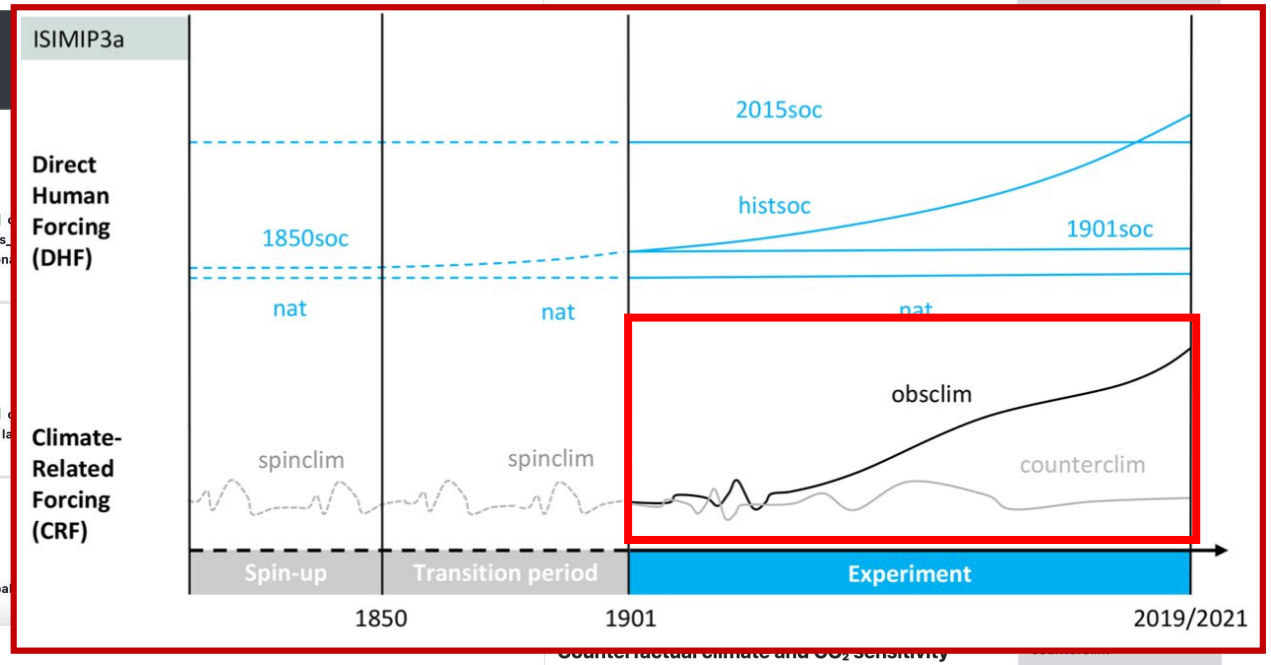
- Ito *et al.* Pronounced and unavoidable impacts of low-end global warming on northern high-latitude land ecosystems, *Environmental Research Letters* 2020 **NPP, CVeg, CSoil**
- Shi *et al.*, Saturation of Global Terrestrial Carbon Sink Under a High Warming Scenario, *Global Biogeochemical Cycles* 2020 **GPP, NBP**
- Xu *et al.*, Reducing Uncertainties of Future Global Soil Carbon Responses to Climate and Land Use Change With Emergent Constraints, *Global Biogeochemical Cycles* 2020 **NPP, SOC**
- Gaedeke *et al.*, Climate change reduces winter overland travel across the Pan-Arctic even under low-end global warming scenarios, *Environmental Research Letters* 2021 **(Permafrost)** **TSoil, Snow depth**
- **Cross-sectoral analysis:** Lange et al., Projecting Exposure to Extreme Climate Impact Events Across Six Event Categories and Three Spatial Scales, *Earth's Future* 2020 **(Fire)** **Wildfire**
- Thiery et al., Intergenerational inequities in exposure to climate extremes **Wildfire**
- Guo et al., Forest product demand and supply in a bioeconomy transition: the possible role of wood in the context of climate change mitigation, in prep. **NPP**
- Hickler *et al.*, Impacts of climate and land use change on biogeographic range shifts, in prep.

ISIMIP3a

- Objectives: "**i) impact model evaluation and improvement and ii) detection and attribution of observed impacts according to the framework of IPCC AR5 Working Group II Chapter 18**"
- Forcings and Scenarios: GSWP3-W5E5, 20CRv3-W5E5, 20CRv3-ERA5, 20CRv3 historical + counterfactual
- Land use: **historical (HYDE3 + MIRCA)**
- 16 Biome models

Table 2.1: Experiment set-up. Each experiment is specified by the climate related forcing (top row) and the direct human forcing (bottom row). Sensitivity labels indicate deviations from the default settings. The subtitles in the first row indicate how the experiment is defined in filenames.

Experiment	ISIMIP3a
Model evaluation obsclim_histsoc_default 1st priority ISIMIP3a agriculture biodiversity biomes … forestry health groundwater labour lakes_… marine-fishery_global marine-fishery_region… water_global water_regional	Direct Human Forcing (DHF)
Model evaluation obsclim_2015soc_default 1st priority ISIMIP3a agriculture biodiversity biomes … health groundwater labour lakes_global … permafrost water_global water_regional	Climate-Related Forcing (CRF)
Model evaluation obsclim_1901soc_default 2nd priority ISIMIP3a biomes groundwater lakes_global… permafrost water_global	
Counterfactual climate counterclim_histsoc_default 1st priority ISIMIP3a agriculture biodiversity biomes coastal diarrhea fire forestry groundwater health labour lakes_global lakes_local peat permafrost water_global water_regional	counterclim histsoc
counterclim_histsoc_obsco2 2nd priority ISIMIP3a biomes forestry	Sensitivity experiment: obsco2 histsoc



Model	contact
CARAIB	Louis Francois
CLASSIC	Sian Kou-Giesbrecht
CLM5.0	Wim Thiery
DLEM	Hanqin Tian/ Hao Shi
JULES-ES-VN6P3	
JULES	Eleanor Burke
LPJ-GUESS-Spitfire	Matthew Forrest. Thomas Hickler
LPJ-GUESS-Simfireblaze	Lars Nieradzik
LPJmL	Sebastian Ostberg
LPJ-wsl	Zhen Zhang, Ben Poulter
ORCHIDEE-MICT	Jinfeng Chang
VEGAS	Fang Zhao
VISIT	Akihiko Ito
ELM-ECA	Qing Zhu, Bill Riley
MC2-USFS-r87g5c1	John Kim
SSiB4/TRIFFID	Huilin Huang
<ENTER NEW MODEL HERE>	

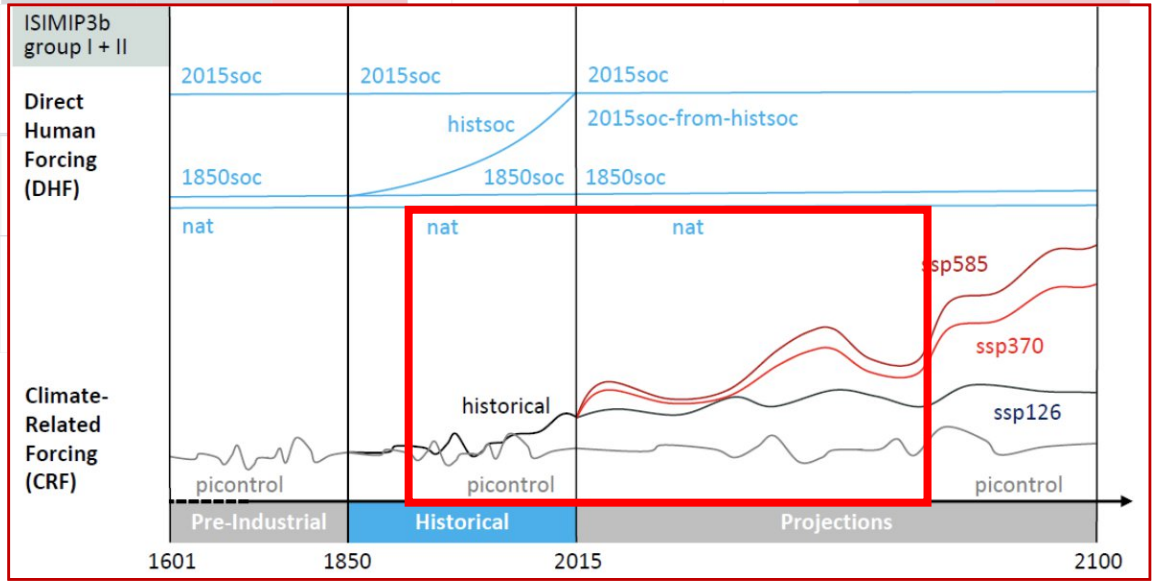
ISIMIP3b

- Objectives: "**quantification of climate-related risks at different levels of climate change and direct human forcing**"
- Forcings and Scenarios: 3-5 SSPs (SSP126, 370, 585, and more), 5 GCMs
- Land use: historical (HYDE3 + MIRCA) and future (SSP126, 370, 585 from MAgPIE, IMAGE, GLOBIOM)
- 16 and more?? Biome models

Table 2.1: Experiment set-up. Each experiment is specified by the climate related forcing (top row) and the direct human forcing (bottom row). Sensitivity labels indicate deviations from the default settings. The subtitles in the first row indicate how the experiment is defined in filenames.

Experiment	Period: Pre-industrial 1601-1849	Period: Historical 1850-2014	Period: Future 2015-2100
Pre-industrial control picontrol_1850soc_default picontrol_histsoc_default picontrol_2015soc-from-histsoc_default 1st priority ISIMIP3b agriculture biodiversity biomes diarrhea fire forestry health coastal fs-n labour lakes_global lakes_local marine-fishery_global marine-fishery_regional peat permafrost water_global water_regional	picontrol	picontrol	picontrol
RCP2.6 ssp126_histsoc_default ssp126_2015soc-from-histsoc_default 1st priority ISIMIP3b agriculture biodiversity biomes diarrhea fire forestry health coastal fs-n labour lakes_global lakes_local marine-fishery_global marine-fishery_regional peat permafrost water_global water_regional	1850soc	histsoc	2015soc-from-histsoc
RCP7.0 ssp370_2015soc-from-histsoc_default 1st priority ISIMIP3b agriculture biodiversity biomes diarrhea fire forestry health coastal fs-n labour lakes_global lakes_local peat permafrost water_global water_regional			
RCP8.5 ssp585_2015soc-from-histsoc_default 1st priority ISIMIP3b agriculture biodiversity biomes diarrhea fire forestry health coastal fs-n labour lakes_global lakes_local marine-fishery_global marine-fishery_regional peat permafrost water_global water_regional			

Climate sensitivity RCP2.6 with RCP8.5 CO_2 ssp126_2015soc-from-histsoc_ssp585co2 2nd priority ISIMIP3b peat	Identical to the similar **picontrol/1850soc** run above.	Identical to the similar **historical/histsoc** run above.	ssp126 Sensitivity experiment: ssp585co2 2015soc-from-histsoc
Nitrogen deposition sensitivity RCP8.5 ssp585_2015soc-from-histsoc_ssp585ndep 2nd priority ISIMIP3b biomes	Identical to the similar **picontrol/1850soc** run above.	Identical to the similar **historical/histsoc** run above.	ssp585 2015soc-from-histsoc Sensitivity experiment: ssp585ndep
No nitrogen cycling sensitivity RCP8.5 historical_histsoc_nondep ssp585_2015soc-from-histsoc_nondep 2nd priority ISIMIP3b biomes	Does not have to be simulated, spin-up should not include any nitrogen cycling (see note below the table).	historical histsoc Sensitivity experiment: nondep	ssp585 2015soc-from-histsoc Sensitivity experiment: nondep



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SSiB4/TRIFFID	Huilin Huang
<ENTER NEW MODEL HERE>	

ISIMIP3b forcing updates

Input	Status
Climate	All ready
Land use	Will be ready soon for SSP126, SSP370, SSP585
Population (Fire)	SSP1 ready
N fertilization & deposition	Ready; NCAR CCMI 1850-2100; will be in the protocol

ISIMIP3a/3b Status & Planned Publications

- 3a: 8 Model uploaded (CLASSIC, DLEM, JULES-ES-VN6P3, ORCHIDEE-MICT, VISIT, ELM-ECA, MC2-USFS-r87g5c1, SSib4/TRIFFID), 4 Models ready (CARAIB, LPJ-GUESS-SPITFIRE, LPJ-GUESS-Simfireblaze, LPJmL)
- 3b: 5 Models uploaded/ready (CLASSIC, DLEM, LPJmL, ORCHIDEE-MICT, VISIT)

Title	Lead author team	List of Variables
Dynamics of permafrost soil carbon from a few LSMs (including 3a and 3b output).	Jinfeng Chang	cveg, csoil, etc.
Carbon-nutrient interactions during future permafrost thaws	Qing Zhu	Tsoil, soilmoist, cveg, csoil, nveg, nsoil
Benchmarking of ISIMIP3a outputs by biome models focusing on global carbon cycle	Akihiko Ito	cveg-total, clittre-total, csoil-total, npp-total, lai-total
Global nitrogen cycling in historical and future simulations	Sian Kou-Giesbrecht	nitrogen pools and nitrogen fluxes
RECCAP2 carbon budget historical and future constrainted by reanalysis	Eleanor Burke	carbon budget
Benchmarking of ISIMIP3a permafrost outputs over Qinghai-Tibetan plateau	Jinfeng Chang	Tsoil, soilmoistat each level (profile), altmax, cnpveg, cnpsoil
Cross-sectoral 3b paper	Karim Zantout/ Jacob Schewe	BurntArea

Gaps and potential integrations (beyond vegetation)

Progress

- Carbon -> Carbon & Nitrogen & Phosphorus
- Vegetation types + Permafrost & Peatland & Fire

Gaps

- Vegetation and soil carbon turnover
- Response to future extremes like drought
- Terrestrial Carbon & Nitrogen & Phosphorus risks under climate change
- Uncertainty in the land-use patterns
- Forest management and better representing forestry
- Extreme disturbances such as storms, fire, insects at large scale and not background mortality

Integrations

- Biome-Fire-Permafrost-Peatland
- Biome-Water
- Biome-forestry
- Biome-biodiversity

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Thank you!