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Climate change and mitigation in agriculture and forestry: An integrated assessment of impacts on poverty

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in collaboration with M. Gusti,…

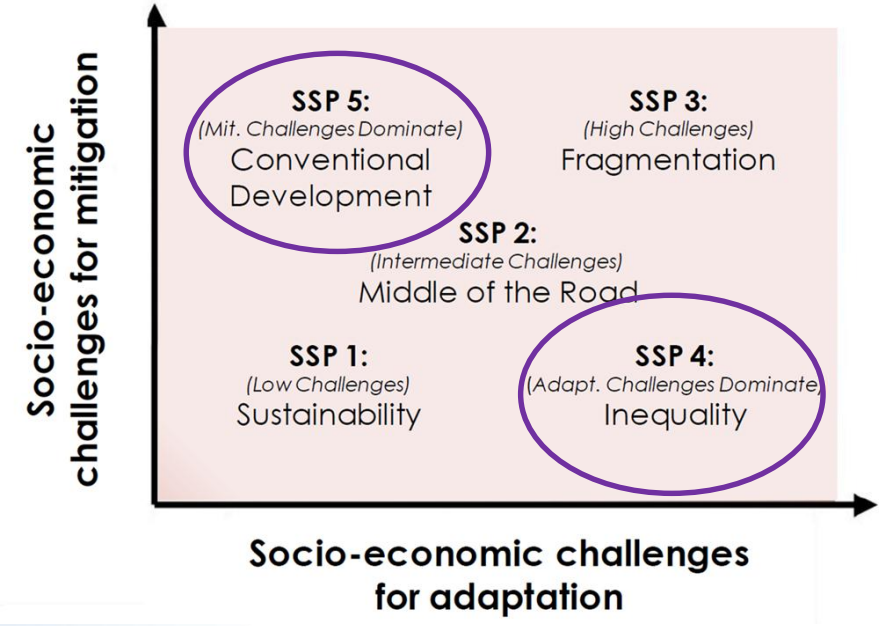
Introduction

- Agriculture plays a key role in developing countries
  - Source of food in food insecure regions with limited market access
    - 70% of population of low income countries living in rural area
  - Source of income and economic growth
    - 60% of African labor force working in the agricultural sector
- Agriculture particularly exposed to climate change
- At the same time, large expectations for mitigation from the land use sectors
  - Direct non-CO_2 emissions reduction
  - Avoided CO_2 emissions and carbon sequestration
  - Biomass for energy

Outline

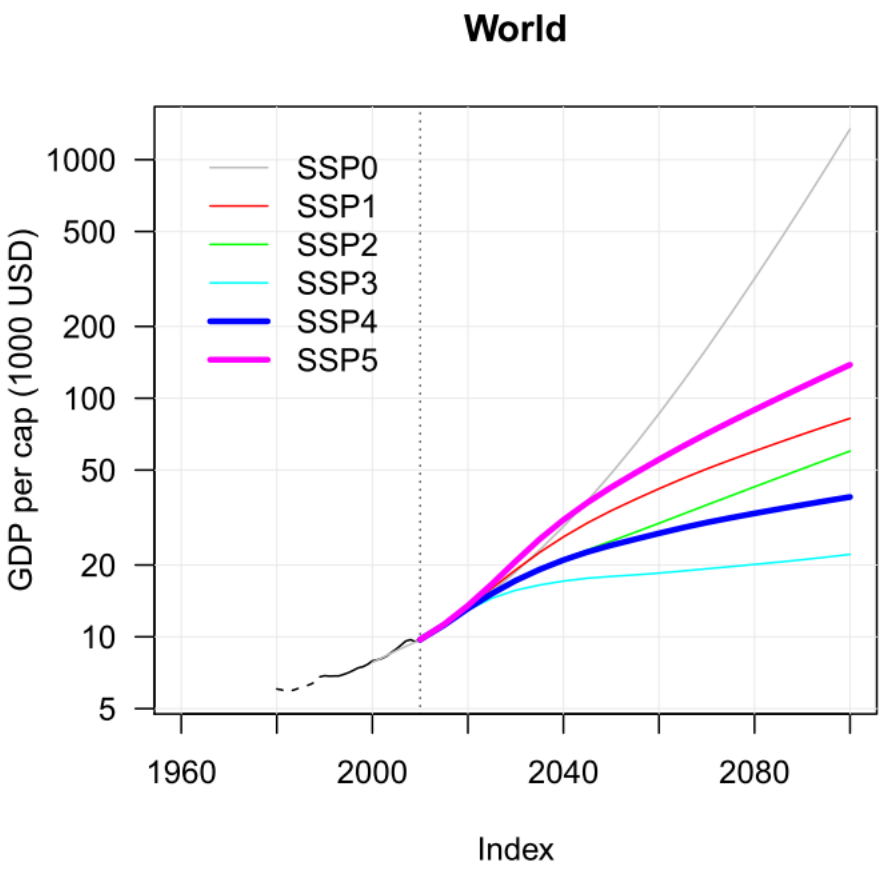
1. Socio-economic scenarios
2. Modeling approach
3. Climate change impacts: Scenarios and Results
4. Climate change mitigation: Scenarios and Results
5. Climate change impacts *versus* mitigation
6. Discussion

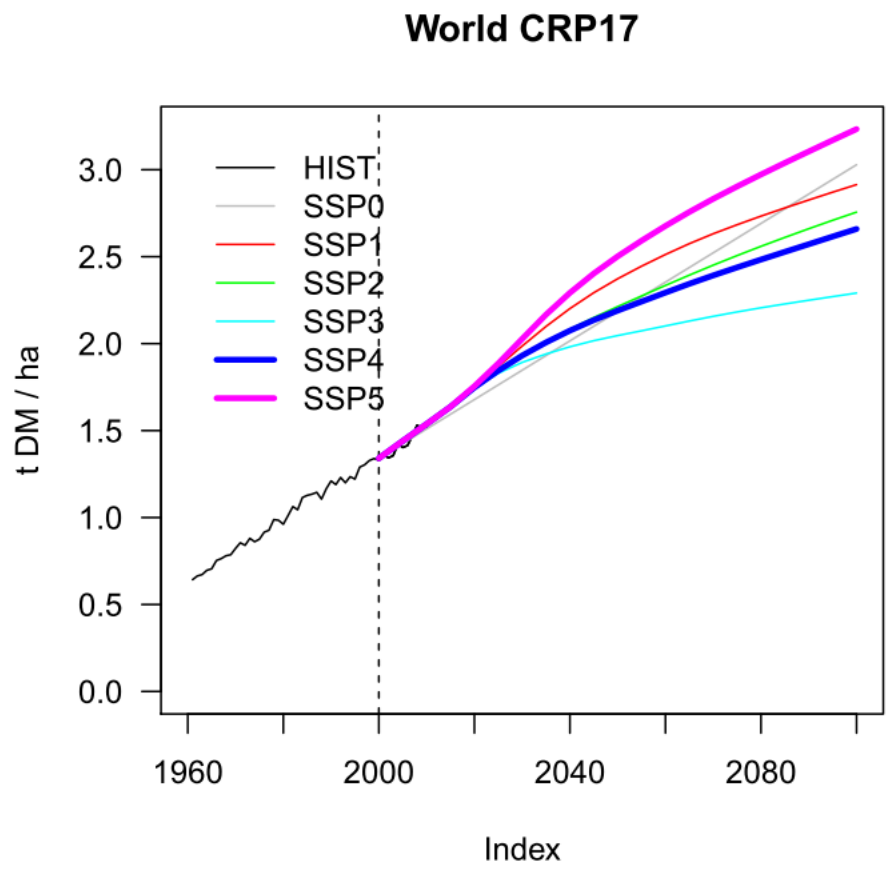
Scenarios: Shared Socio-economic Pathways



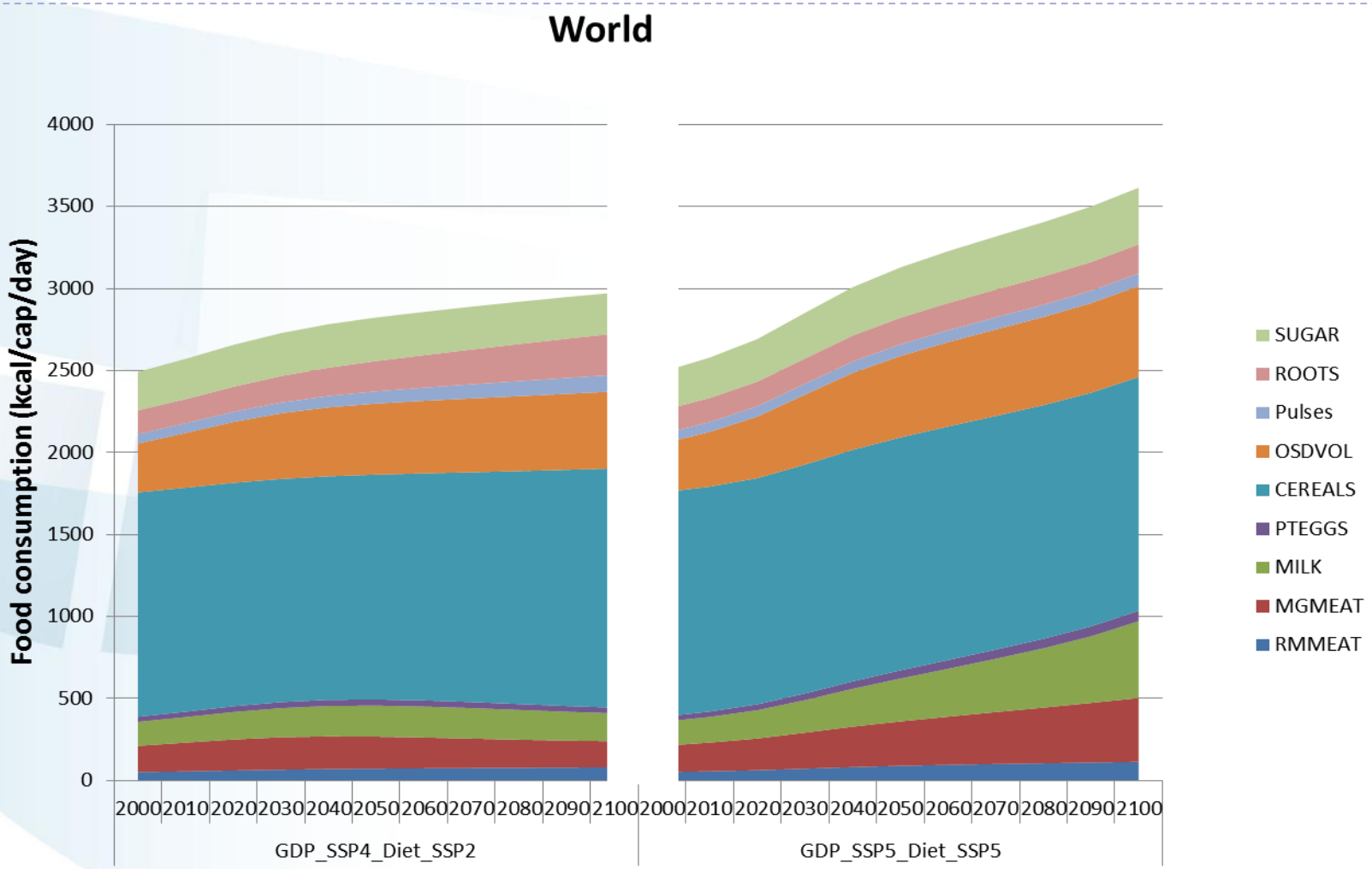
SSP4	SSP5
- Fast growth in rich regions - Slow growth in developing regions - Inequality remains high - Economies isolated - Limited adaptive capacity	- Rapid economic growth - High energy demand - Investment in human capital - Slower population growth -Globalized economy

Implications for crop yield development





Different patterns of food demand



GLOBIOM

- **Global scale model based detailed spatial resolution** (>200k cells)
- **Partial equilibrium**
  - Agricultural, wood and bioenergy markets
  - 30 world regions
  - Bilateral trade flows based on spatial equilibrium approach
- **Bottom-up approach**
  - Explicit description of production technologies a la Leontief
  - Technologies specified by production system and grid cell
- **Linear programming approach**
  - Maximization of consumer + producer (incl. trade costs) surplus
  - Non linear expansion costs
  - Optimization constraints
- **Base year: 2000**
- **Time step**: 10 years, **time horizon**: 2030/2050 but also 2100

Population, GDP, consumer preferences

Demand

Food | Fibers | Energy | Industry

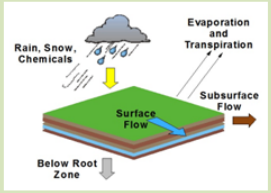
Markets

MARKET & TRADE: EU + WORLD → **PRICES**

Production

FEED | FEEDSTOCK | FEED | BIOMASS

EPIC
Crop model



RUMINANT
Digestibility model

→ Feed intake
→ Animal production
→ GHG emissions

BIOENERGY
Processing

→ MJ biofuel
→ MJ bioelectric
→ Coproducts

G4M
Global Forest model

→ Harvestable wood
→ Harvesting costs

Land use

Worldwide:
18 crops (FAO + SPAM)
Management systems:
low/high input & irrigated

EU28:
9 additional crops,
crop rotations.
Management options:
fertilizer, irrigation & tillage

7 animals
(FAO + Gridded livestock)

Cattle & Buffalo
Sheep & Goat
Pig
Poultry

8 different systems

Perennial crops
Short rotation coppice

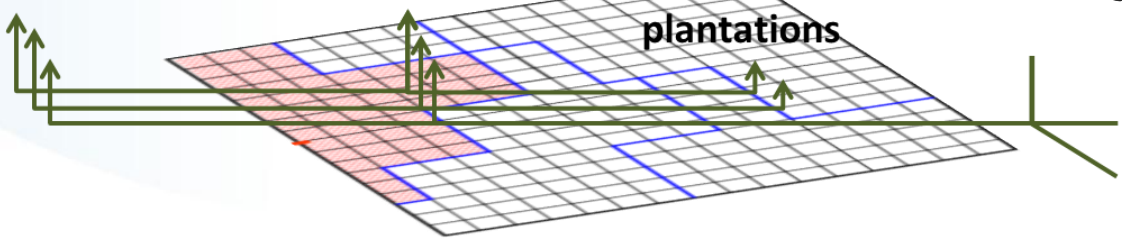
Conversion technologies
First generation biofuels
Second generation biofuels
Biomass power plants

Downscaled FAO FRA at grid level

Area
Carbon stock
Age
Tree size
Species
Rotation time
Thinning

Land cover

Cropland | **Grassland** | **Short rotation plantations** | **Managed forest**

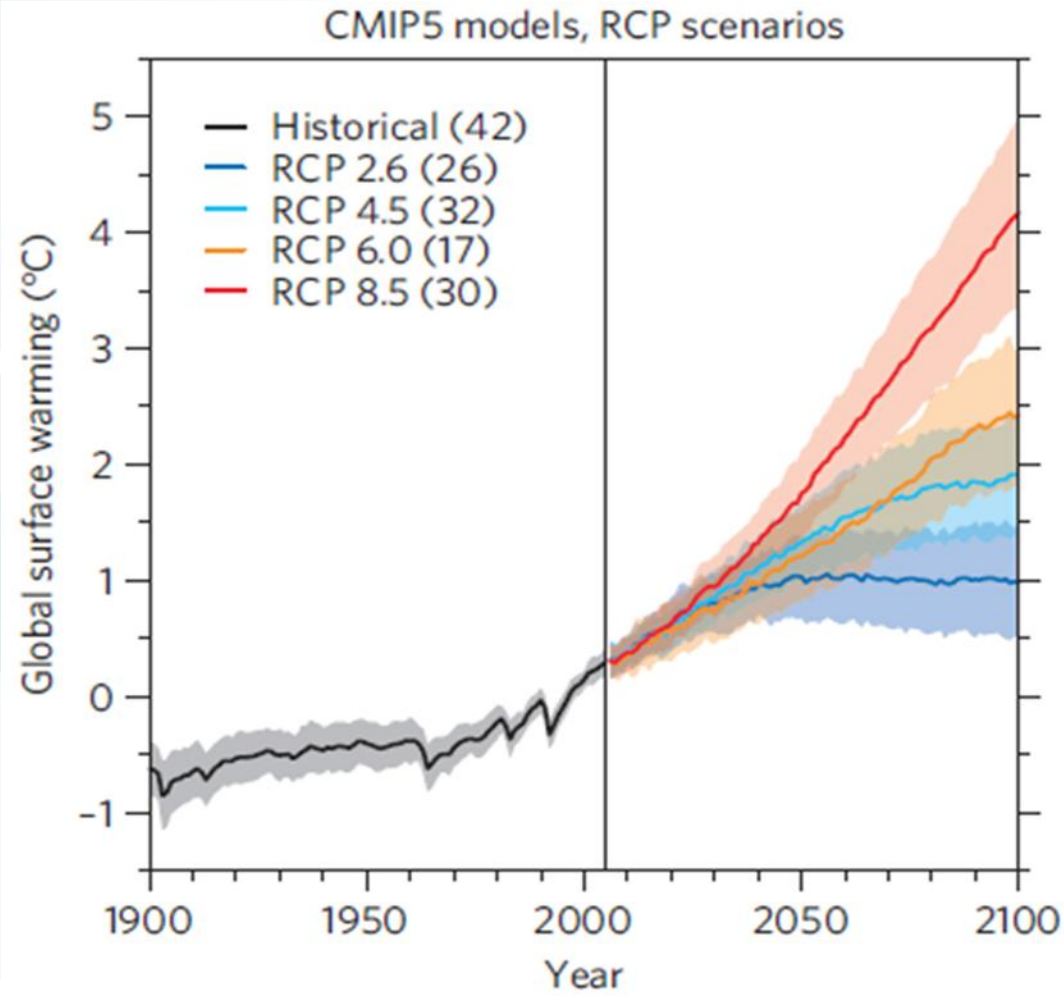


Natural forest

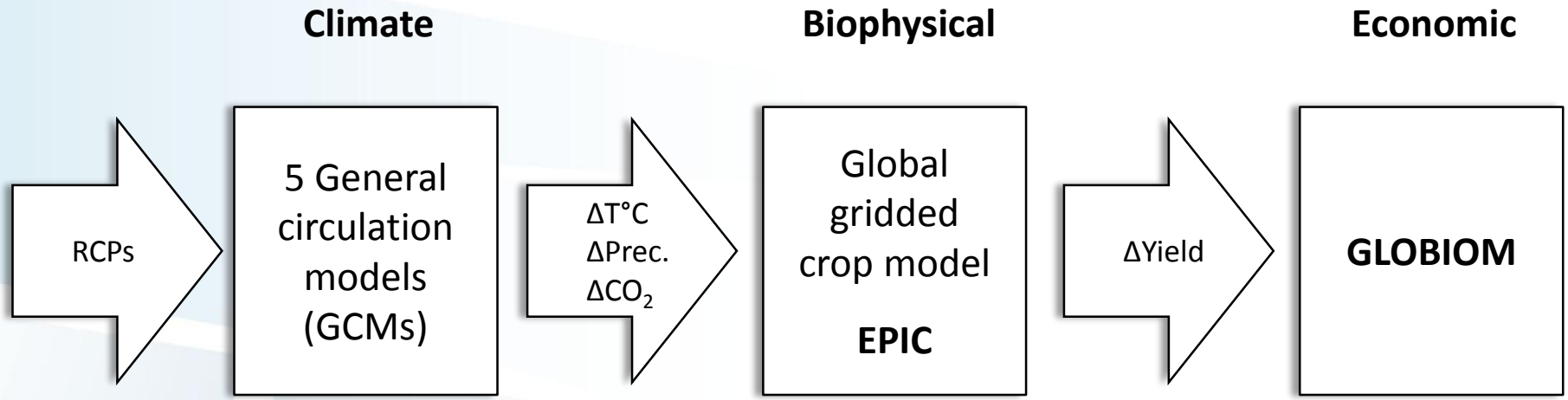
Other natural land

Gridded representation of world land use

Climate change scenarios



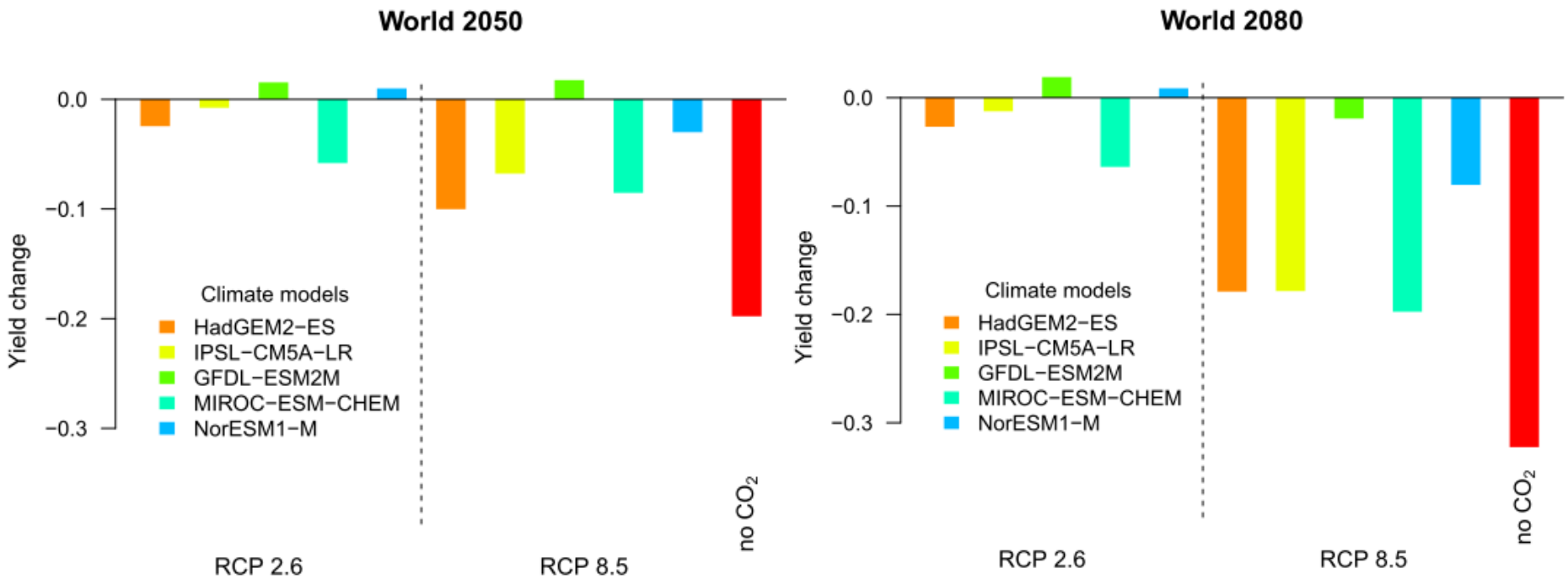
Climate change impacts modeling chain



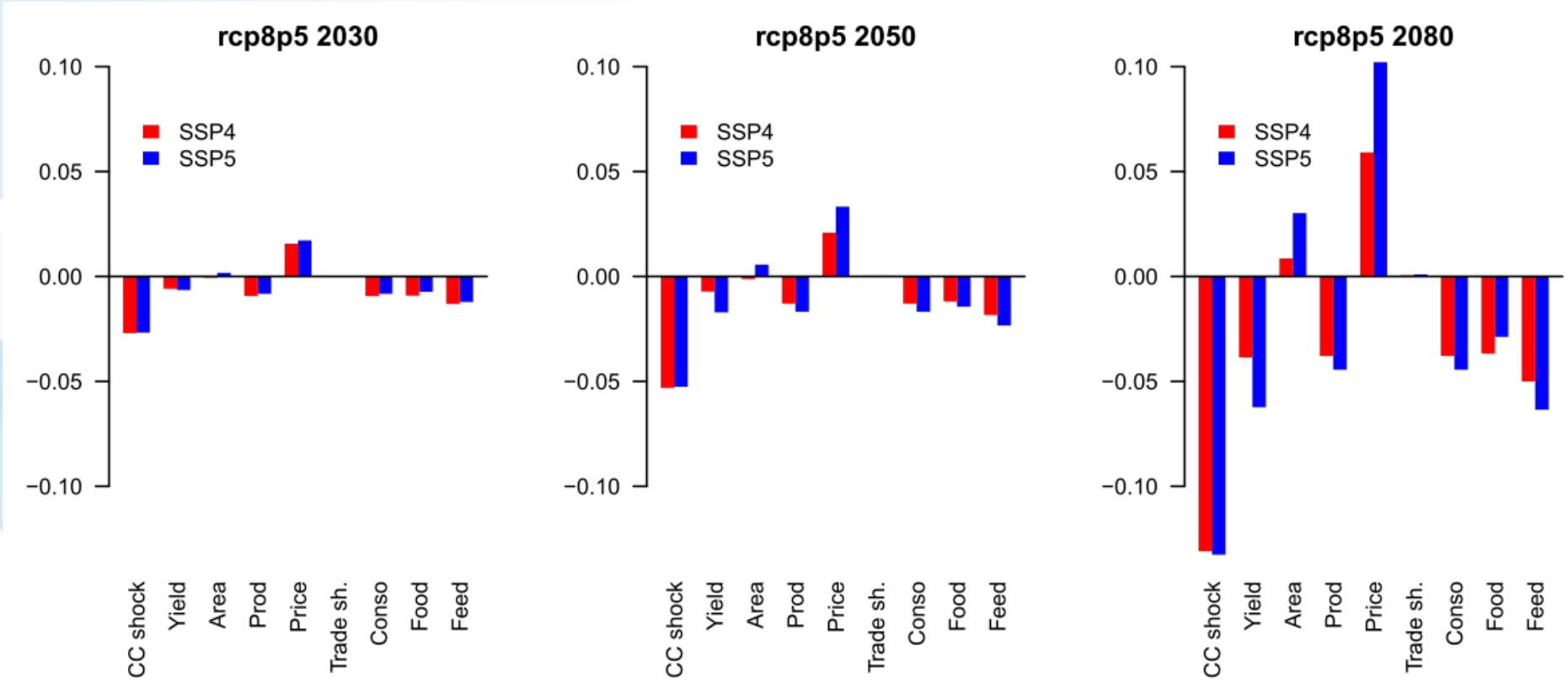
- 2 Representative Concentration Pathways (RCP)
  - Strong climate change: RCP 8.5 (radiative forcing 8.5 W/m^2)
  - Contained climate change: RCP 2.6 (radiative forcing 2.6 W/m^2)
- 5 General Circulation Models
  - HadGEM2-ES, IPSL-CM5A-LR, GFDL-ESM2M, MIROC-ESM-CHEM, NorESM1-M
- 1 Global Gridded Crop Model: EPIC

CC impacts on crop yields - Global

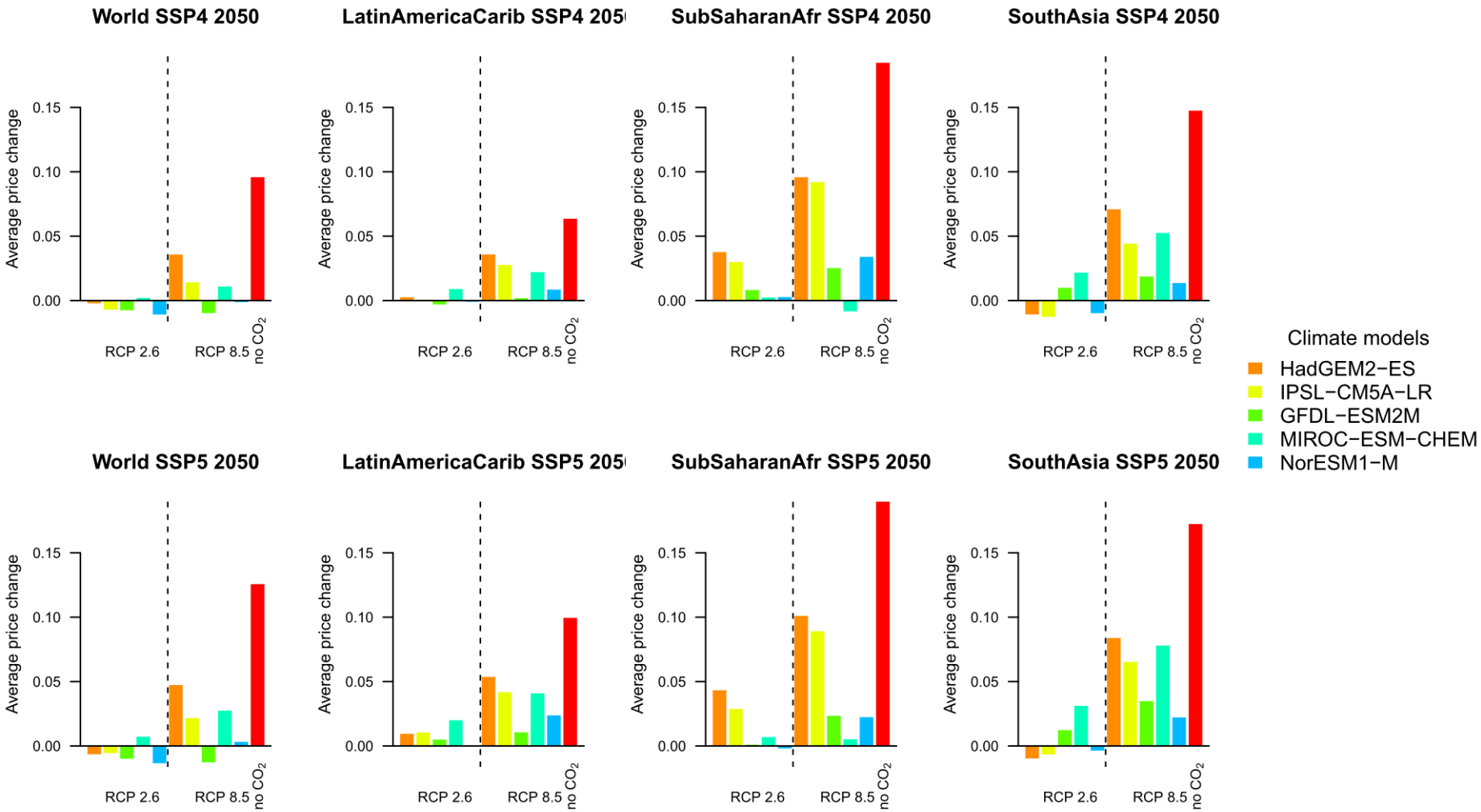
[% variation t dm]



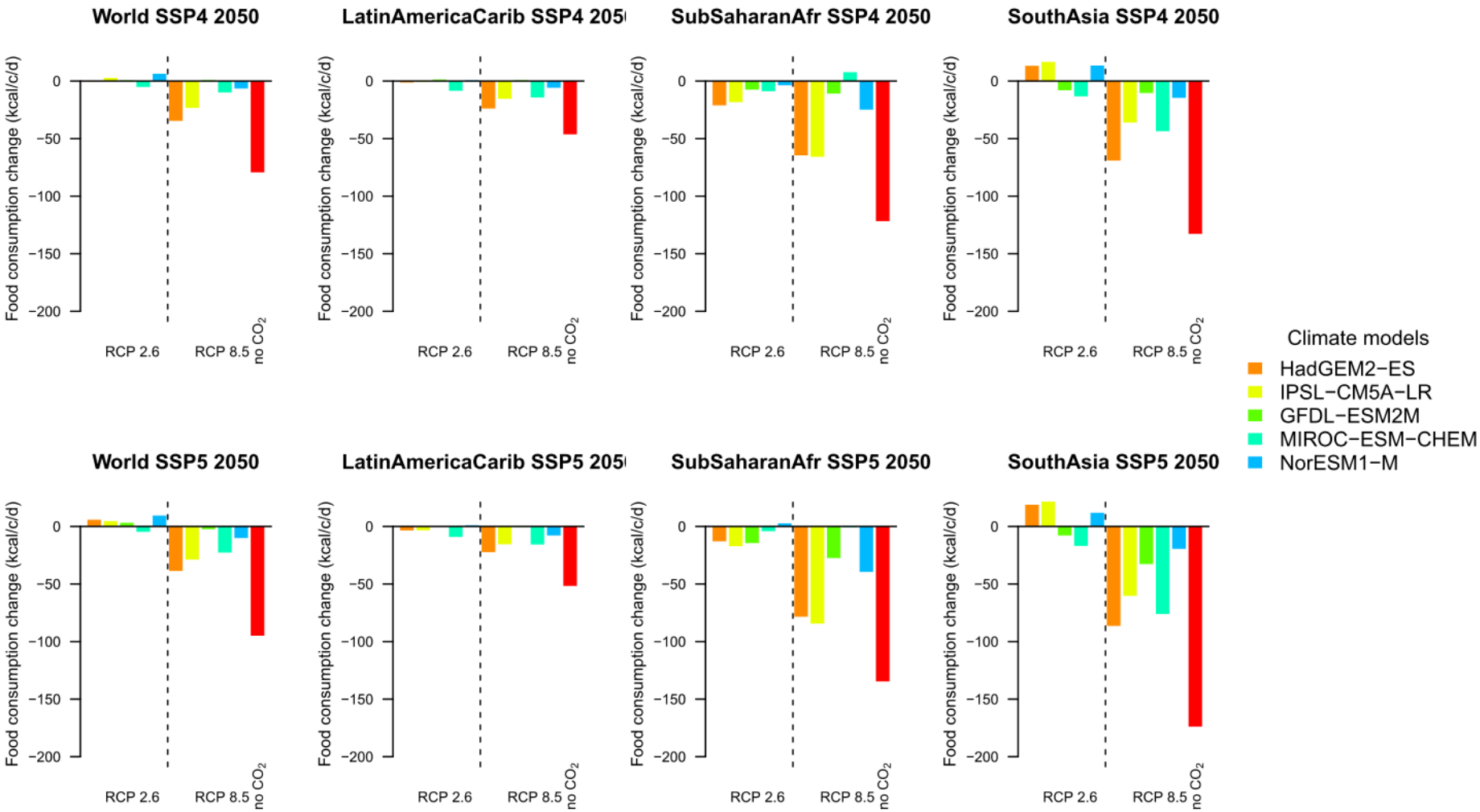
Propagation of CC shocks through global markets



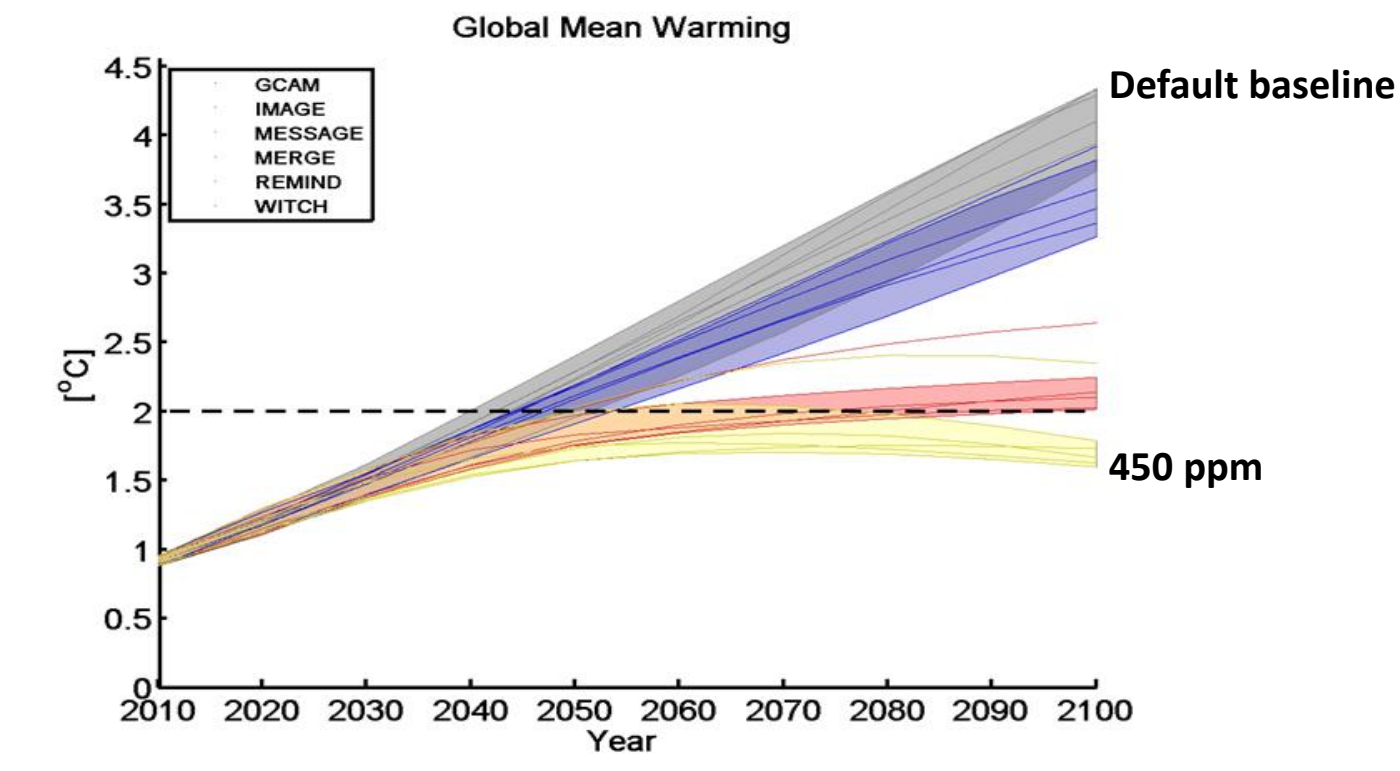
Price impact



Food consumption per capita change



Climate change mitigation scenarios



Source: Kriegler et al. 2014

Scenarios: Mitigation

- Based on EMF 27 scenarios set up (Kriegler et al. 2014)
  - Technology assumptions

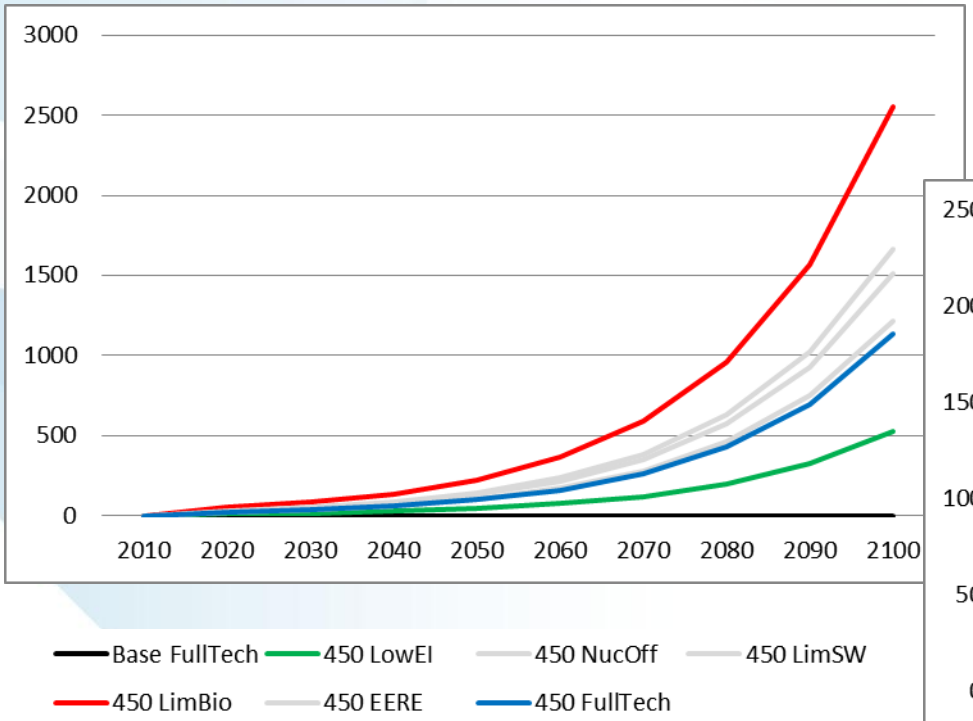
FullTech	all modeled technologies included, reference energy intensity improvements
LowEI	low energy intensity: 20-30% lower final energy demand in 2050 and 35-45% in 2100 compared to the reference case
NoCCS	carbon capture and storage excluded from technology portfolio in all sectors
NucOff	phase out of nuclear energy with no new nuclear power plants built beyond those under construction; existing plants operated until end of their technical lifetime
LimSW	share of electricity production from intermittent solar and wind technologies (wind, solar PV and CSP) limited to 20%
LimBio	global primary bio-energy supply – including purpose grown crops, residues and municipal solid waste, but excluding traditional biomass –limited to 100 EJ/yr
Conv	Combined LimSW & LimBio
EERE	Combined LowEI & NoCCS & NucOff
LimTech	Combined NoCCS & NucOff & LimSW & LimBio

  - Policy dimension: Baseline, 450 $C0_2$eq, 550 $C0_2$eq

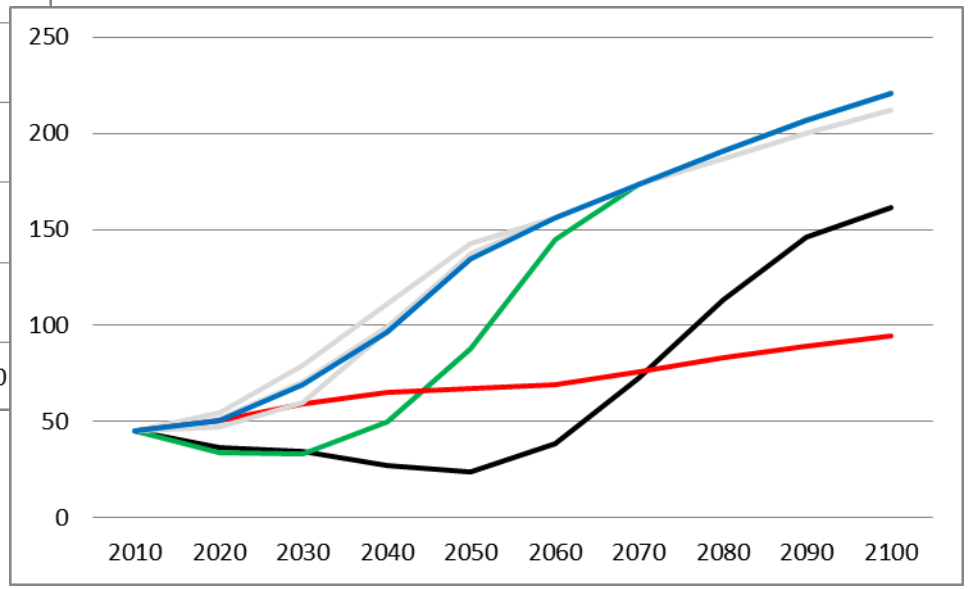
Scenarios: Mitigation

- CC & Poverty scenarios: Drivers from MESSAGE (McCollum et al. 2014)

Carbon price [US$2005/t CO2]



Bioenergy demand [EJ/yr]



- Applied to SSP4 and SSP5 until 2100, here focus on 2050

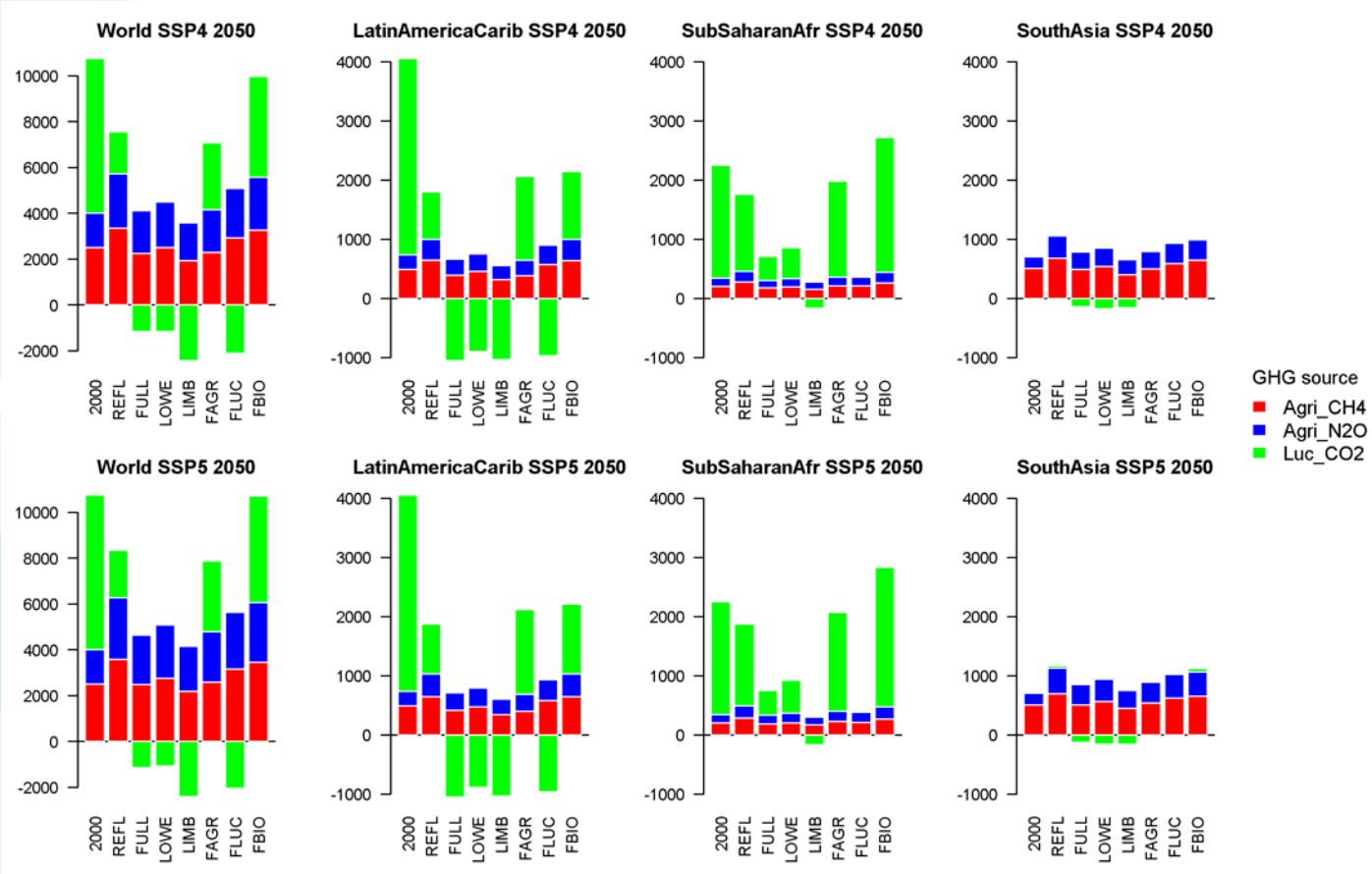
Scenarios: Mitigation

- CC & Poverty scenarios

	Policy scenario	Bioenergy demand	Carbon price	Carbon sector
REFL	**Base FullTech**	**Base FullTech**	**NA**	**NA**
FULL	**450 Fulltech**	**450 Fulltech**	**450 Fulltech**	**AFOLU**
LOWE	**450 LowEI**	**450 LowEI**	**450 LowEI**	**AFOLU**
LIMB	**450 LimBio**	**450 LimBio**	**450 LimBio**	**AFOLU**
FAGR	450 Fulltech	Base Fulltech	450 Fulltech	Agri Non-CO2
FLUC	450 Fulltech	Base Fulltech	450 Fulltech	LUC CO2
FBIO	450 FullTech	450 FullTech	NA	NA

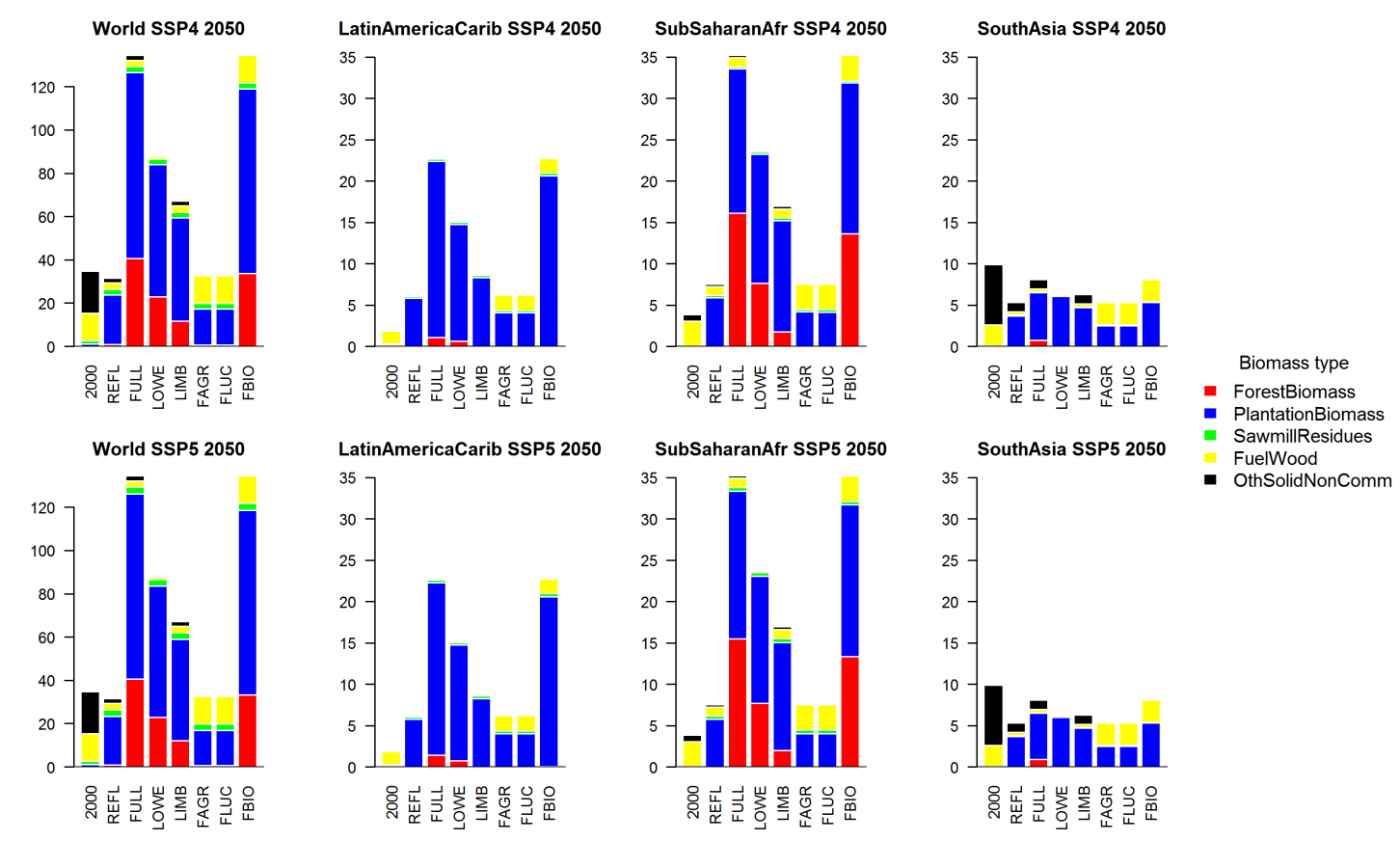
- Applied to SSP4 and SSP5 until 2100, here focus on 2050

AFOLU emissions [MtCO2eq]



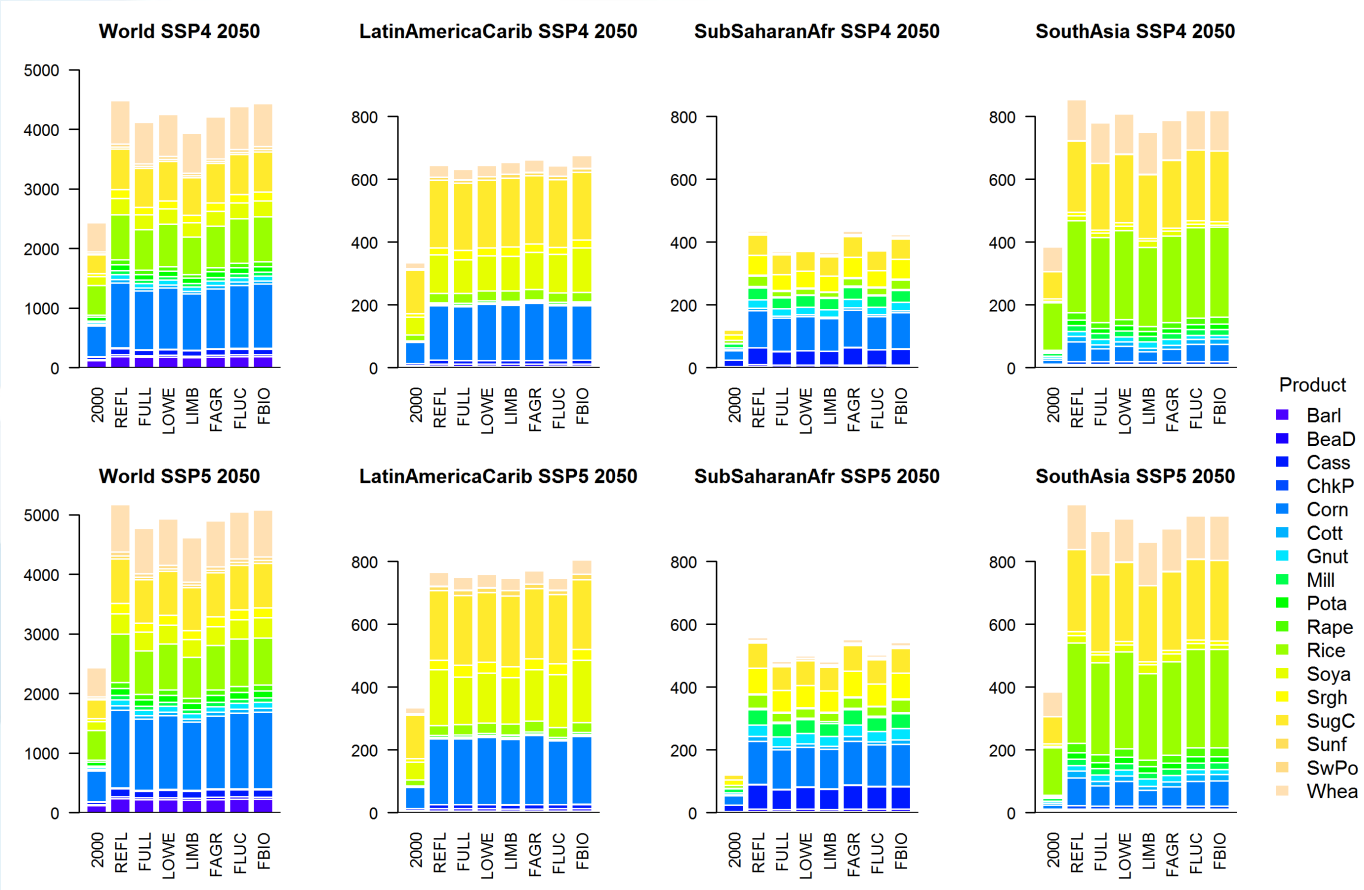
- AFOLU emissions globally to be reduced by 61% to today (mostly LUC)
- 47% of reduction coming from LAM and 23% from AFR

Biomass supply for bioenergy [EJ primary]



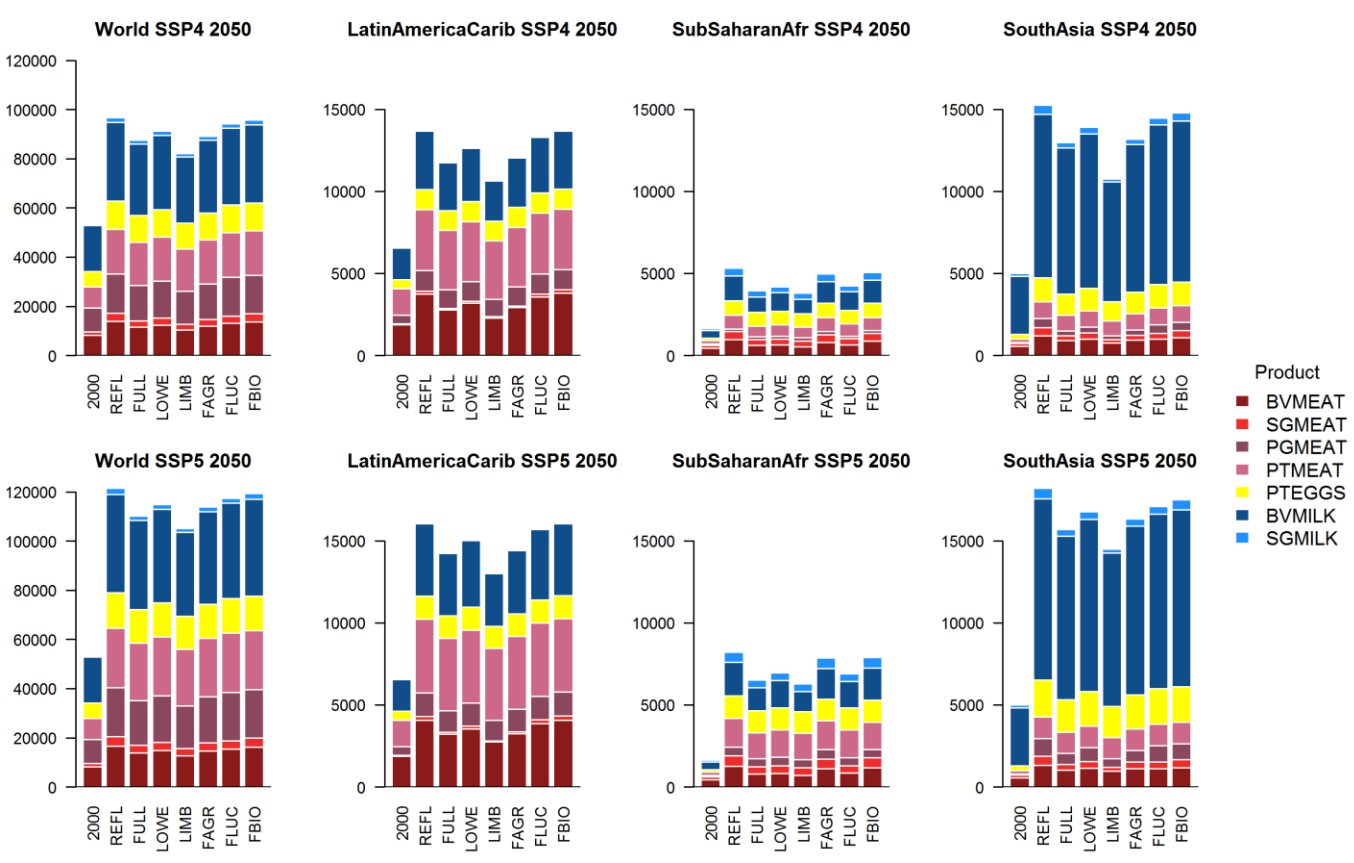
- Biomass supply for bioenergy multiplied by 4 in FULL compared to REFL
- 16% to come from LAM and 27% from AFR
- Potential source of new income

Crop production [tDM]



- Increase by 84% globally,122% in SAS and 155% in MEA and 241% in AFR
- Increase lower by 6% in MEA and 16% in SAS under FULL
- Increase lower by 34% in MEA and 22% in SAS under LIMB

Livestock production [t protein]



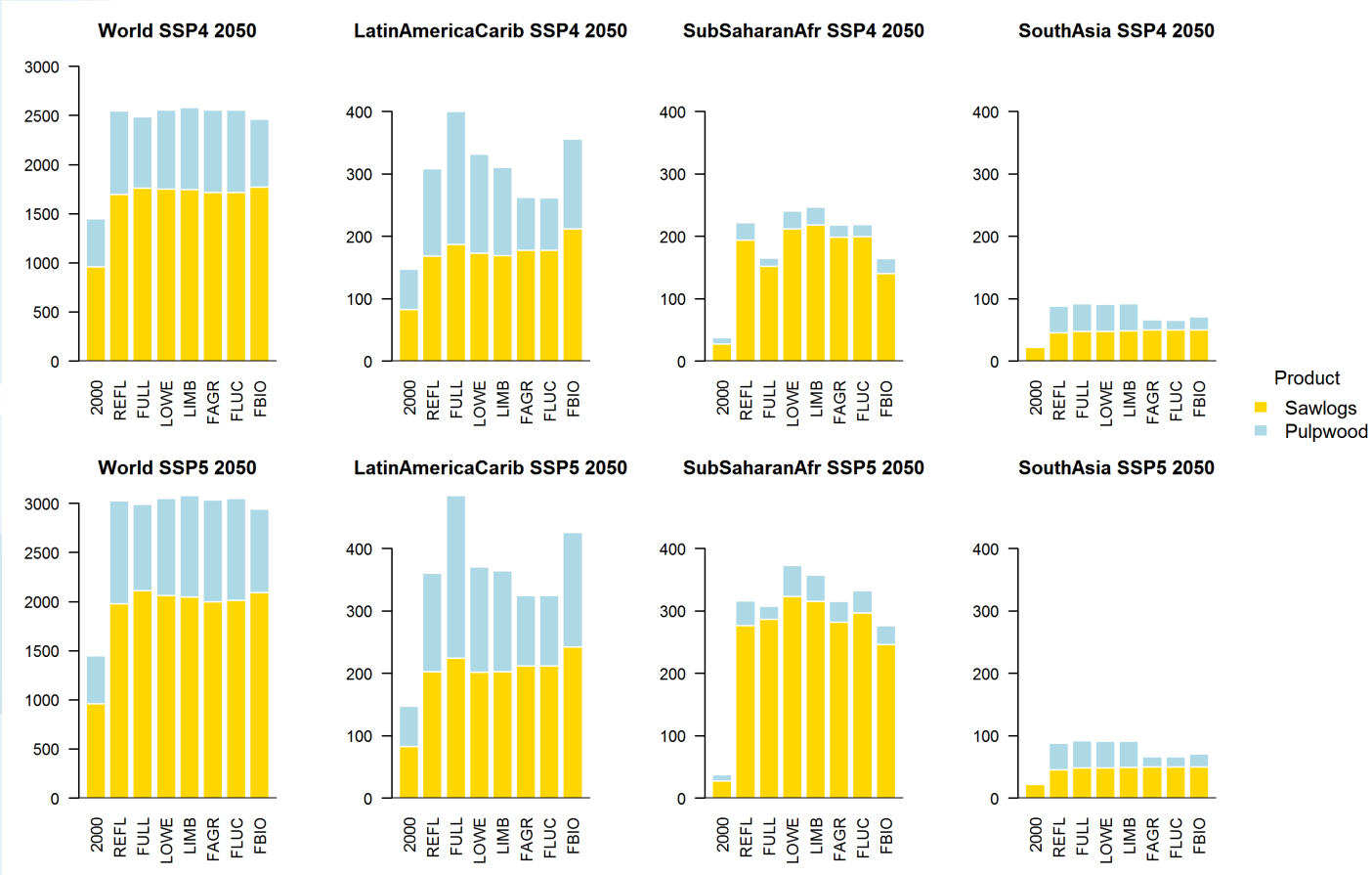
- Livestock production to increase by 81% globally, 205% in SAS and 227% in AFR
- Bovine meat, small ruminant meat, and small ruminant milk production -20%
- Poultry production -4%

Beef production systems [%]

- Globally, intensive systems share increase from 33% to 40% in FULL and LIMB
- In AFR, intensive systems represent 36% under FULL

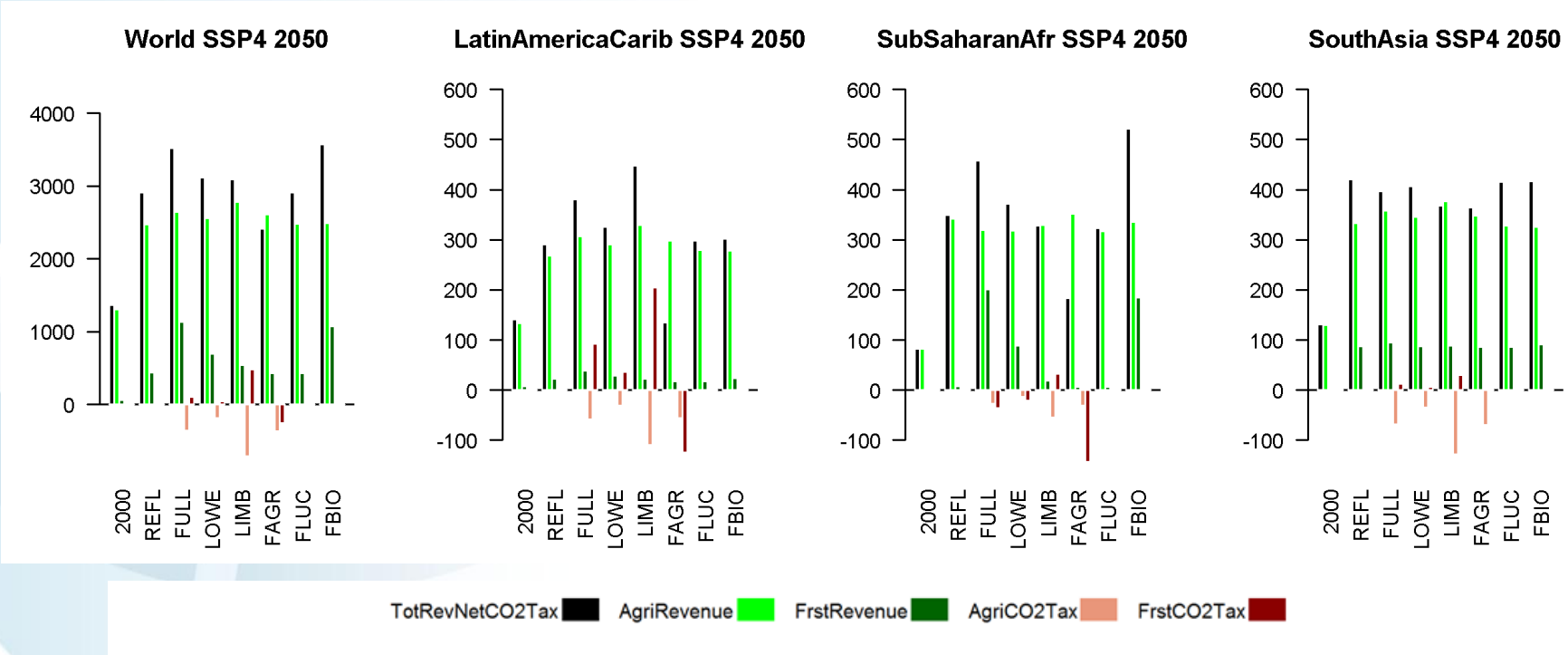
compared to 26% in REFL

Industrial round wood production [Mm3]



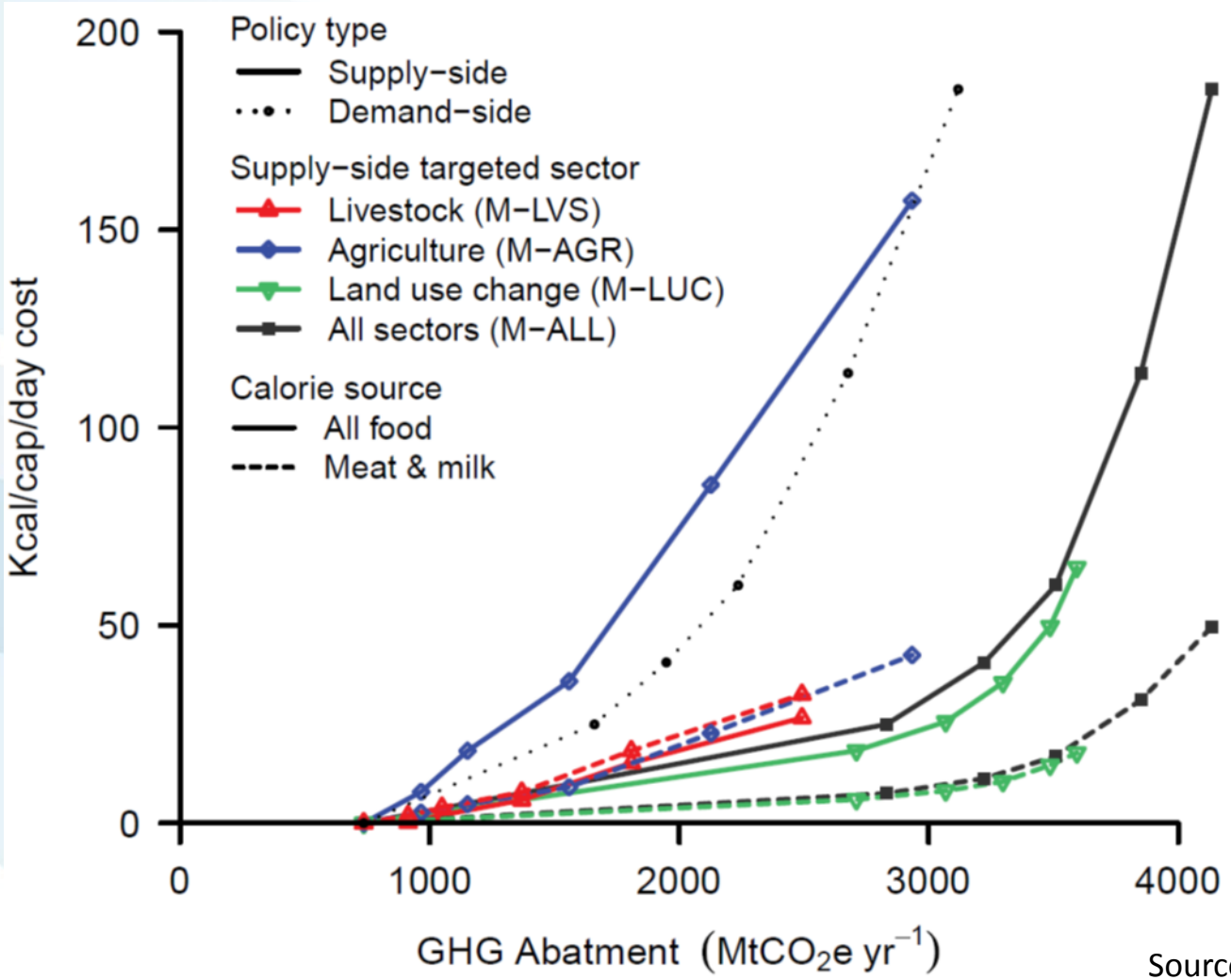
- Industrial round would supply to increase by 76% between 2000 and 2050
- Little effect of mitigation policies globally (+/-5%)
  - Complementary with bioenergy in LAM and competing in SSA

Sectorial revenue and CO2 tax [billion USD2000]



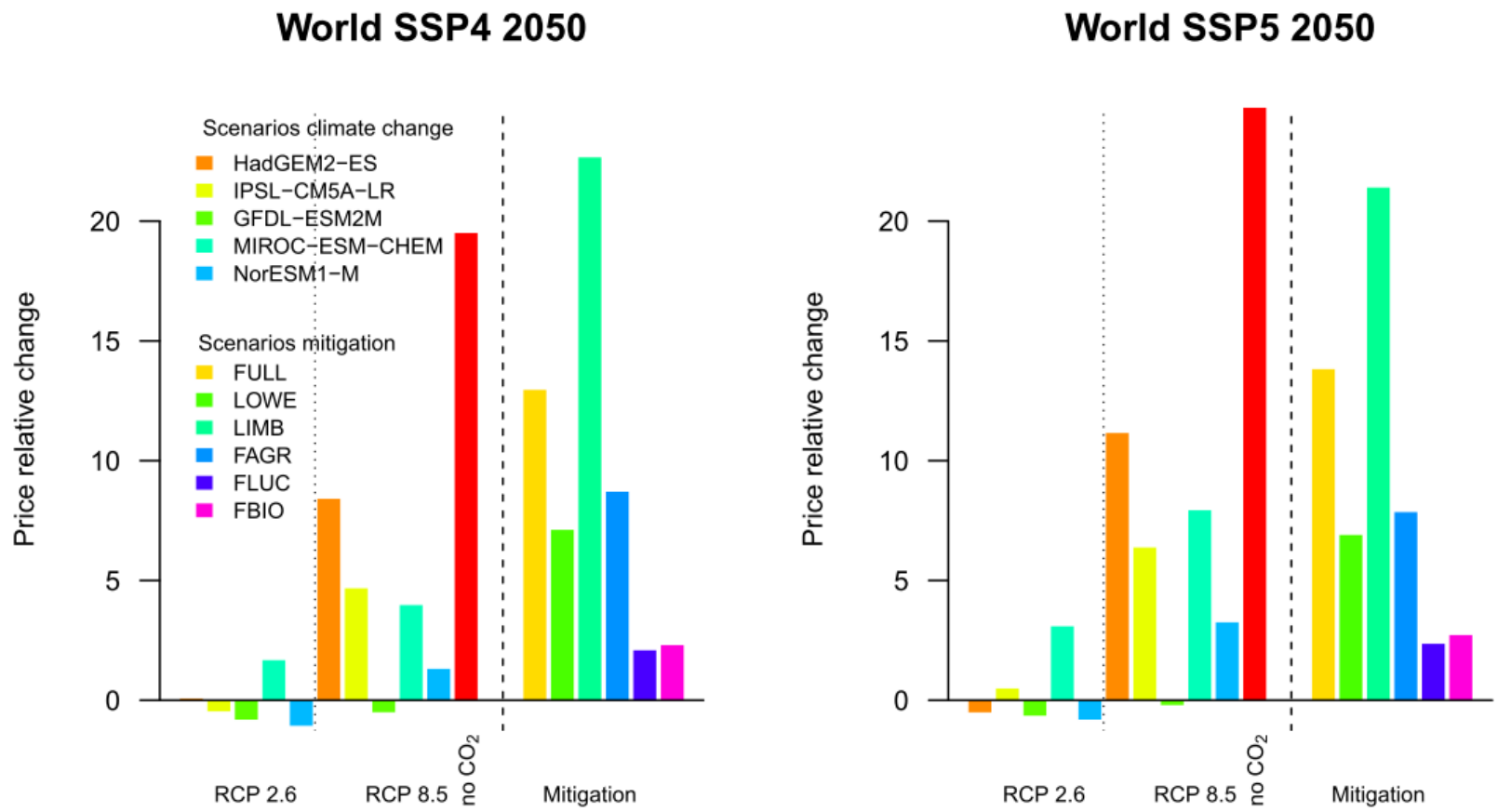
- Total revenue net tax +21% in FULL and 6% only in LIMB
- LAM: +31% – agriculture and forest carbon sequestration
- AFR: +31% – biomass for bioenergy

Total abatement calorie cost (TACC)

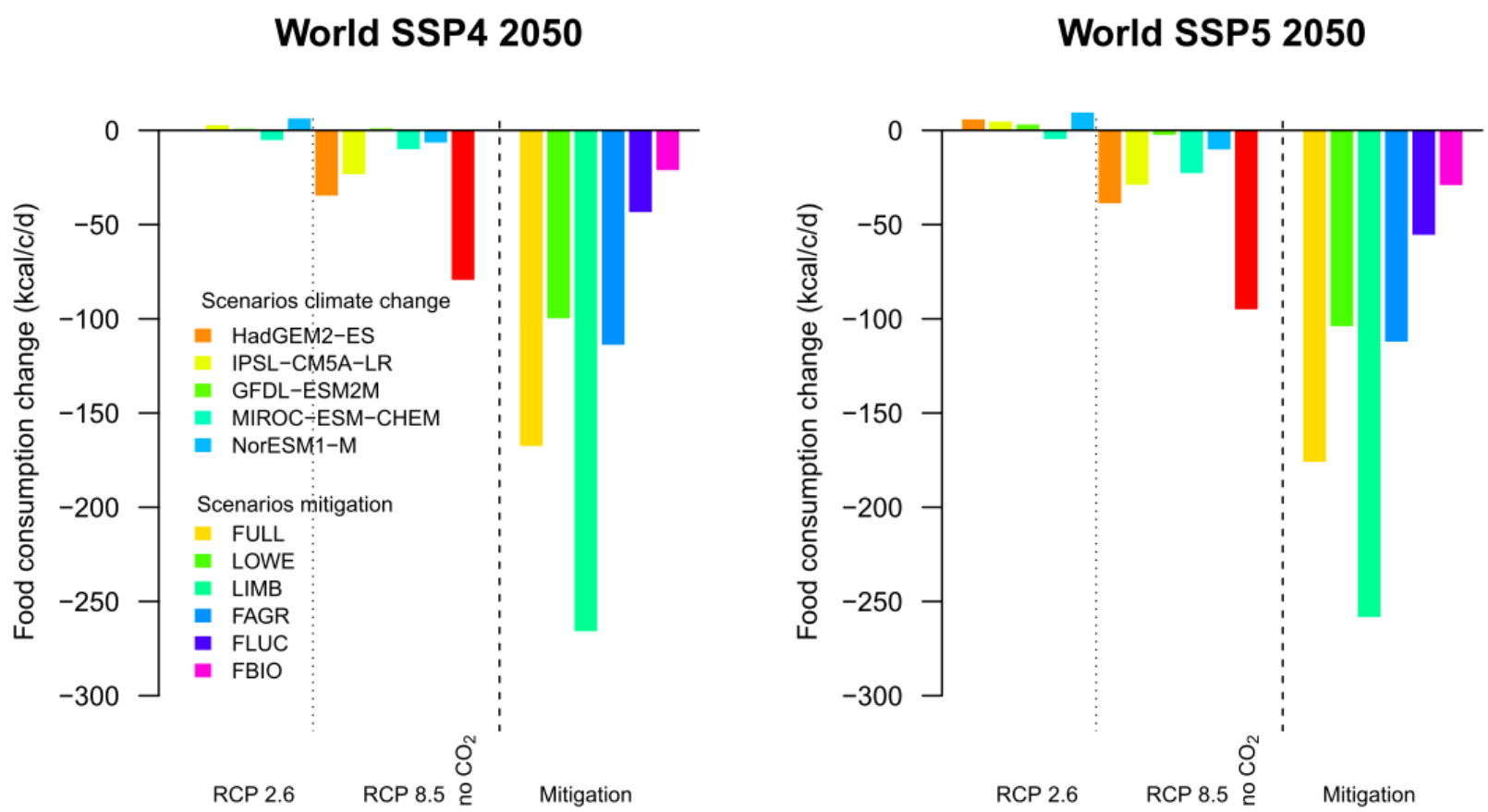


Source: Havlík et al. 2014

Impact versus mitigation: Crop prices



Impact versus mitigation: Food supply



Discussion

- Climate change impacts low income countries more than some other regions due environmental context, and vulnerability to change in food prices

- Mitigation presents opportunities for land use sectors
  - New demands (biomass)
  - Payments for carbon sequestration
  - Higher prices (producers)
- Mitigation presents also challenges
  - Higher production cost
  - Restructuring of the sectors
  - Higher prices (consumers)
- Sectors and regions affected very differently
  - Forestry tends to benefit and agriculture to loose
  - Developed regions marginally affected and least developed most afected

- If mitigation not implemented carefully, potentially worse effects than climate change itself, at least in medium term

RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

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Thank you !

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