International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

SUPREMA GLOBIOM-MAGNET Training

December 4, 2020

Baseline and scenarios

Center for Environmental Resources & Development

Presenter: Hugo Valin

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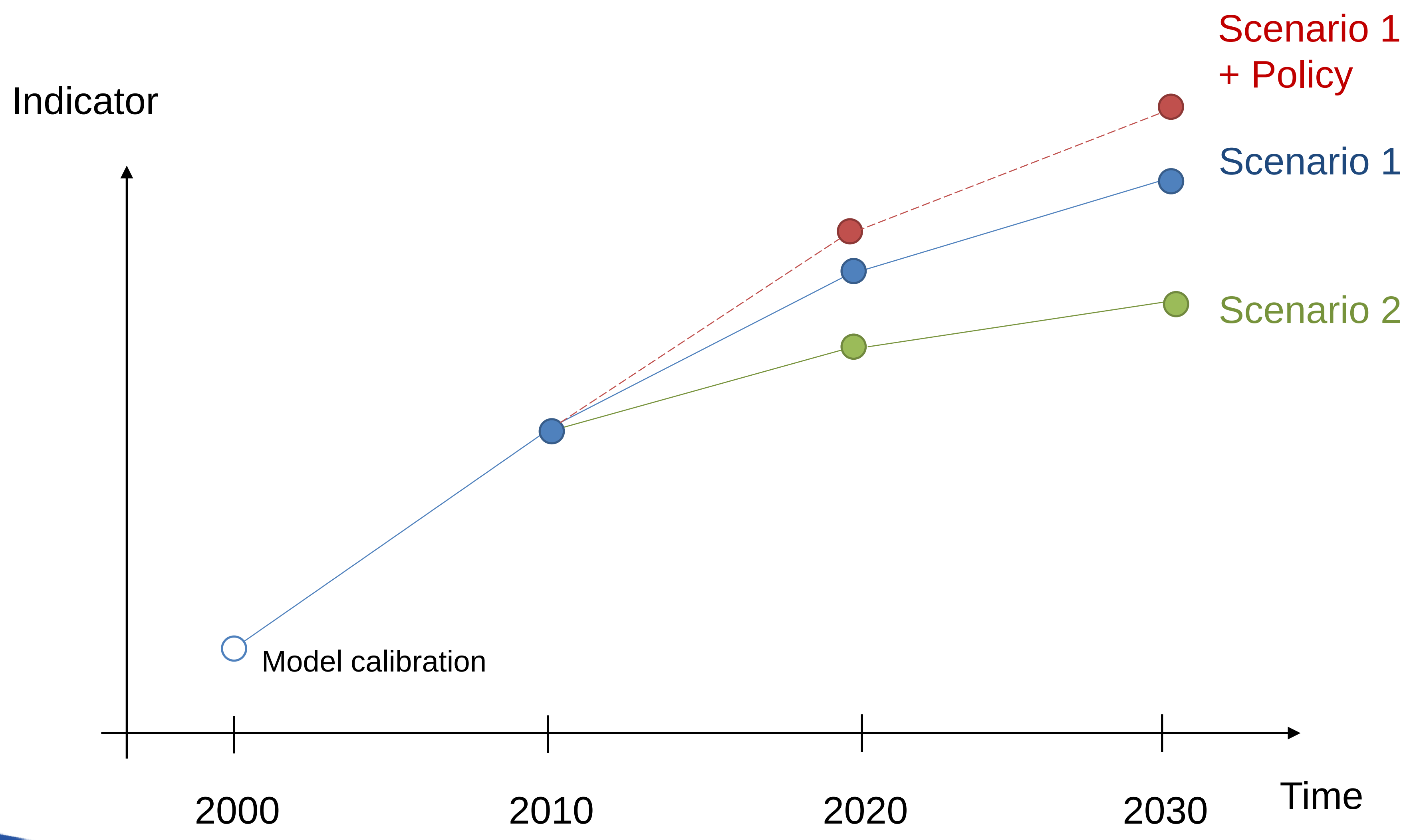
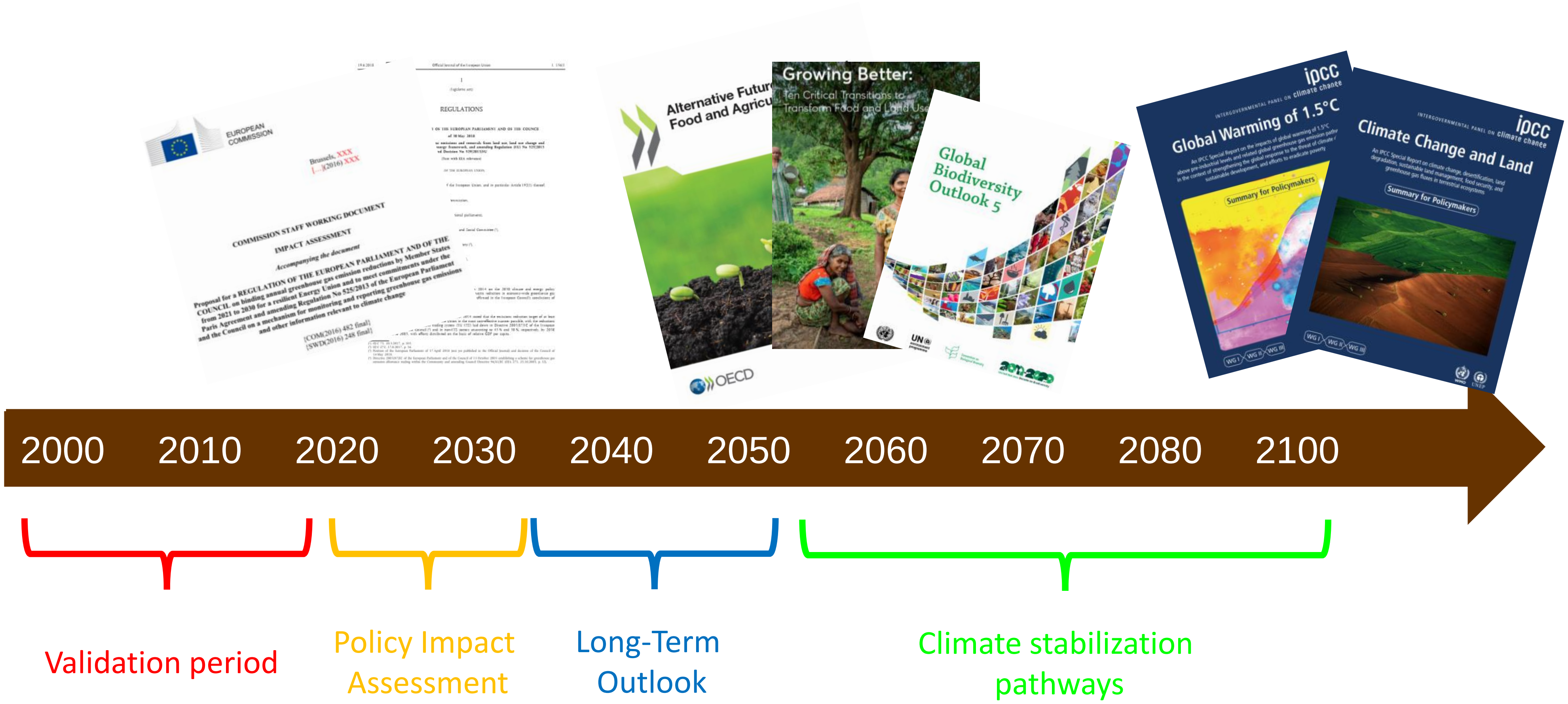
suprema

Baseline and scenarios with GLOBIOM

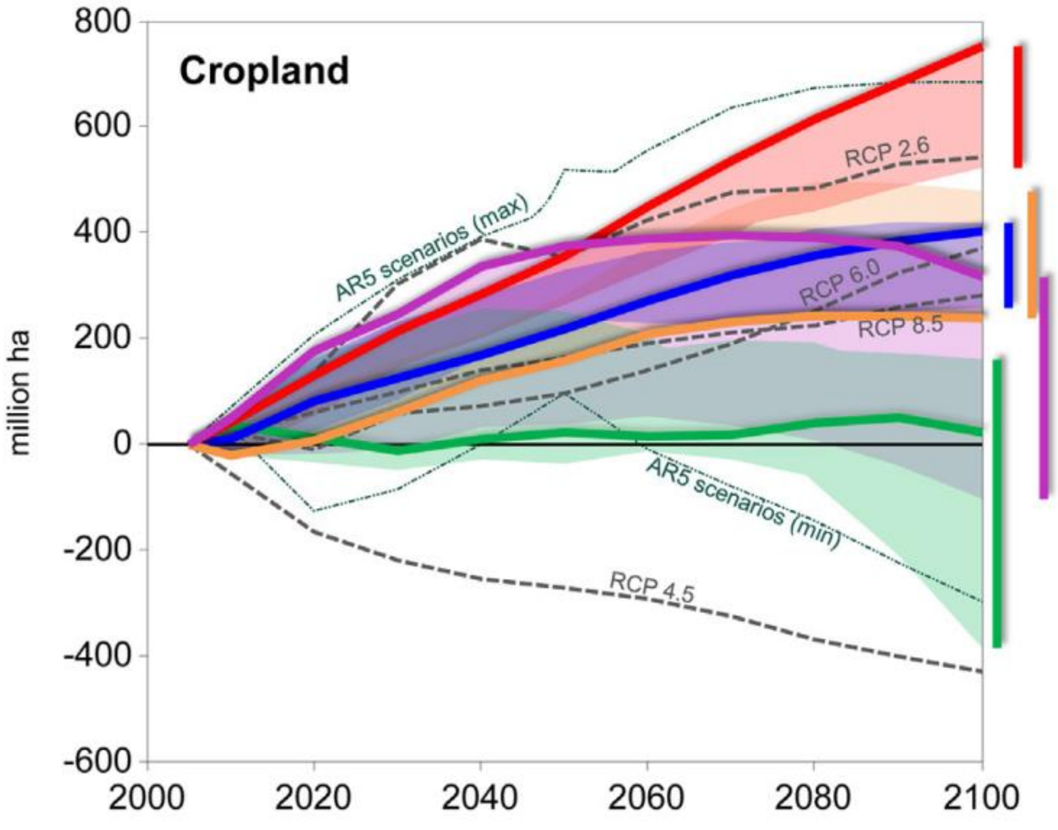


Time dimension and applications

- GLOBIOM: 10-year time steps (standard), 5 years, 1 year



Some GLOBIOM baseline repositories



Source: Riahi et al. 2017

- SSP database

  https://tntcat.iiasa.ac.at/SspDb/

- AgMIP/AgCLIM50

  https://datam.jrc.ec.europa.eu/

- 1.5°C Scenario Explorer

  https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/

Digging into the baseline / scenario code

```
***
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* Top-level script of the GLOBIOM model. It executes the numbered stages of
* the model in-sequence, passing the output of a stage as input to the
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$set env ide=%gams.ide% lo=%gams.lo% errorlog=%gams.errorlog% errmsg=1 pw=130 cerr=5

$setLocal X %system.dirSep%
execute "gams 1_loaddata.gms          %env%                          -s .%X%t%X%a1_v1                    ";
execute "gams 2_activesets.gms        %env% -r .%X%t%X%a1_v1         -s .%X%t%X%a2_v1   gdx=.%X%gdx%X%a2_v1 ";
execute "gams 3_precompute.gms        %env% -r .%X%t%X%a2_v1         -s .%X%t%X%a3_v1   gdx=.%X%gdx%X%a3_v1 ";
execute "gams 3b_calibtrade.gms       %env% -r .%X%t%X%a3_v1         -s .%X%t%X%a3b_v1 gdx=.%X%gdx%X%a3b_v1";
execute "gams 4_model.gms             %env% -r .%X%t%X%a3b_v1        -s .%X%t%X%a4_v1   gdx=.%X%gdx%X%a4_v1 ";

*execute "gams 5_precompute_scen.gms  %env% -r .%X%t%X%a4_v1         -s .%X%t%X%a5_v1   gdx=.%X%gdx%X%a5_v1";

* Identifier of the output file
$set output_name Baseline_may18_adj

execute "gams 6_scenarios.gms         %env% -r .%X%t%X%a4_v1         -s .%X%t%X%a6_v1_test  gdx=.%X%gdx%X%a6_v1_test";

*execute "gams 7_output.gms  %env%  -r .%X%t%X%a6_v1  //CSV=1 //lab=%output_name%";

***
* Arguments for ``7_output.gms``:
*   - ``//CSV=1`` for production of a CSV file using GDXVIEWER.

* Use this command to convert a .g00 into .gdx
*execute "gams blank.gms               %env% -r .%X%t%X%a6_v1 gdx=.%X%gdx%X%a6_v1  FW=1"
```

Scenario listing

- Scenarios can be run in GLOBIOM with two methods:
  - All scenarios the ones after the other (can take some time)
  - Scenarios can be run separately with an argument to the 6_scenario.gms file (nsim) → Allow for distributed computing on servers and computer clouds

- Scenario assumptions can be set-up as:
  - Parameter changes
  - Change in optimization function (new tax or subsidy, new preferences)
  - New set of constraints (extra active equations)

    –> additional scenario equation file

Scenario parameter updates

- The scenario file define parameters value depending on the framing PE assumptions
  - Large part of the scenarios are derived from the SSP assumptions used for GLOBIOM
    0) Population
    1) Technical progress for crops and livestock sector
    2) Losses and waste scenarios
    3) Food demand scenarios
    4) Land use change scenario
    5) Afforestation scenario
    6) Wood sector scenarios
    7) Biofuels and bioenergy scenarios
    8) Trade policy scenarios
    9) Climate policy scenarios

Shared Socio-economic Pathways (SSPs)

Source: O'Neill et al. (2015)

SSP2: Middle of the Road

General

- medium economic growth overall
- slow convergence between LIC and HIC
- **inequality remains high**
- population growth moderate – high in some LICs
- **reducing resource intensity** (slower than SSP1)
- **reducing fossil fuel dependency** (slower than SSP1)
- **uneven planned urbanization in LIC**
- world economy fragmented – **reduced flows of trade and technologies**
- **rapid technological change in HIC** but not shared with LIC

Agriculture

- **trade barriers in agricultural markets remain**

GLOBIOM SSP scenario elements

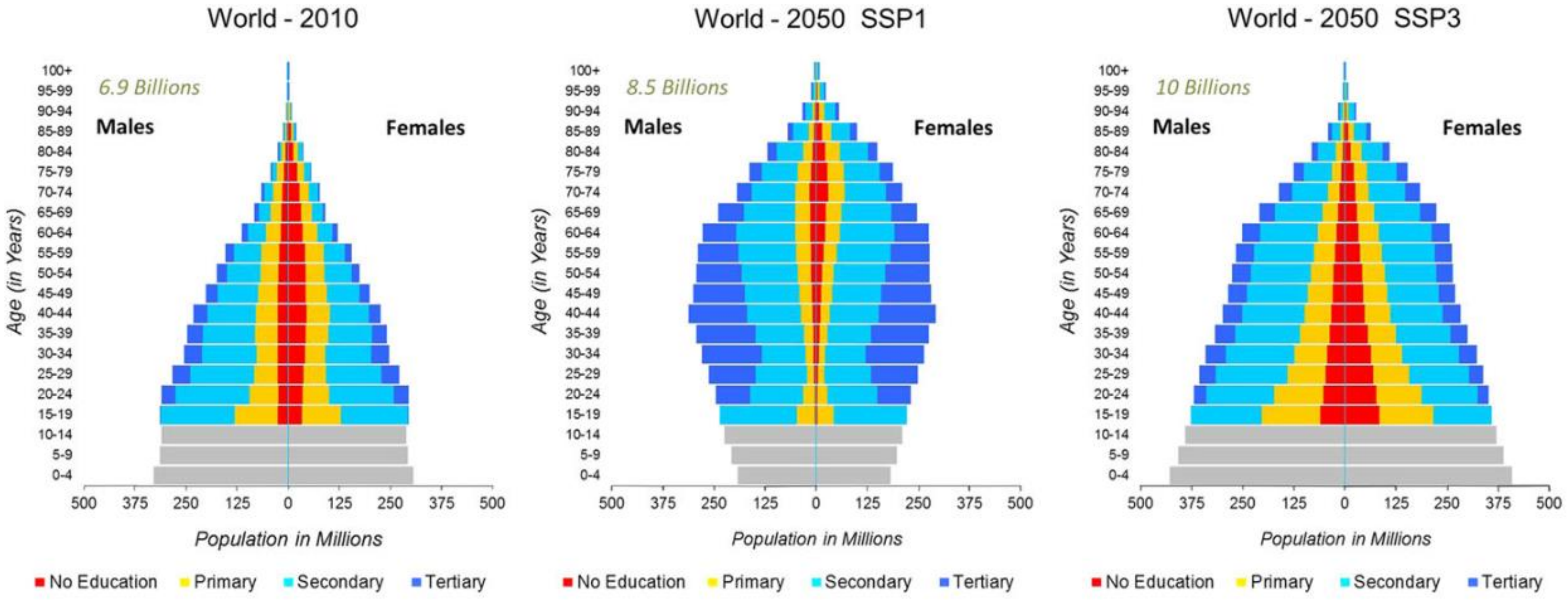
Source: Fricko et al. (2017)

Agriculture and land use			
	SSP1	SSP2	SSP3
Net deforestation	Afforestation *(No net deforestation by 2050, +3% forest area by 2100 compared to 2010)*	Deforestation/Afforestation (Forest loss of 1% by 2050, back to 2010 area by 2100)	Deforestation *(Net forest loss of 3% by 2050 and 6% by 2100 compared to 2010)*
Land productivity growth			
Crops: Yields	High yield growth *(Annual yield growth from 0.51% p.a. in the North to 0.66% in the South)*	Moderate yield growth *(Annual yield growth from 0.46% p.a. in the North to 0.60% in the South)*	Slow yield growth *(Annual yield growth from 0.35% p.a. in the North to 0.35% in the South)*
Crops: Input intensity	Low intensity *(Elasticity of variable inputs incl. fertilizer use wrt technological change: 0.75)*	Medium intensity *(Elasticity of variable inputs incl. fertilizer use wrt technological change: 1.00)*	High intensity *(Elasticity of variable inputs incl. fertilizer use wrt technological change: 1.25)*
Livestock: Feed conversion efficiency	Enhanced efficiency growth *(Annual feed conversion efficiency change from 0.10% in the North to 0.26% in the South)*	Moderate efficiency growth *(Annual feed conversion efficiency change from 0.10% in the North to 0.24% in the South)*	Slow efficiency growth *(Annual feed conversion efficiency change from 0.07% in the North to 0.14% in the South)*
Livestock: Endogenous productivity growth	High livestock systems transition *(Annually, up to 5% of livestock production systems can be converted to an alternative system or the activity can be abandoned)*	Medium livestock systems transition *(Annually, up to 2.5% of livestock production systems can be converted to an alternative system or the activity can be abandoned)*	Low livestock systems transition *(No adjustment in the ruminant production system structure)*
Environmental impact of food consumption			
Food demand	Slow consumption growth and more sustainable and healthy diets *(Calorie consumption per capita growing – North : 1%, South: 16%. Livestock product share decreases in North by one third but increases in South, leading to a stable share of 15% globally)*	Moderate consumption growth and increasing share of livestock products in the diet *(Calorie consumption per capita growing by 11% in the North and 22% in the South. Livestock product share in the diet growing from 15% to 18%.)*	Substantial consumption growth but lagging demand for animal proteins in diet in the South *(Calorie consumption per capita growing by 5% in the North and 15% in the South. Livestock product share stays at 15%.)*
Losses & Wastes	Fast reduction of losses & wastes (L&W) *(L&W in the processing chains reduced from 12% to 7% in the Oilseed and Pulses sector and from 7% to 2.5% in the dairy sector over 2000 and 2050)*	Medium reduction of losses & wastes (L&W) *(L&W in the processing chains reduced from 12% to 7.5% in the Oilseed and Pulses sector and from 7% to 3% in the dairy sector over 2000 and 2050)*	Slow reduction of losses & wastes (L&W) *(L&W in the processing chains reduced from 12% to 9% in the Oilseed and Pulses sector and from 7% to 4.5% in the dairy sector over 2000 and 2050)*

SSPs: Quantitative elements

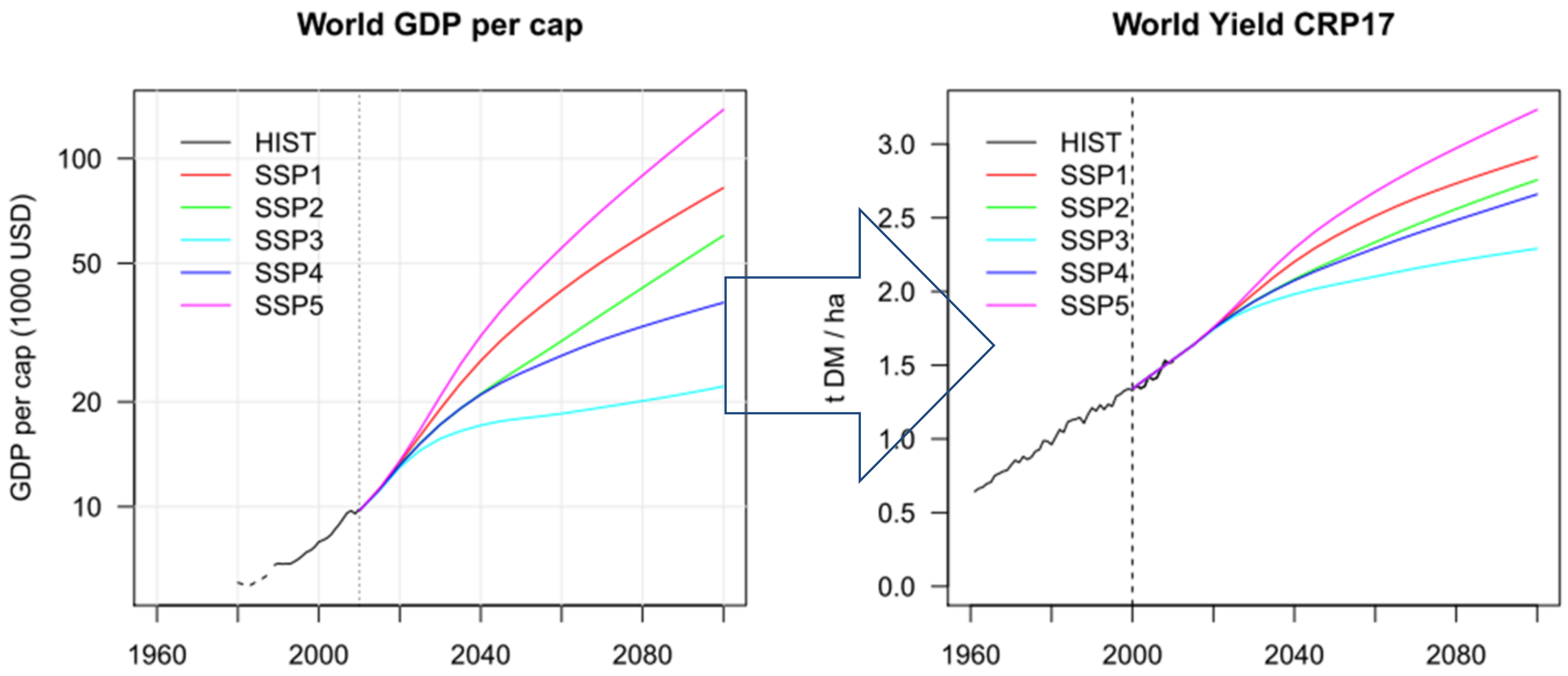
- `MACROSCEN_DATA`

Population



Source: KC & Lutz, 2014

GDP and yield development in GLOBIOM

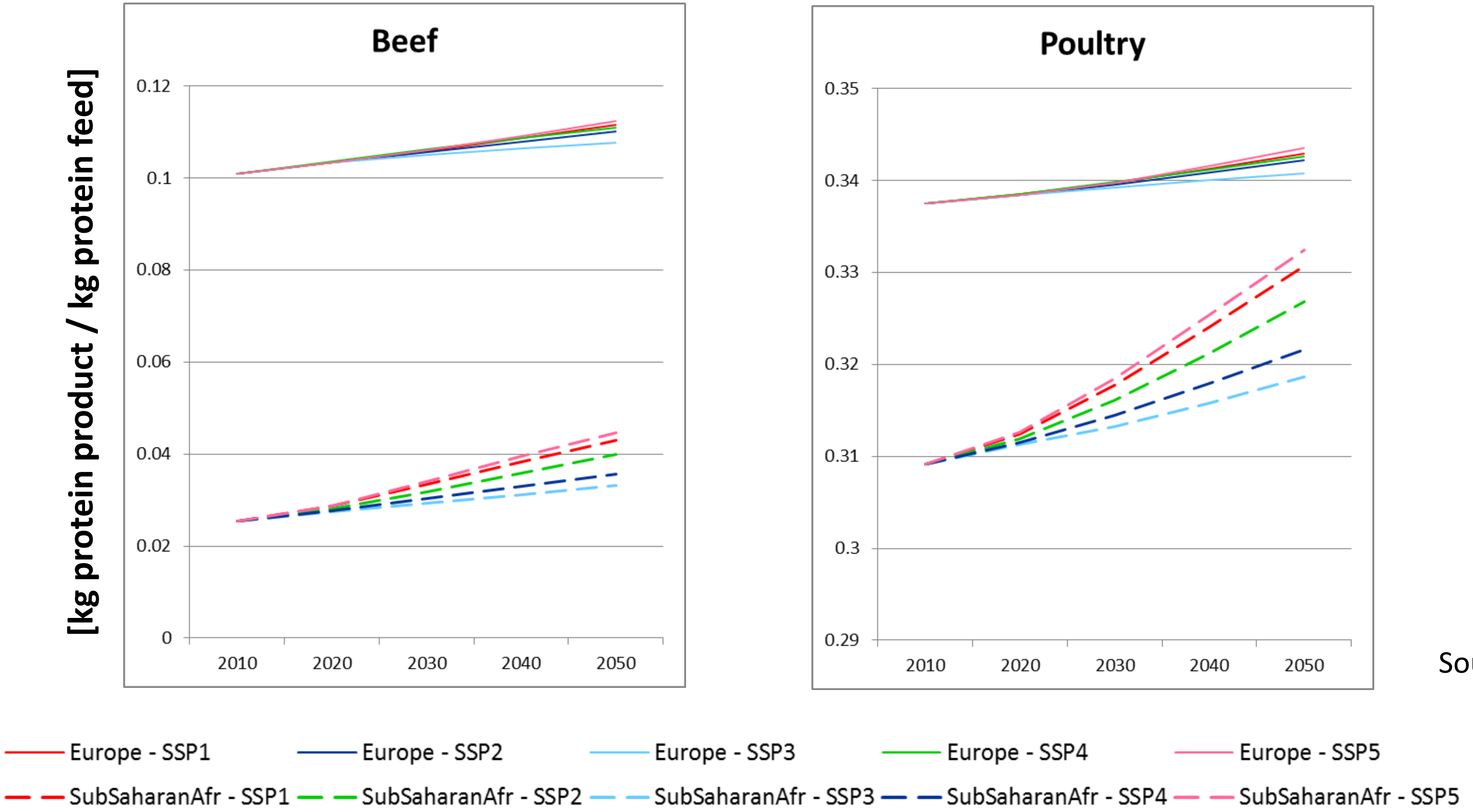


Source: GDP: Dellink et al. (2017), Yield: Herrero et al. (2014)

Crop yield developments projected as a function of GDP per capita
based on econometric estimation on 1980-2010, and 4 income group clusters.

Feed conversion efficiencies across SSPs

- GrowthRel2000_AnimalChange_Data



Source: Herrero et al. (2014)

Scenarios input for diets

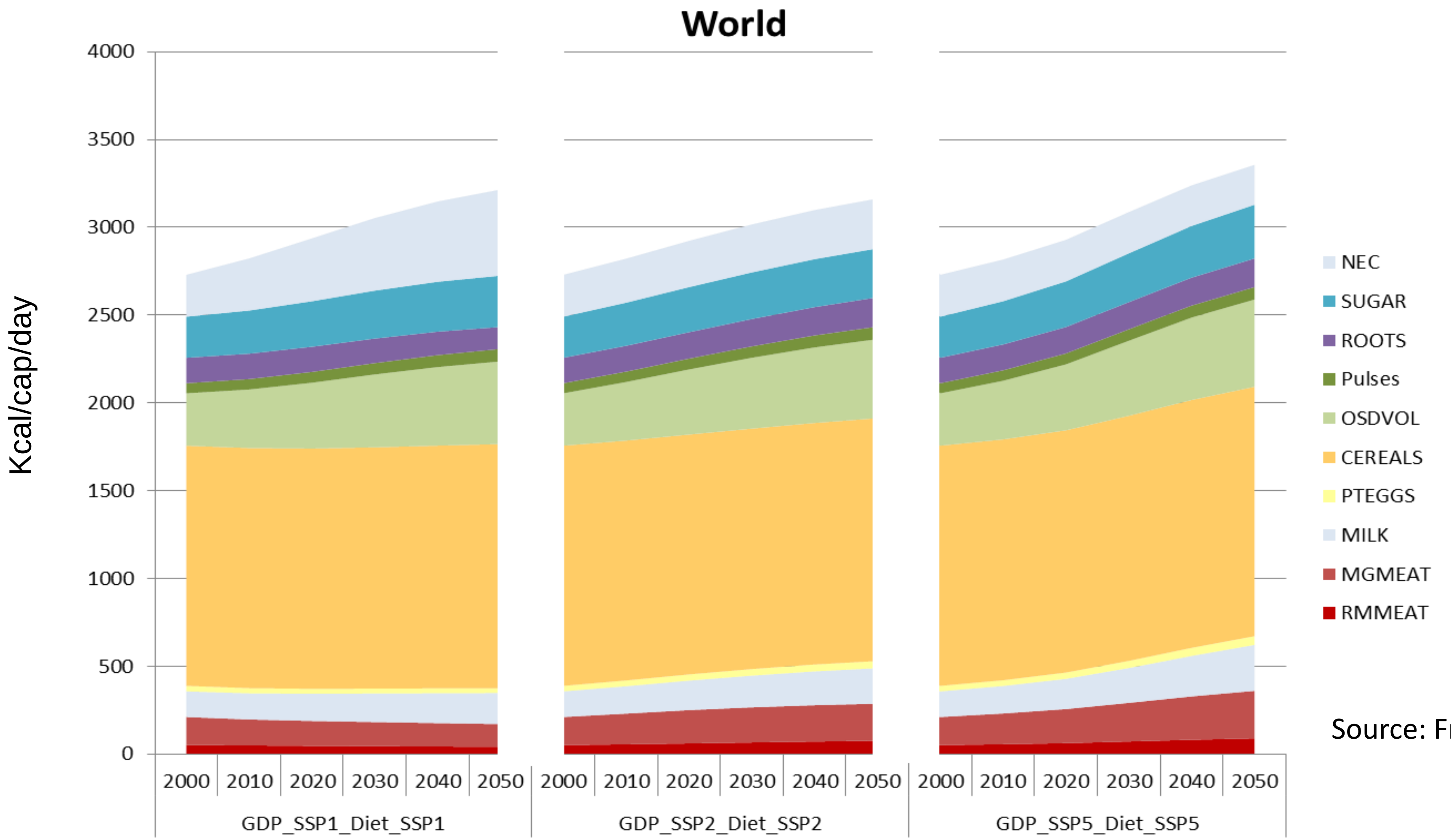
- Different set of scenarios already implemented:
  - Business as usual (SSP2)
    - FAO trends based on linear extrapolation
  - Sustainable diets (SSP1)
    - Sustainable diets targetting proteins and energy intake taking into account initial level of consumption in each product
  - Western diets (SSP5):
    - Countries converge to diets of USA & Europe composition
  - EAT-Lancet Diet

	Macronutrient intake grams per day (possible range)	Caloric intake kcal per day
Whole grains		
Rice, wheat, corn and other	232	811
Tubers or starchy vegetables		
Potatoes and cassava	50 (0–100)	39
Vegetables		
All vegetables	300 (200–600)	78
Fruits		
All fruits	200 (100–300)	126
Dairy foods		
Whole milk or equivalents	250 (0–500)	153
Protein sources		
Beef, lamb and pork	14 (0–28)	30
Chicken and other poultry	29 (0–58)	62
Eggs	13 (0–25)	19
Fish	28 (0–100)	40
Legumes	75 (0–100)	284
Nuts	50 (0–75)	291
Added fats		
Unsaturated oils	40 (20–80)	354
Saturated oils	11.8 (0-11.8)	96
Added sugars		
All sugars	31 (0–31)	120

Source: Willet et al. (2019)

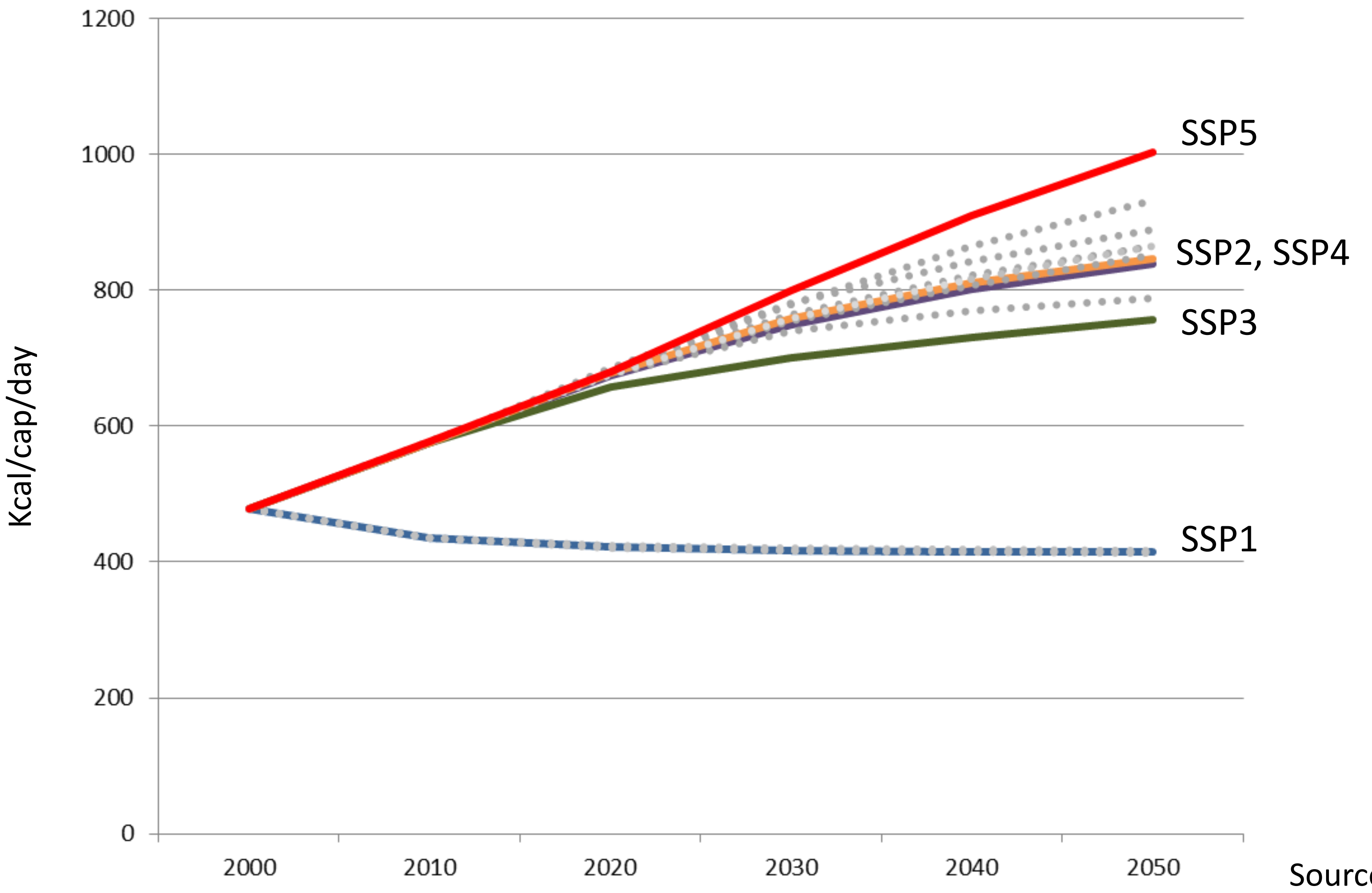
Quantification of diet preferences

- EXODEM_G / EXODEMCAP_G



Source: Fricko et al. (2017)

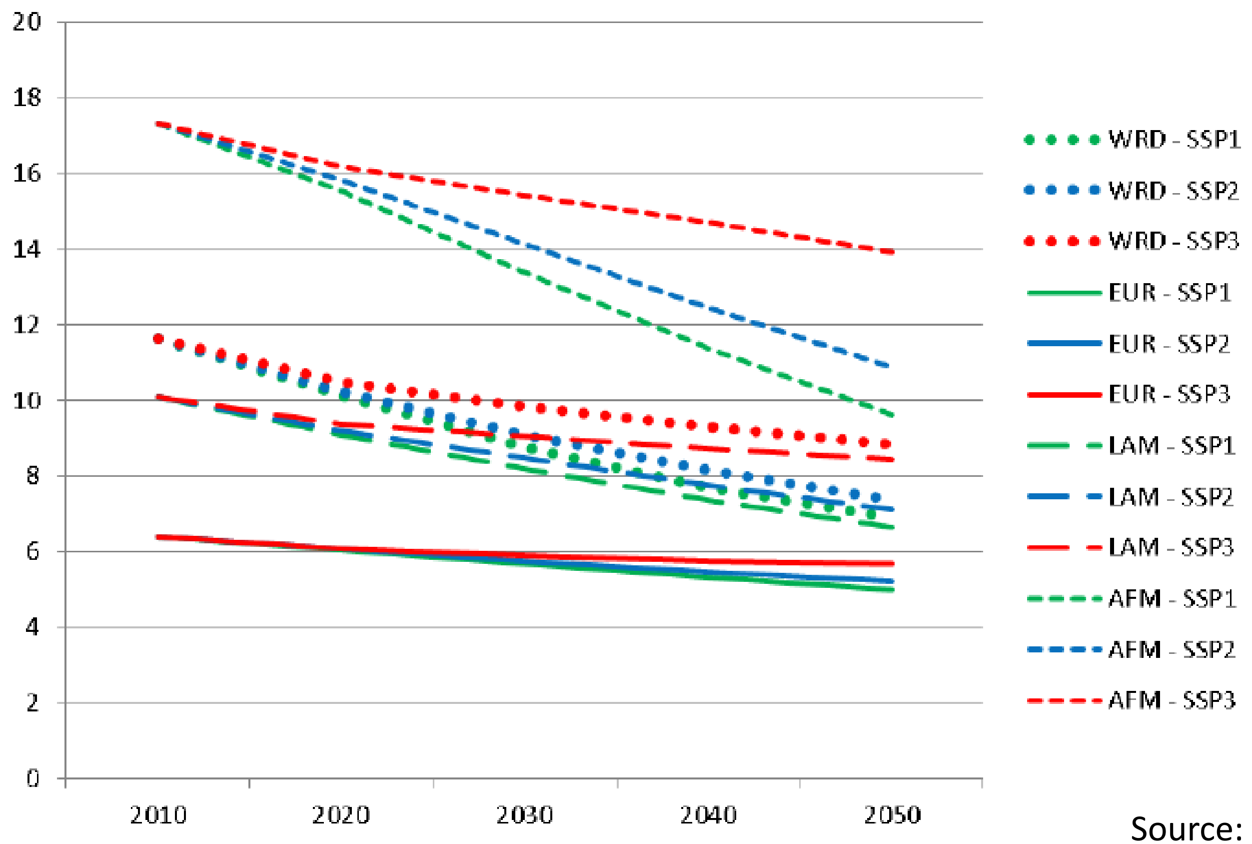
China – Animal products food consumption



Source: GLOBIOM results

Losses and waste across the supply chain

- GrowthRel2000_LossWaste_Data



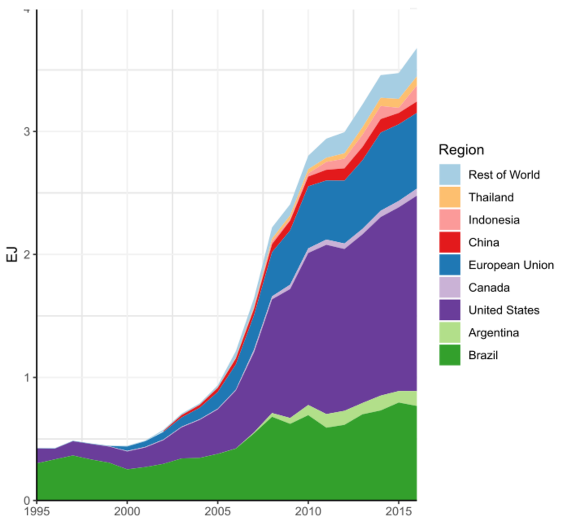
Source: Herrero et al. (2014)

Losses and waste development in the Oilseeds and pulses sector (%)

Other scenario elements

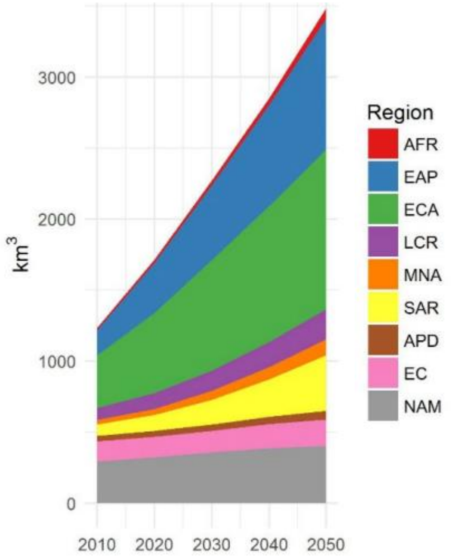
- Afforestation levels (from G4M model)
  - Different scenarios available in `G4Mbase_Data`
- 1st generation biofuel scenario
  - Projections used from AgMIP in `BFL_CROP_1G`
- Other biomass for bioenergy
  - MESSAGE SSP scenarios (IIASA SSP database)
- Trade
  - Trade cost change in `Trade_Scen_Data`
- Water availability for irrigation
- Impact shifter from vegetation models on crops, grass, forestry and fisheries yield

Biofuels



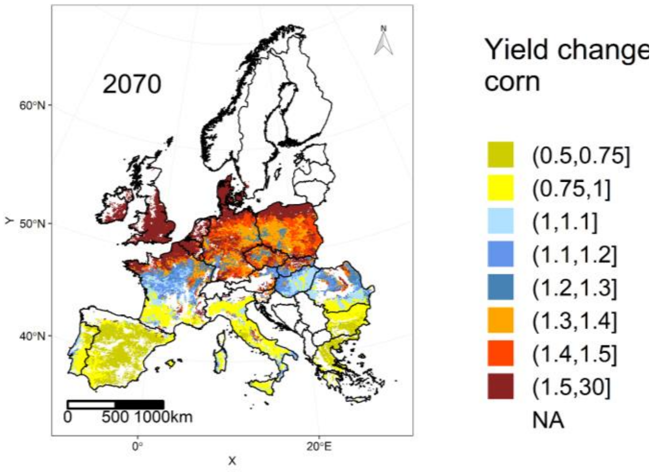
Source: IIASA (2021)

Water demand (industry, domestic)



Source: Palazzo et al. (2019)

Climate change impact



Source: Boere al. (2020)

Extracting GLOBIOM results

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* Identifier of the output file
$set output_name Baseline_may18

execute "gams 6_scenarios.gms         %env% -r .%X%t%X%a4_v2       -s .%X%t%X%a6_v2  gdx=.%X%gdx%X%a6_v2";

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```

The OUTPUT parameters

- Regional level results for parameters related to markets (flexible level of aggregation from the 37 regions)
- List of indicators with their units – several units available
- Spatially explicit indicators:
  - Directly through the model endogenous output (in particular for regional applications)
  - Through one further stage of downscaling (global down to 5 x 5 arcmin)

Indicators example: Production

- Crop production – Spatially explicit
  - AREA Area cultivated [1000 ha]
  - HARV Area harvested [1000 ha]
  - ARRF Area cultivated - rainfed [1000 ha]
  - ARIR Area cultivated - irrigated [1000 ha]
  - YEXO Exogenous crop yield [t/ha]
  - YILD Crop yield, harvested [t/ha]
  - YILM Crop yield, planted [t/ha]
  - YIRF Crop yield, harvested - rainfed [t/ha]
  - YIIR Crop yield, harvested - irrigated [t/ha]

- Livestock production – Spatially explicit
  - ANIM Animal number [1000 TLU]
  - FEEF Feed productivity (endogenous) [kg prot/t dm feed]
  - FEXO Exogenous feed productivity trend [kg prot/t dm feed]
  - LYLD Land productivity (endogenous) [kg prot/ha]
  - LYXO Exogenous land productivity trend [kg prot/ha]
  - ANFD Animal feed intake [1000 t dm]

Indicators example: Markets

- Macroeconomics
  - POPT Total population [Mln pers]
  - GDPT Total GDP [Bln USD 2005]
  - QBFL Mandated bioenergy [PJ, %]

- Market balances
  - PROD Production [1000 t, PJ]
  - CONS Domestic use [1000 t]
  - IMPO Imports [1000 t]
  - EXPO Exports [1000 t]
  - NETT Net trade [1000 t]
  - NTMS Net trade share in market volume [%]

  - FOOD Food use [1000 t]
  - FEED Feed use [1000 t]
  - BIOU Biofuel use [1000 t]
  - OTHU Other use [1000 t]

  - XPRP Real producer price [USD/t or USD/GJ]
  - XPRI Real producer price index [USD/t or USD/GJ] (aggregated as Laspeyres)

Indicators example: Impacts

- Environment – spatially explicit
  - LAND Land cover [Mha]
  - LRNT Land rent [USD/ha]

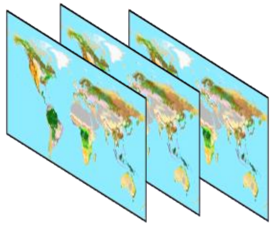
  - WATR Water for irrigation [km3]
  - FRTN Fertiliser N [1000 t]
  - FRTP Fertiliser P [1000 t]
  - BIID Biodiversity Intactness Index [0-1]

  - EMIS Emissions from agriculture [MtCO2eq]
  - ECO2 CO2 emissions [MtCO2eq]
  - ECH4 CH4 emissions [MtCO2eq]
  - EN2O N2O emissions [MtCO2eq]
  - ENCO Non-CO2 emissions [MtCO2eq]

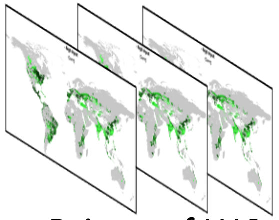
- Food security
  - XCPI Real consumer price index [USD/t or USD/GJ or USD/1000 kcal]
  - CALO p.c. calory availability [kcal/cap/d]
  - CALI net calorie intake [kcal/cap/day]
  - NUTR p.c. nutrient availability [g/cap/d]
  - UNDN undernourishment [Mln persons, %]

Spatially explicit results

Land use econometric downscaling



LUC Data 2000-2010



Drivers of LUC

$$\Pr(y_i = j) = \frac{\exp(\mu_{i,j})}{1 + \sum_{j=1}^{J} \exp(\mu_{i,j})}$$

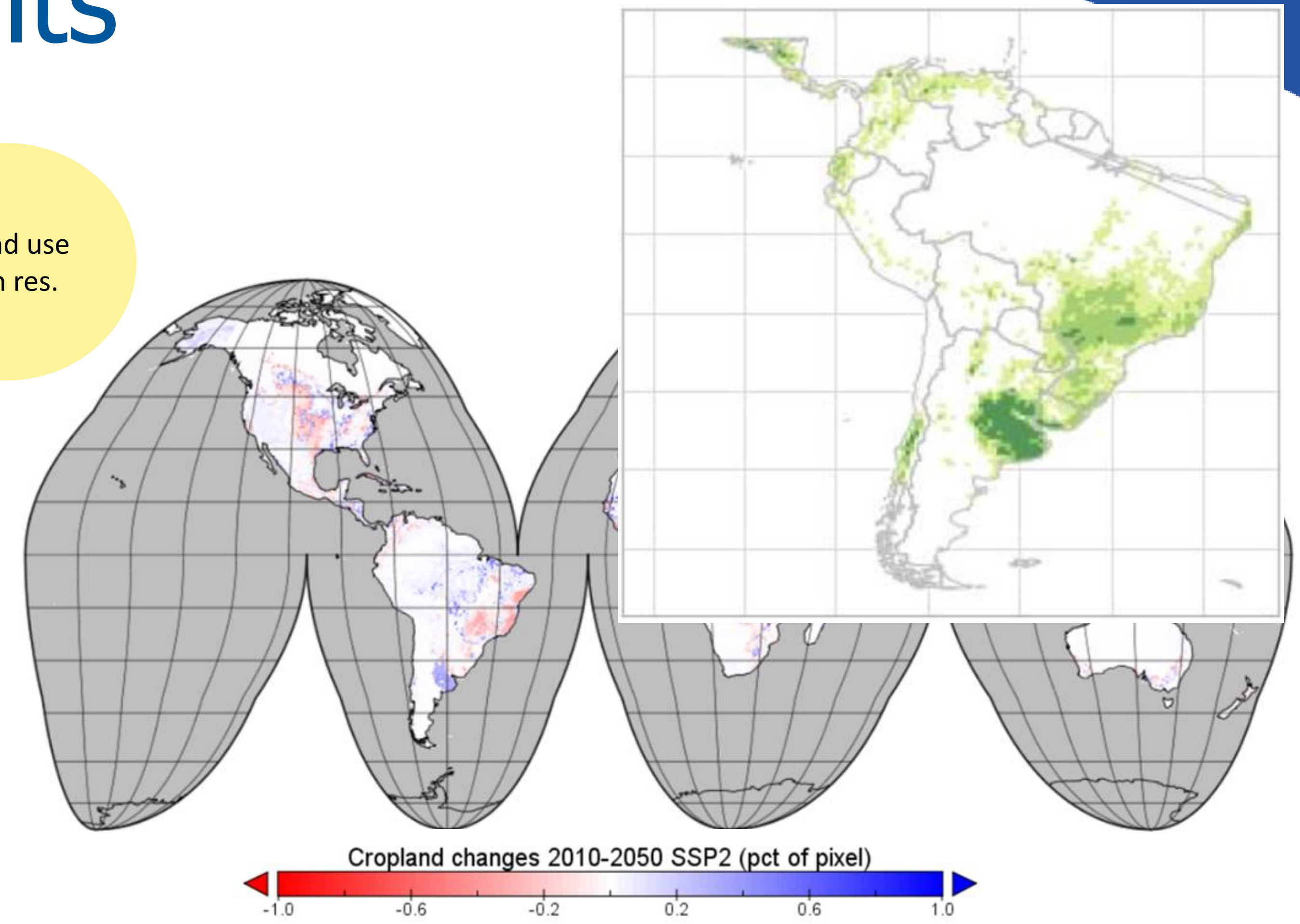
$$\boldsymbol{\mu}_j = \boldsymbol{X\beta}_j + \boldsymbol{W}(\phi)\boldsymbol{X\theta}_j + \boldsymbol{\iota}_N \alpha_j$$

Econometric Model

Δ land use high res.

Δ land use (regional)

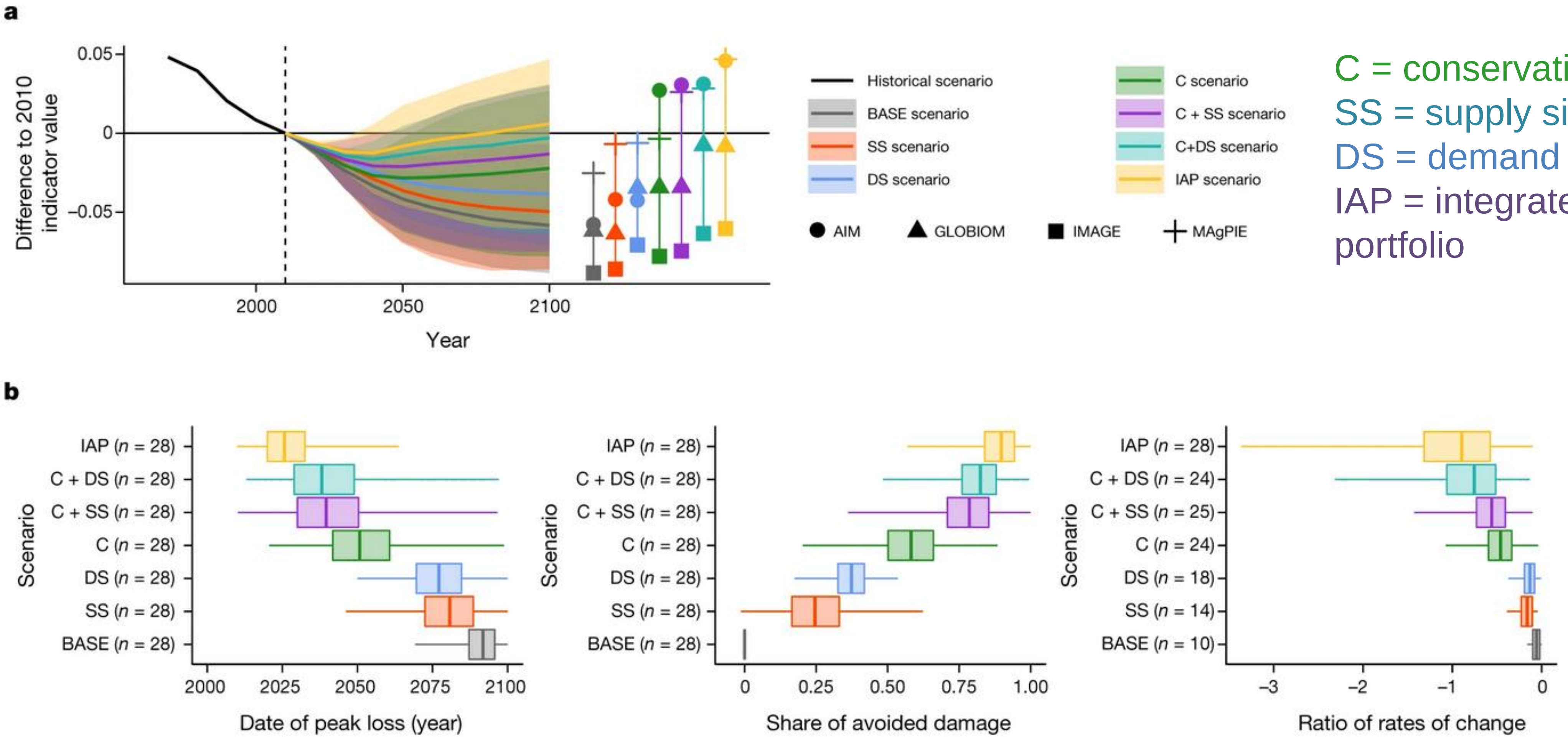
Krisztin et al., in prep.



Posterior projections of results along scenarios, 2010-2100
@ 5 arcminutes, 10 years

Example 1: “Bending the curve of terrestrial biodiversity”

Contributions of various efforts to reverse land-use change-induced biodiversity trends



C = conservation
SS = supply side
DS = demand side
IAP = integrated action portfolio

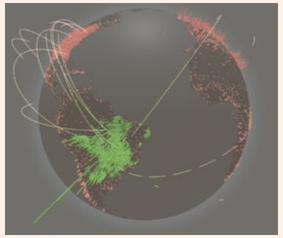
Source: Leclère et al., 2020, *Nature*, https://doi.org/10.1038/s41586-020-2705-y

Integrated set of parameter shifts and new constraints

Additional efforts to reverse trends in biodiversity

Increased conservation		Supply side		Demand side	
Increased extent and management of protected areas	Increased restoration and landscape-level conservation planning	Sustainably increased crop yields	Increased trade of agricultural goods	Reduced waste of agricultural goods from field to fork	Diet shift to a lower share of animal calories



No-go areas (constraints)

+ Subsidy on biodiversity

Faster yield increase

More flexible trade

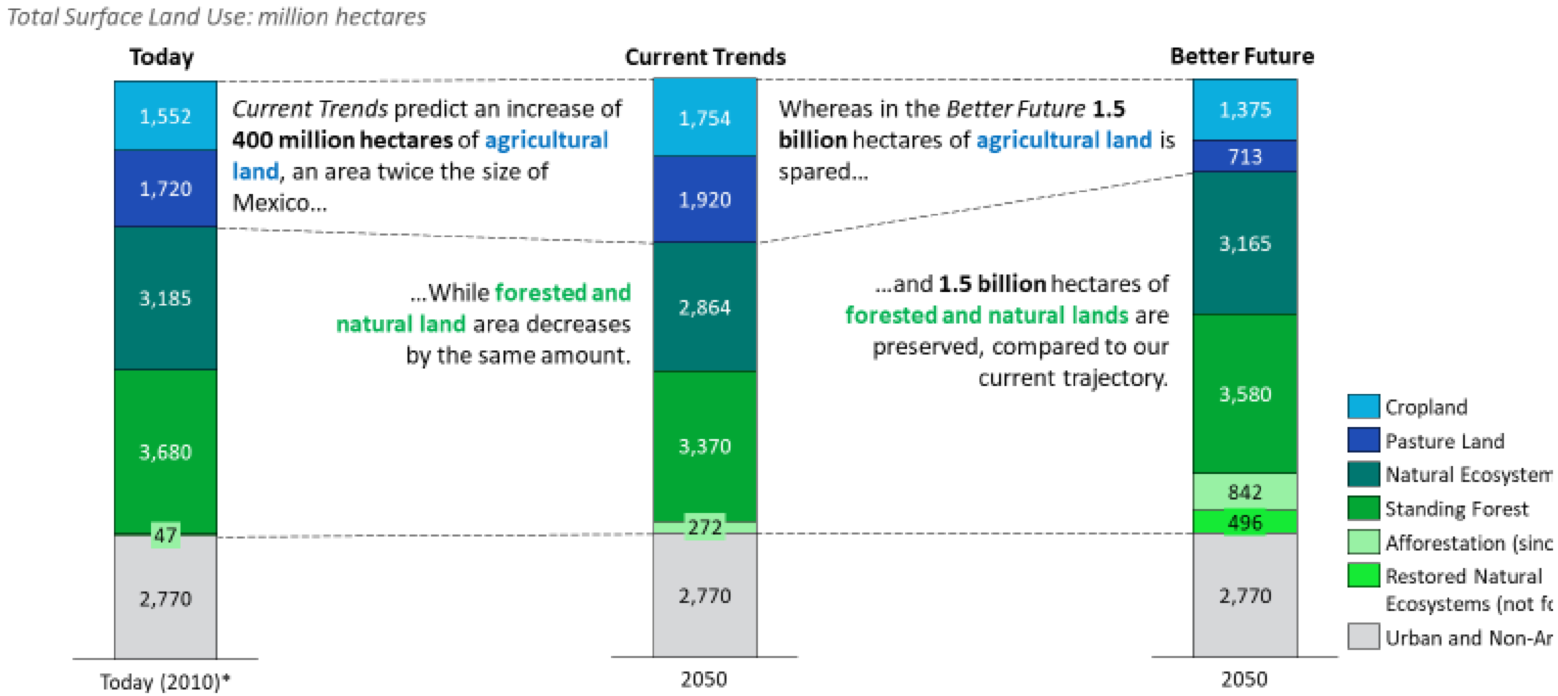
Food consumption shifts

Waste coefficient reduction

Source: Leclère et al., 2020, *Nature*, https://doi.org/10.1038/s41586-020-2705-y

Example 2: Food systems transformations

Source: Food and Land Use Coalition 2019



* Baseline data forecast from 2000

Source: *IIASA* GLOBIOM 2019

Note: According to IIASA estimates, parts of the permanent pastures, as defined in the IPCC 2019 Special Report on Climate Change and Land report, are pastures without significant contribution to total livestock production and thus, are included in the land use classification 'Natural Ecosystems Land'. The 'Pasture' land use classification includes only grassland utilized for agricultural production.

More information: https://www.foodandlandusecoalition.org/global-report/

FOLU Scenario assumptions overview

CC Mitigation		Biodiversity		Food Security
1.5 ° C target	**LED**	**Stopping BD loss**	**'Bending the Curve'**	**'Zero hunger'**
- additional demand for 82 EJ Energy from Biomass (in 2050) - GHG price: 238$ (2050)	- additional 11 EJ Energy from Biomass (in 2050) - GHG price: 129$ (2050)	- Protecting BD rich area - Stopping deforestation	- Land restoration into pasture and degraded land - 300$ BioD. Subsidy	- Ensure SDG2 is reached by 2030 - Population at risk of hunger < 1%

Healty and Sustainable Diets	Zero Net Deforestation	High Technical Progress	Trade Scenarios	
			Regionalization	**Facilitated trade**
- Switching to EAT-Lancet diets in 2050 - Reduction of food waste and losses	- Global Deforestation = Afforestation from 2030 on	- 10% higher increase in technical progress - Bridging yield gap 25% - cost and input neutral	- Stylized scenario: increase of trade costs between 37 GLOBIOM regions (trade costs increase)	- 50% trade cost reduction within Sub-Saharan Africa

Indicators FOLU "Growing better" report

2050: CURRENT TRENDS scenario

Deforestation
Deforestation continues at a rate of 6.7 million hectares (Ha) per year — **6.7 mHa/yr**

Agricultural land
The area of land dedicated to agriculture increases by 400 million Ha (12% of area today) — **400 mHa**

Restored natural land
225 million Ha are restored to natural ecosystems since 2010. — **225 mHa**

Biodiversity
Biodiversity loss continues to decline at a rate similar to the last 40 years. — **-3.2% loss**

Food and land use emissions
Emissions account for 12-13 $GtCO_2e$ putting a 1.5 degree future pathway out of reach. — **12-13 $GtCO_2e/yr$**

Food insecurity (2030)
By 2030 the number of food insecure people globally is 475 million. — **475 million**

Death due to high Body Mass Index
10.1 million people die prematurely each year due to high body mass index (BMI) — **10.1 million**

Ocean food economy
Wild catch declines by 15% due to overfishing leading to continued decay of global fish stocks — **15% decline**

2050: BETTER FUTURES scenario

Deforestation
Deforestation reduces to a rate of 0.2 million hectares (Ha) per year — **0.2 mHa/yr**

Agricultural land
The area of land dedicated to agriculture decreases by 1200 million Ha (37% of area today) — **1200 mHa**

Restored natural land
1300 million Ha are restored to natural ecosystems since 2010. — **1300 mHa**

Biodiversity
Biodiversity recovers by 0.2% compared to 2010. — **0.2% recovery**

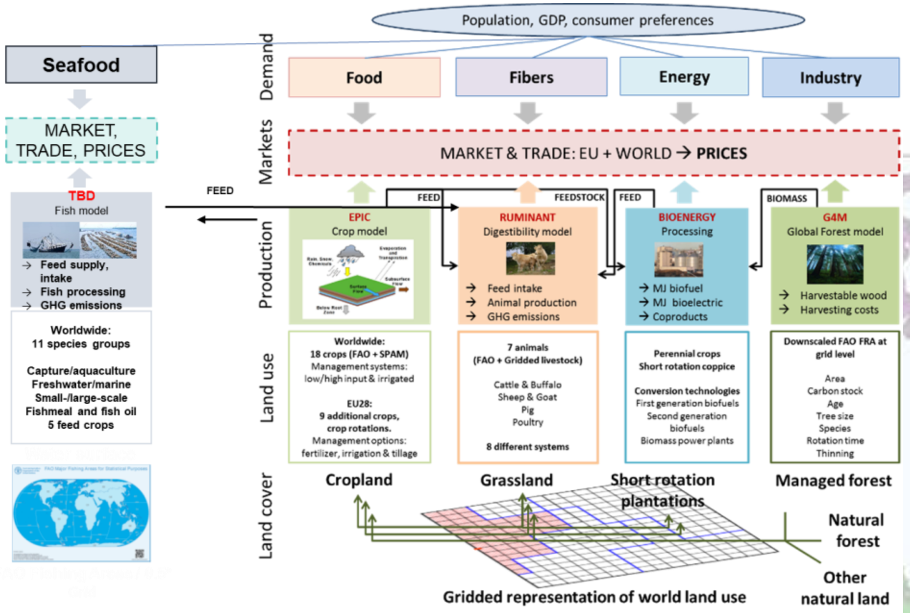
Food and land use emissions
Emissions from food and land use systems reduce to net zero. — **Net Zero**

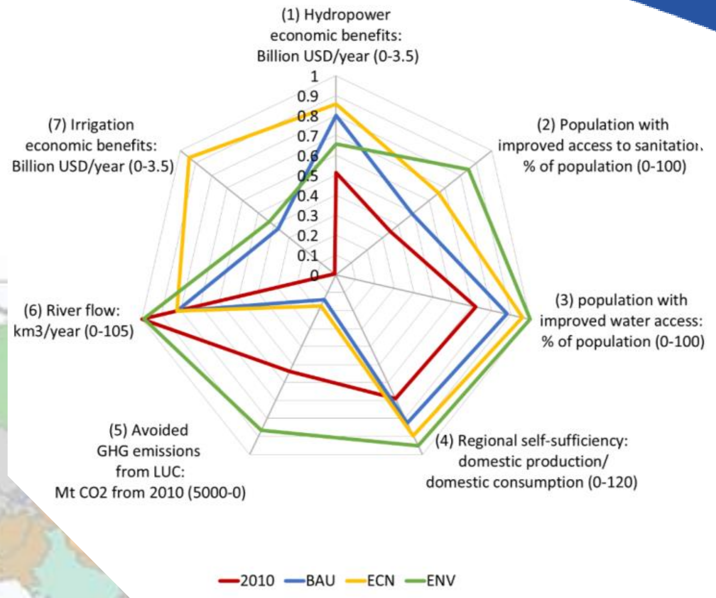
Food insecurity (2030)
Enough food is produced to completely eliminate food insecurity. — **Sufficient Production**

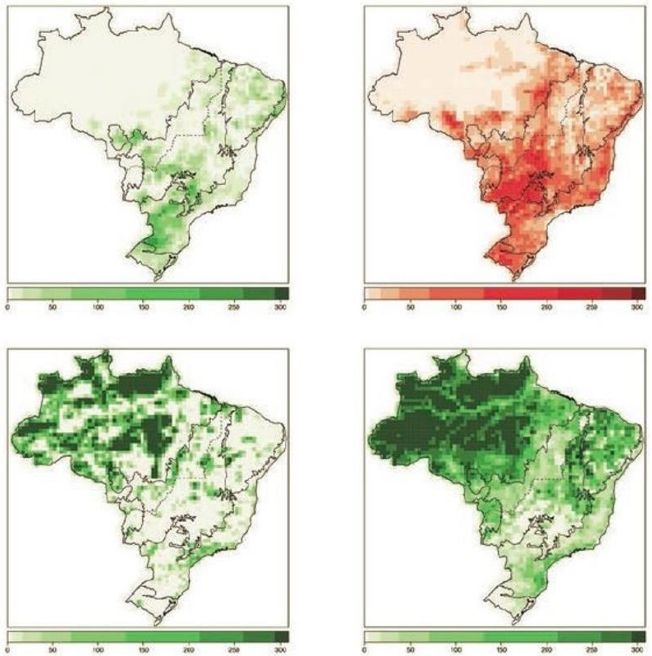
Death due to high Body Mass Index
5.6 million people die prematurely each year due to high BMI – 50% compared to current trends — **5.6 million**

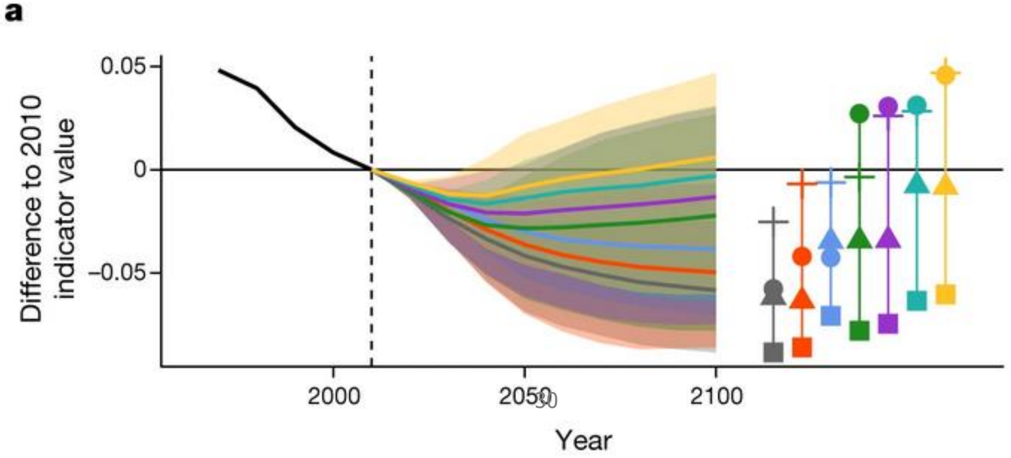
Ocean food economy
Wild catch improves by 24%as all fisheries are managed within maximum sustainable yield. — **24% increase**

>> Thank you, stay engaged!









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Research scholar in Food Systems Economics

Application by 15th January

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