

Agricultural Labor under Heat Stress: Productivity Shocks and Macroeconomic Consequences

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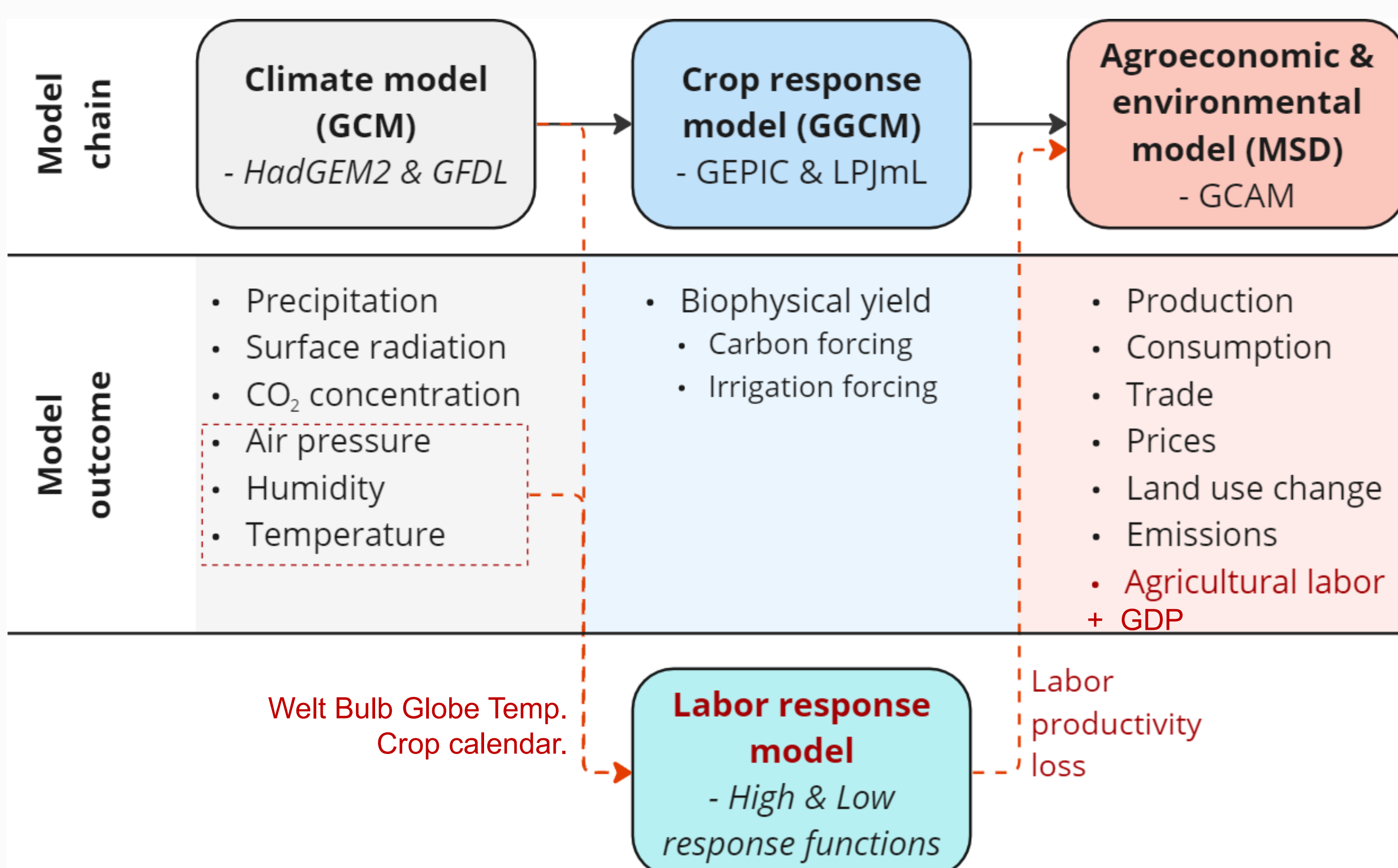
We illustrate how labor productivity shocks ripple through agroeconomic and macroeconomic systems (GCAM-Macro KLEAM).

Motivation

- Labor is one of the most crucial inputs in agricultural production, and its productivity is highly sensitive to the increasing heat stress under a changing climate.
- However, the role of labor has been overlooked in multisector dynamic modeling, and the agroeconomic and macroeconomic implications of heat stress shocks have not been fully explored.
- Existing studies predominantly focus on biophysical yield (land) shocks (Nelson et al., 2014), with only a few exceptions (de Lima et al., 2021).
- Here, we incorporate economy-wide labor markets and macroeconomic responses into the **Global Change Analysis Model (GCAM)** to re-evaluate climate impact on agriculture, considering both biophysical shocks on crops and labor.

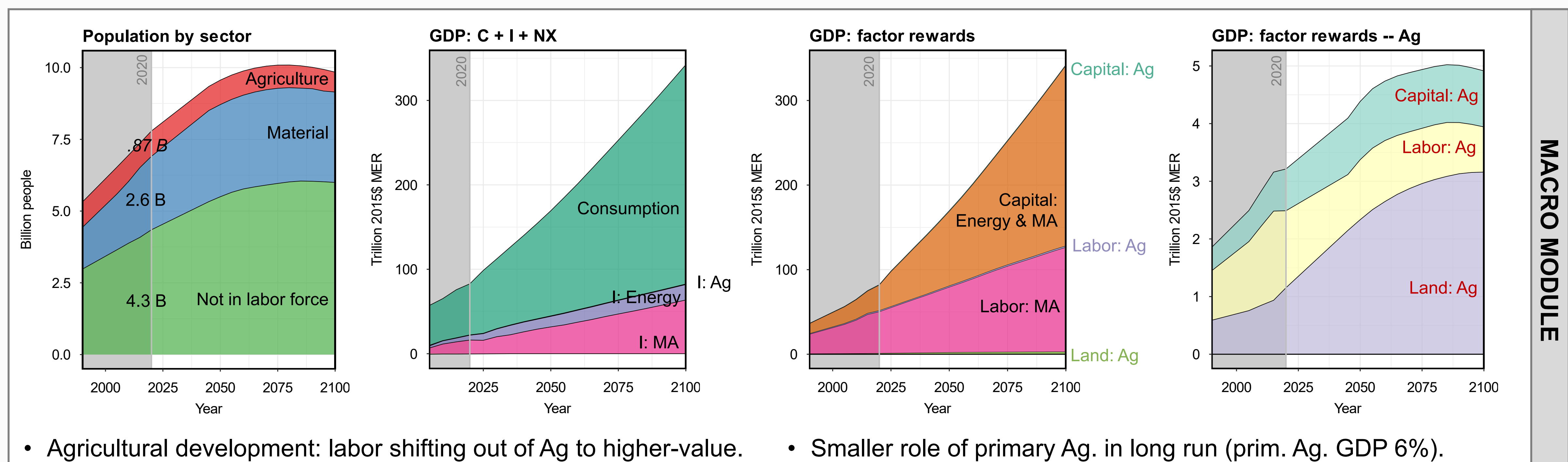
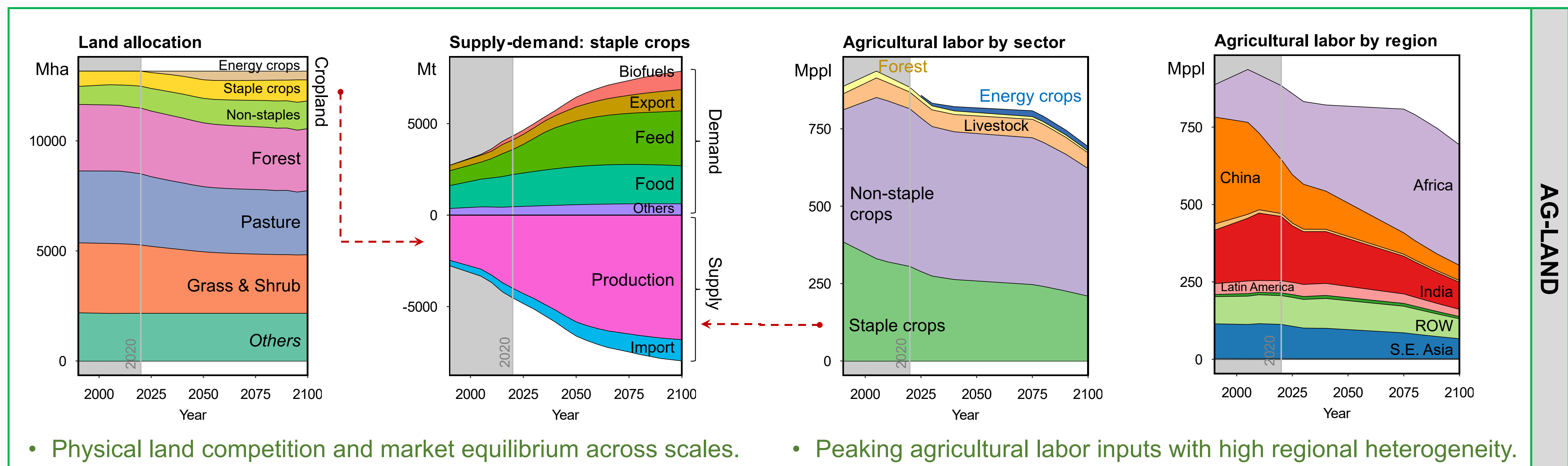
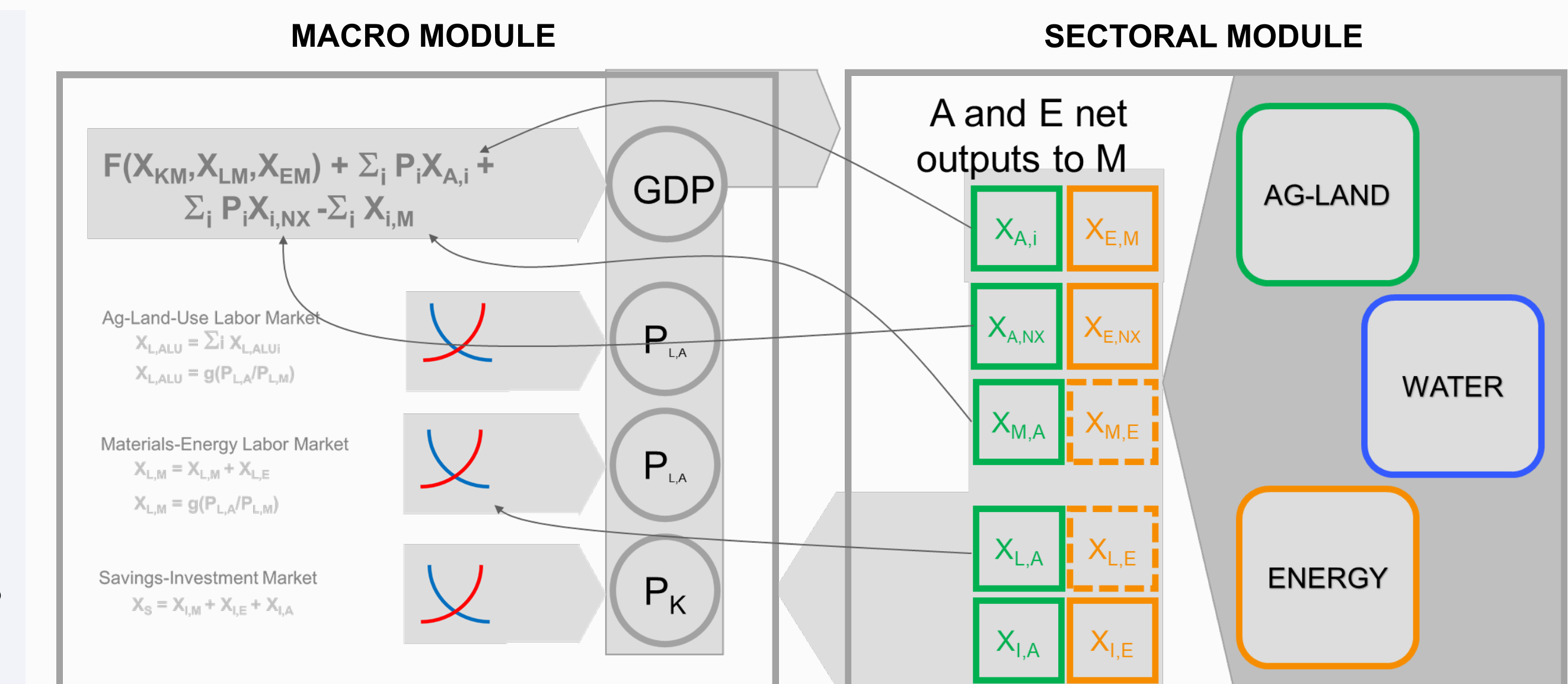
Climate Impact on Agriculture

- The assessment requires a combined use of climate, crop, and economic models (AgMIP/ISIMIP) to translate climate and biophysical shocks to changes in economic variables.
- We expand this framework to incorporate a labor response model.
- Scenario: **RCP 6.0**



GCAM-Macro KLEAM: from Agroeconomics to Macroeconomics

- The macroeconomy defines the scale of human activity and determines the scale of human-physical Earth system interactions.
- KLEM + **Agriculture**
 - + agricultural labor and capital in production along with land, water, fertilizer, etc.
 - The Materials (M) sector produces final goods using K, L, E, & A.
 - Clear labor and capital (investment/saving) markets
 - Productivity represent in A and TFP recalibrated in M.



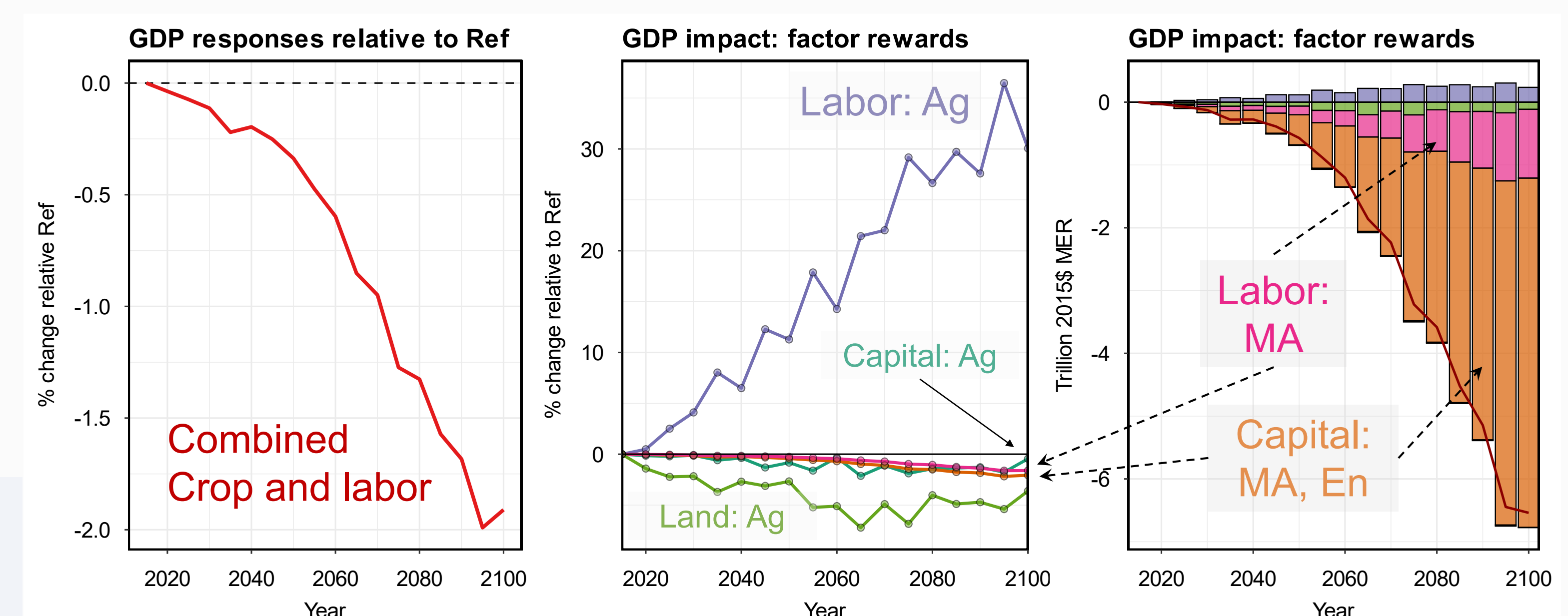
Combined crop and labor impacts relative to Ref.

Global AG-LAND (physical) impact by 2100

	World	Africa, India & S.E. Asia	ROW
Production	-5%	-9%	-2%
Crops (staple)			
Land input	-2%	-4%	-0.5%
Labor input	+28%	+33%	+10%
Labor			
Ag. (Mpppl.)	+23% (+140)	+30% (+125)	+7% (+15)
Material	-4%	-7%	-1%

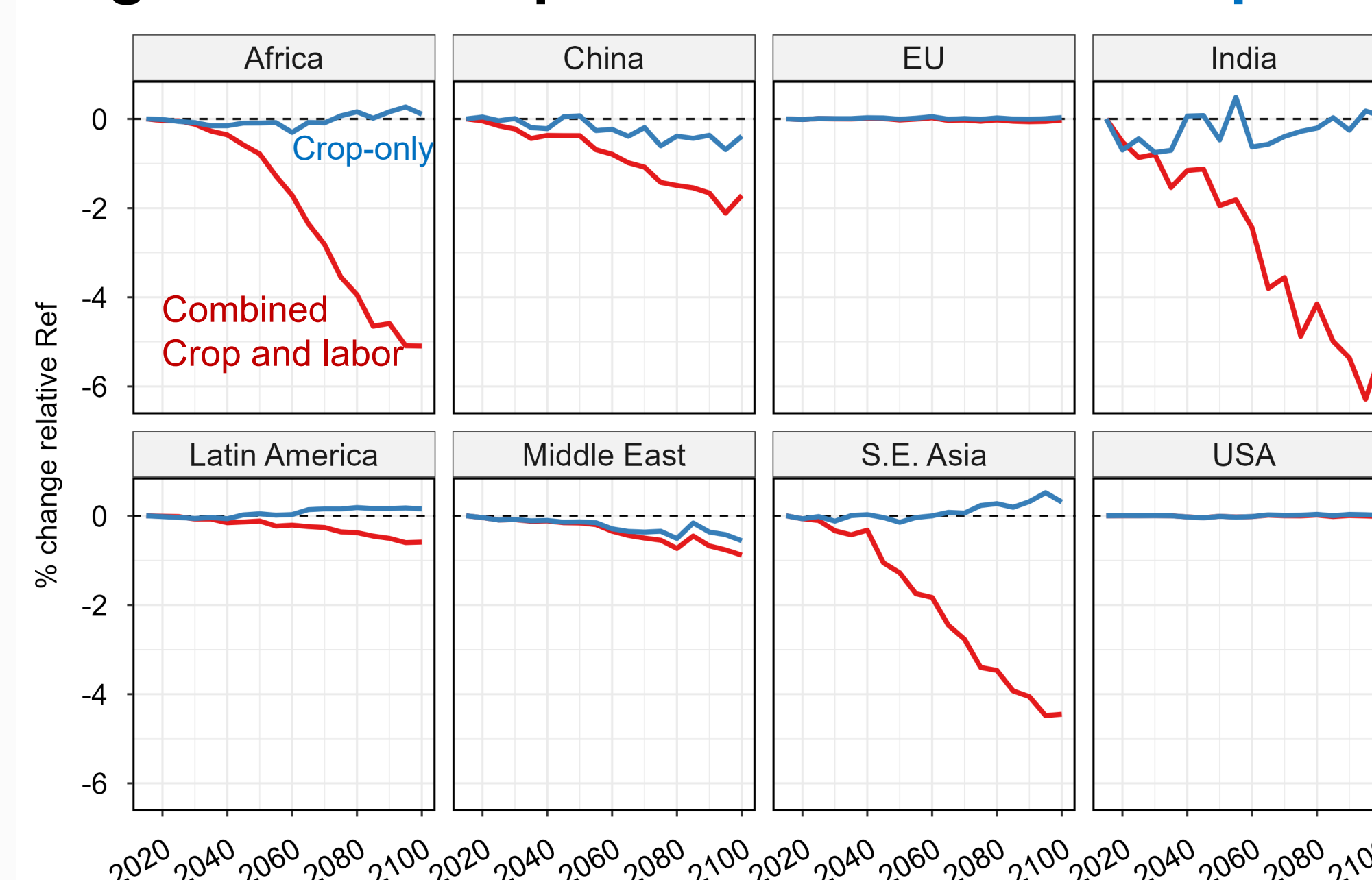
- About 140 million more people work in primary agriculture, mainly in tropical regions.
- Compared to land markets (only in Ag.), larger impacts will be likely in labor markets.

GDP impact and decomposition by factor revenue



- 2% impact on 2100 GDP; the labor market impact ripples directly to other sectors.

Regional GDP impact: Combined vs. Crop-only



Climate impacts on agriculture (RCP 6.0)

- Including agricultural labor and macroeconomic feedback is critical
- Highly regional heterogenous, exacerbating north-south income inequality.
- GDP losses were dominated by labor productivity loss!**

KLEAM: more than GDP responses

- Better representing multisector dynamics through labor and capital markets
- Capture the GDP feedback: macro-micro "tradeoffs"
- Broader factor productivity considerations
- Strengthen the macro-micro-environment connections

Global Change Analysis Model (GCAM)

Previous versions were widely used for studying biophysical yield shocks, **with fixed GDP**. GCAM-KLEM (Capital-Labor-Energy-Material) was released in 2023 (GCAM v7.1)

- Adding **Agriculture** now (KLEAM): GCAM v7.3+

Reference scenario:

- Projects to 2100 with 5-year steps under SSP2 assumption (v3).
 - 2100 climate: **6+ W/m²; 3+ °C; 700+ ppm**; No climate impacts on agricultural production
- Climate impact scenario: Combined Crop & Labor** and **Crop-only** (RCP6-HadGEM)

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