Direct Human Forcing for climate impact simulations

- Adaptation to extreme events-opportunities to generate adaptation scenarios for the socio-economic impacts of extreme events
- Which improvements in DHF do we want to achieve in ISIMIP4?
  - Which improvements are necessary and who can deliver them?
  - Constraints and needs of sectors, which are not participating yet

Adaptation to extreme events

- Adaptation to climate change impacts is very relevant in AR7
- Changes in frequency and intensity of extreme events
- Adaptation in terms of a extreme event risk reduction may be key to address key gaps (e.g. distributional impacts)

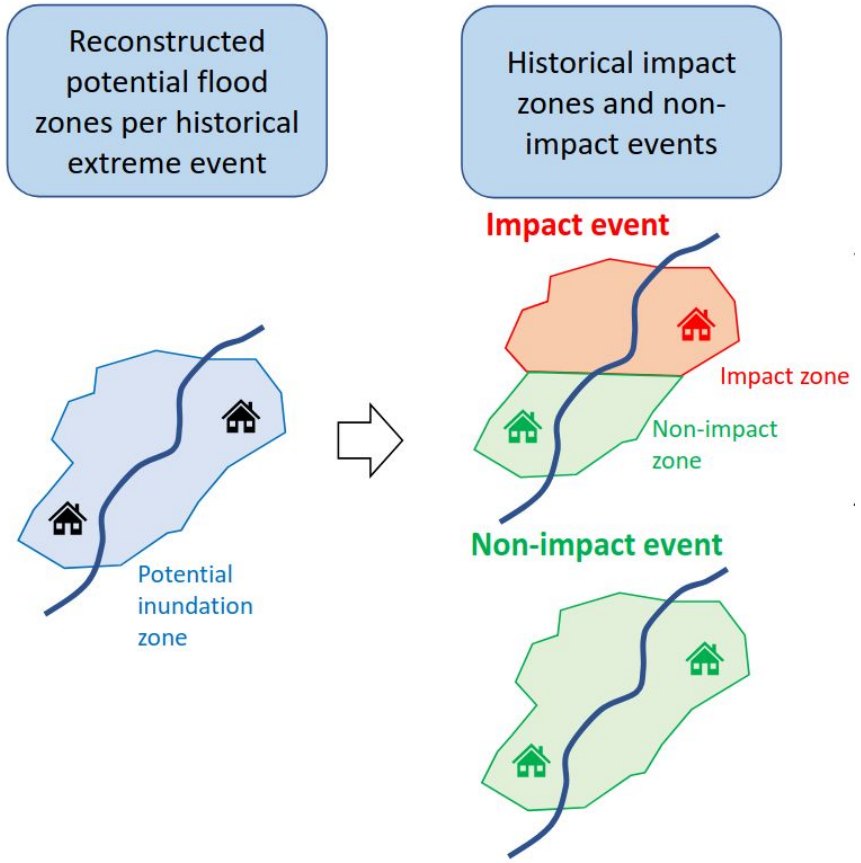
⟶ Bringing adaptation scenarios in our derived output data




Ideas for the development of a harmonized flood protection dataset

Historical datasets

- FLOPROS
  - mostly based on policy standards and GDP dependent modeling
- Flood protection levels based on HANZE (Paprotny et al. 2024)
  - strong observational
  - limited to Europe



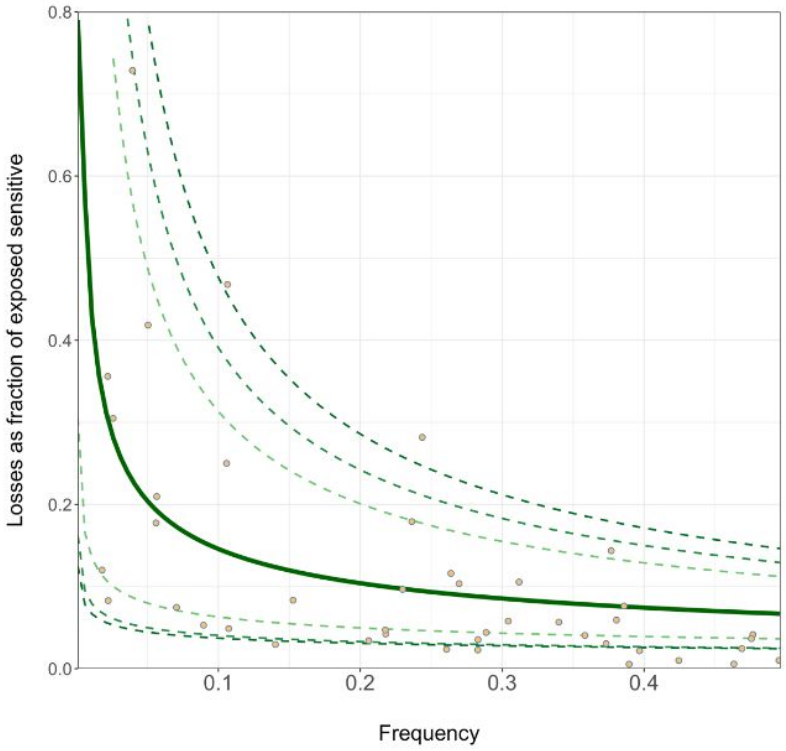
Globalization required

Ideas for the development of a harmonized flood protection dataset

Opportunities for future projections

- Approach presented by Jeroen Arts based on an Agent-based model - taking into account flood experience, behavioural and socio-economic constraints
- DIVA (based on a cost benefit analysis comparing dike unit costs and protected) (Hinkel et al. 2013)
  - limited to the coastal area
  - considers only dikes under SLR

More general approach to simulate vulnerability changes dynamically



Given you have an impact function based on return frequencies

- usually return frequencies are determined in the pi or historical period
- determining return frequencies in more recent periods and assuming may assume adaptation
- adaptation is stronger the closer the fitting period and the assessment period are

Group III forcing datasets

Land use (fraction of grid cell)
Irrigation (fraction of grid cell)
Land transformation
Synthetic fertilizers N (disaggregated)
Total N deposition
Crop calendar

Wood harvest

Dams and reservoirs
Non-irrigation water use (withdrawal and consumption)
Seawater desalination
Inter-basin water transfer
Irrigation techniques share

Gridded Population: total, urban, rural (people/yr)
National Population: total, urban, rural (people/yr)
Gridded Gross domestic product Int$ PPP 2005
National Gross domestic product Int$ PPP 2005 and GDP in MER 2005

Now ready!

Almost ready!

Sectors ready to start Group III:

- Water (global)
- Energy (demand)
- Fire
- Permafrost
- Biomes *(almost)*
- Agriculture *(almost)*

Sectors with no Group III plan yet:

- Food Security and Nutrition
- Groundwater
- Labour
- Lakes
- Water (regional
- …plus sectors with no ISIMIP3b protocol

Animal manure N
Animal manure P
Livestock numbers
Synthetic fertilizers (P) on cropland
Synthetic fertilizers (P) on grassland

Marine fishing effort

Forest management

Sectors where Group III input data is under construction:

- Water quality
- Marine Ecosystems & Fisheries
- Forests (regional)
- Peatland

Anything missing? Let us know!

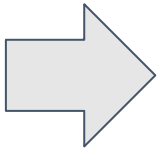
Inter-Sectoral Impact Model Intercomparison Project

Funded by the European Union

DHF in ISIMIP3 - challenges and achievements

What will be easier for the ISIMIP4-FT than it was for ISIMIP3b, group III?

Gridded Population data.
So far: inconsistencies in the transition from observations to projections, no-updates to latest SSP scenarios on the grid level
For ISIMIP4-FT: Projections directly starting from latest observational data, generated already now and consistent across all three WGs



Presentation by Dominik Paprotny

Gridded GDP.
Can be constructed already now. Data will be derived from the gridded population, build-up areas and national GDP information.
Construction already on its way.

DHF in ISIMIP3 - challenges and achievements

What will be easier for the ISIMIP4-FT than it was for ISIMIP3b, group III?

Population data.

So far: inconsistencies in the transition from observations to projections, limited resolution, …

For ISIMIP4-FT:

- In ISIMIP3 gridded population data issues arose due to
  - inconsistencies in the transition from observations to projections
  - inconsistencies in country masks
  - no updated future gridded population distributions

- For ISIMIP4, we tackled these issues by integrating
  - best available data products
  - into a method allowing for a continuous transition between those
  - updated gridded SSP projections (FuturePop)

What will be easier for the ISIMIP4-FT than it was for ISIMIP3b, group III?

No-adapt land use, irrigation and N fertilizer input data.

For ISIMIP4-FT: Will be directly available as identical to the land use data provided to CMIP, we still have to disaggregate the information from crop group specific data to crop specific data

Where do we have to update the ISIMIP3b, group III adapt forcing based on the existing methods?

Dam locations:

No-adapt hydropower dam locations will have to be updated based on new hydropower demands from the new IAM-ScenarioMIP runs. Method could be identical to the one applied in ISIMIP3b, group III, where runoff ia based on historical observational climate forcings.

Additional information about fertilizer inputs:

Phosphorus input, N manure, P manure will have to be generated in the same way as for ISIMIP3b, group III (by IMAGE-GNM) and in line with the IMAGE land use projections provided to CMIP7 (all scenarios for CMIP7 simulated?)

N update, P uptake, livestock numbers:

will have to be generated in the same way as for ISIMIP3b, group III (by IMAGE-GNM) and in line with the IMAGE land use projections provided to CMIP7

Wishes for longer-term improvements

New Harmonisation of LU information with historical data that

- directly provides crop specific land use information, irrigation fractions, and fertilizer inputs that do not have to be further disaggregated
- includes information about

  Peattypefrac (Percentage of grid cell covered by the natural, drained, restored or mineral (i.e. not peat) peat types)

  Drainage depth (Depth of drainage of artificial drainage network) Drainage density (Density of drainage network as total length of drainage network per km^2)
- Land-use incl. irrigated areas and natural/semi-natural vegetation change (e.g., between grassland/pasture and forest) (biodiversity)
- more detailed information about management of grassland and forests for the biodiversity sector

Additional information about fertilizer inputs:

Phosphorus input, N manure, P manure will have to be generated in the same way as for ISIMIP3b, group III (by IMAGE-GNM) and in line with the IMAGE land use projections provided to CMIP7 (all scenarios for CMIP7 simulated?)

N update, P uptake, livestock numbers:

will have to be generated in the same way as for ISIMIP3b, group III (by IMAGE-GNM) and in line with the IMAGE land use projections provided to CMIP7

Wishes for longer-term improvements

PV and wind installation demand (resolution?) (Energy sector)

Air pollution, Ozone for some crop and biomes models

Total lake surface area derived from dam dataset and dam demolition (lakes)

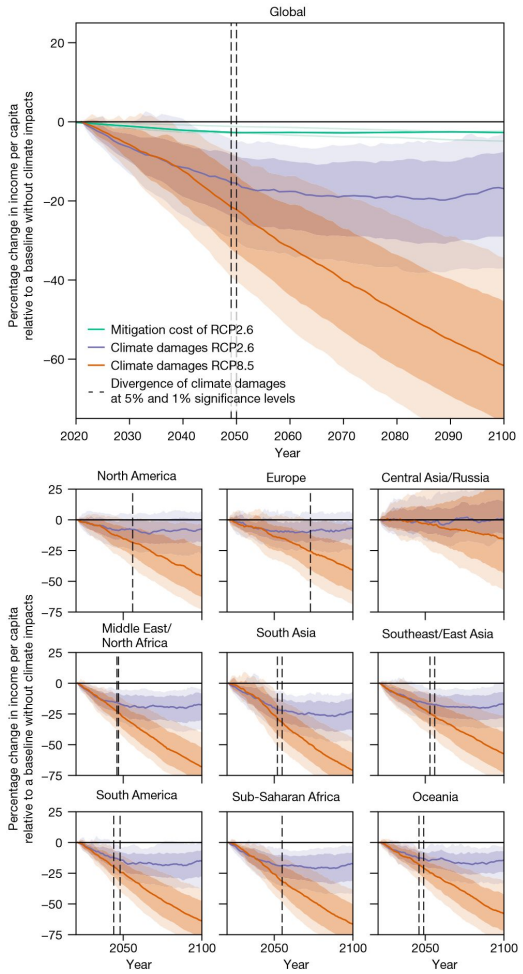
Sanitation, waste management, aquaculture (Water quality)

Crop waste management (burning or not, how much…) (Fire sector)

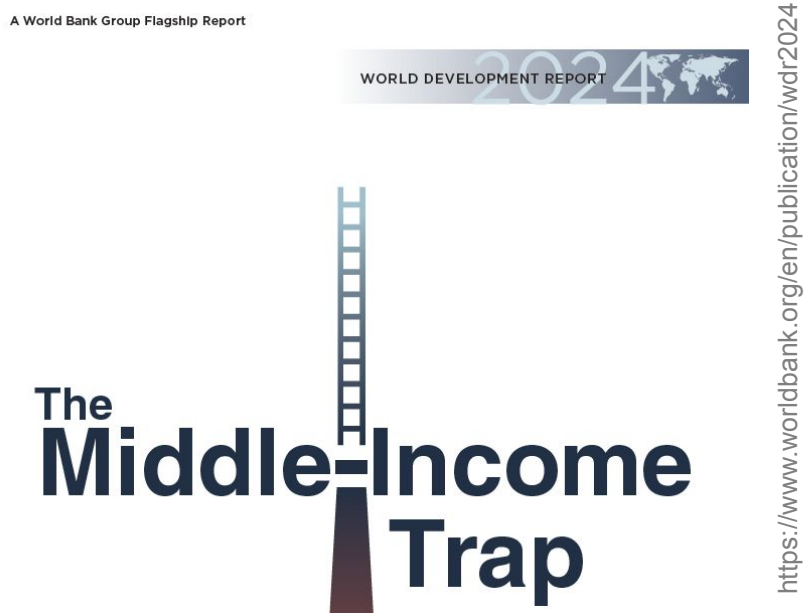
IAM Scenarios and Direct Human Forcers

Input Nico

Climate change: a challenge for development



https://www.nature.com/articles/s41586-024-07219-0



https://www.worldbank.org/en/publication/wdr2024

These difficulties are compounded by others. In some middle-income countries, fragility, conflict, and violence are hampering development. **And in almost every country, climate change is putting pressure on the government to rethink its development strategy**. (Worldbank 2024, Page 36)

Major Research Questions

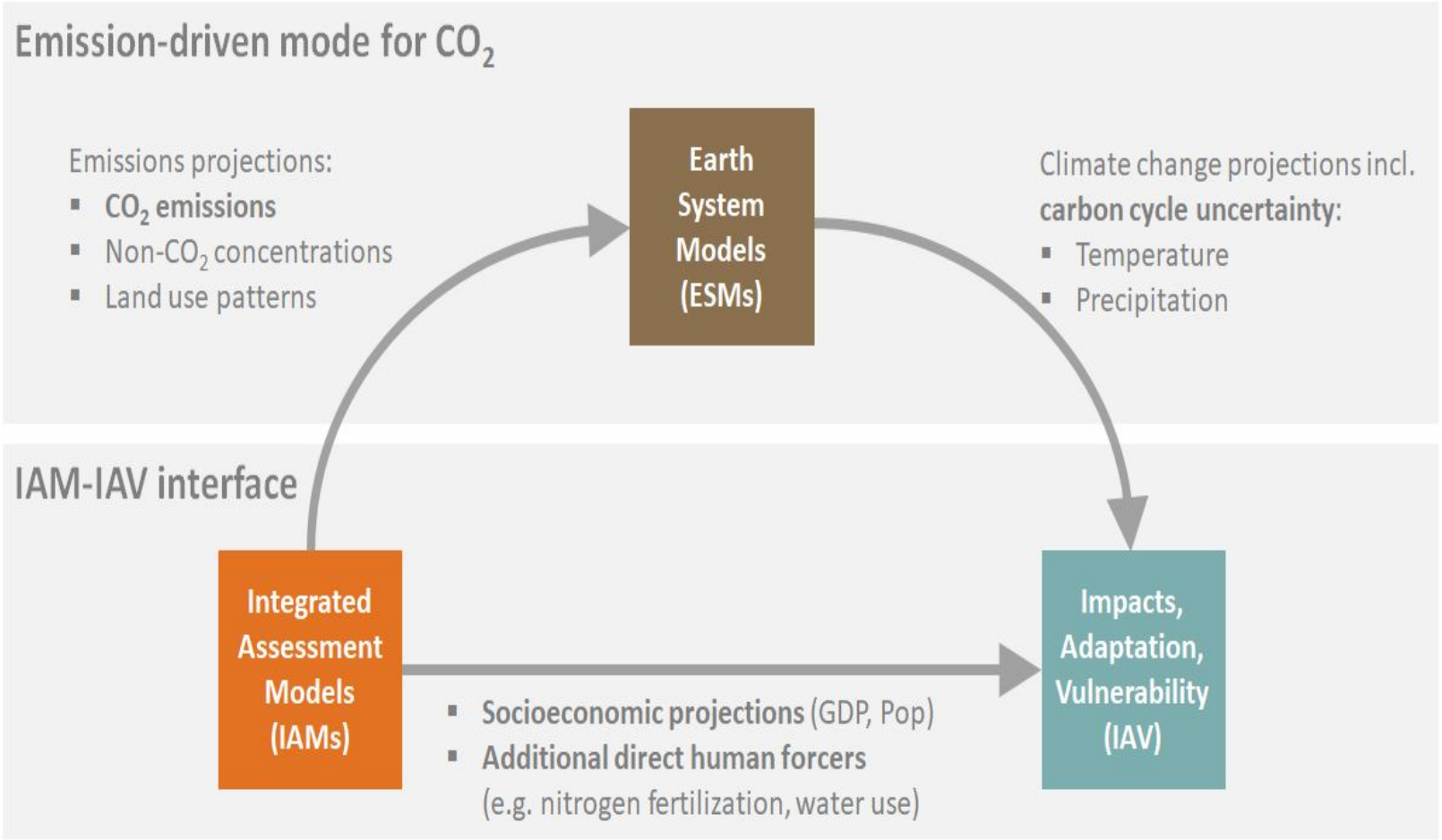
- What are the transmission channels? Role of DHF?
- How do development and climate change interact?
- What adaptation strategies support development?

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

OptimESM Optimal high resolution **Earth System Models** for exploring future climate change

Funded by the European Union

Assessing Climate Change: The Trinity of Communities



ScenarioMIP requests that the IAM teams produce simulations that do not include climate change impacts on managed systems (e.g. agriculture, energy use, or economic growth). At this point in time, there are two main reasons for this.

First, one of the main uses of the scenarios and their climate outcomes is to drive **impacts estimation by the impact modeling community, which uses both the climate projections and the direct human drivers** (such as land use and agricultural systems changes) as input to their analyses.

If the IAM scenarios (and therefore the climate projections based on them) already include impacts, further impact modeling based on these scenarios would lead to double counting.

[Note: it is not explicit where the DHFs come from.]

ScenarioMIP & DHF

Socioeconomic drivers: Population and GDP ⇒ exogenous to IAMs

IAMs and Marker Scenarios to be run in ScenarioMIP/CMIP7

- Smallest Common Denominator SCD problem
- Models report different variables and sectoral/regional resolutions
  ⇒ Substantial constraint for comprehensive DHF basis
- If ISIMIP does not use all ScenarioMIP scenarios the SCD is greatly reduced
- Is blending/infilling a potential compromise?
  - climate forcers from marker models
  - DHFs from different model

Fast-Track (I): An un-official assessment of potential DHF data

Variable	IAM representation	Resolution	Gridding	Comments
PV-demand, wind energy demand	Capacities GW and electricity generation EJ/yr	Native model regions	Potential downscaling using wind and solar atlas	Requires area exclusions
Diets	Calorie intakes cal/day	Native model regions; maybe even national (only REMIND-MAgPIE	Urban/rural split enough?	Are averages useful? SDG
Peat land	Not standard in IAMs; in REMIND-MAgPIE, IMAGE	Native model regions	REMIND-MAgPIE 0.5°, IMAGE not known	Drained, intakt, rewetted
Grassland	in REMIND-MAgPIE Differentiation in rangeland and managed pasture		0.5° grid	Comes with LUH3 => compromise infilling
N deposition per crop type	Open, to be clarified			
Fertilizer input per crop	5 different types (C3/4, annual/perenniel, N-fixing)	Native model regions	0.5° grid	Comes with LUH3 => compromise infilling
Livestock numbers	Livestock production levels ruminant (not animal numbers)	native model regions	none	
Irrigation per crop	Teams are asked to report REMIND-MAgPIE yes	Native model regions	0.5° grid	Comes with LUH3 => compromise infilling

Fast-Track (II): An un-official assessment of potential DHF data

Variable	IAM representation	Resolution	Gridding	Comments
Forest harvests	Teams are asked to report, REMIND-MAgPIE yes	Native model regions	0.5° grid	Comes with LUH3 => compromise infilling
Forest management	Classification needs clarification Teams are asked to report, REMIND-MAgPIE yes			Comes with LUH3 => compromise infilling
Hydropower dams and reservoir	Hydropower capacities	Native model regions	Post processing	Tool available, but needs update
non-irrigation water use	Drivers are available	Native model regions		Tools available, but need updates
irrigation efficiency	Exogenous assumptions			
sea water desalination	None, not yet			Working on it, but uncertainty about readiness
inter-basin water transfer	None			
Biological fixation	Unclear, what that means here			
Residential cooling energy demand	Varies in resolution and detail	Native model regions		Definition of this variable depends on research question
Air pollution, O3 precursors	Full suite		Available via Climate Forcers	Standard input to ESMs

Are simulations further limited by missing climate related forcing data?

For example

- sub-daily climate data seems to be valuable for many sectors
- higher spatial resolution of climate data
- heat exchange between lakes and the atmosphere (lakes)
- drought indices

We can also make use of the panel discussion to collect more missing data/variables and gather further CRF needs

Panel discussion

FishMIP: Tyler Eddy
Lakes: Don Pierson
Groundwater: Robert Reinecke
Water-global: Yadu Pokherel
Fire: Matt Forrest
Peat: Michel Bechthold
Biomes: Christopher Reyer
Biodiversity: Damaris Zurell
Agriculture: Sam Rabin
Energy: James Glynn

What are the needs in terms of DHF, CRF or (output from other sectors) to address relevant questions related to the impact socio-economic changes in the future?
Where could this data come from?

Direct Human Forcing for climate impact simulations

Needs of DHF data by Sectors:

Lakes: no use of DHF data with the current model set up. If a dynamic water level is implemented, **dam construction and demolition data** will be needed. If water quality modelling is implemented, (at least) **phosphorus and nitrogen data** controlled by the **changes in land use** will be needed. Ana (Uppsala) working with Ana's (VUB) are developing a method to estimate global nutrient loads. Connection between LU and loading therefore does seem to be a relevant issue.

Agriculture:

necessary: fertilizer, N-deposition (wet/dry*NOx/NHy), growing seasons

nice to have: LU, Irrigation amounts and timing, cultivar characteristics other than growing season length

Direct Human Forcing for climate impact simulations

Needs of DHF data by Sectors:

Peat:

necessary: the currently included data, but key need is peatland-specific LU change;

nice to have: peatland management (drainage, rewetting, and further specification and hydrological information), further wetland types (e.g. rice fields)

Labour:

necessary: population data

nice to *have:* land use change data might be interesting as we investigate labour force transition. These changes will likely influence the agri-food system workers.

Direct Human Forcing for climate impact simulations

Needs of DHF data by Sectors:

Biomes:

Necessary: Land-use incl. irrigated areas and natural/semi-natural vegetation change (e.g., between grassland/pasture and forest, forest management), N-inputs (atmospheric deposition, fertilzer, & manure), pop. density, non-irrigation water uses

Nice to have: more information on agricultural management aspects, i.e. crop calendar, residue management; information on pasture management, e.g. grazing density or mowing intervals etc

Direct Human Forcing for climate impact simulations

Links between ISIMIP sectors and IAM community

Lakes: drying of lakes and the demolition of dams (in terms of greenhouse gas emissions); heat exchange between lakes and the atmosphere (in relation to global climate change)

Agriculture: *sector -> IAMs:* crop yield changes in response to climate change and management inputs, irrigation water requirements per hectare/season

IAMs -> sector: LU, fertilizer use, irrigation extent

All models require fertilizer inputs; probably all require growing seasons; and some models require additional inputs such as N deposition and land use areas.

Issues: for consistency with IAMs, productivity levels would be good to calibrate the models to

Needs: Data is needed as package, faster and more reliable data provision

Direct Human Forcing for climate impact simulations

Links between ISIMIP sectors and IAM community

Peat: scenarios for future LU change for peatlands, though currently no established connection to IAM modelers

Labour: MAgPIE can already account for labour impacts, potential to extend the work using empirical temperature-labour supply damage functions developed within ISIMIP; Collaboration underway with IMACLIM-R and IMAGE to integrate our labour supply damage functions.

Biomes: connections with LU data (Yields in the IAMs/landuse models are often different from yields simulated by the impact models⇒Consistency in cropland, pasture and bioenergy targets, likewise for N fertilization)

- Land use projections including CDR options such as afforestation, enhanced weathering, biochar amendment, etc

Direct Human Forcing for climate impact simulations

Links between ISIMIP sectors and IAM community-affected processes and experiments

Lakes: lake-atmosphere heat exchange (with current model setups); for greenhouse gas emissions, lake water level dynamics will need to be implemented

Direct Human Forcing for climate impact simulations

Shortcomings/inconsistencies in the existing data sets

Lakes: Temporal resolution: there is important diurnal variability interacting with non- linear relationships that is not captured in the daily time step, thus sub-daily time step resolution data sets are needed to explore this issue

Biomes:

- LU Harmonization does not preserve internal consistency within a scenario from LU model
- VISIT: I am not sure whether current scenarios consider simultaneous achievement of net zero emission and nature positive by 2030. There may be rooms for improvement.

Direct Human Forcing for climate impact simulations

Shortcomings/inconsistencies in the existing data sets

Lakes: Adding water level dynamics and river inflows and outflows are indispensable to run real lakes. The ISIMIP lake sector now uses a representative lake and it's watershed chosen to represent the lake processes in each ISIMIP grid cell. Finding ways to couple these to the mean grid level outputs will be and important step to implementing more complex lake modelling that includes biogeochemistry. Ana (Uppsala) is working on this. I don't know how important this is - we are doing much modelling on a daily time step now. But at the same time we know that there is important diurnal variability interacting with non- linear relationships that is not captured in the daily time step. Would it be worthwhile to provide some sub-daily time step resolution data sets to begging to explore this issue?

Our perspective: consistent energy demand