Climate Change Impacts on Agriculture:
Regional Economic Adaptation through 2050

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On behalf of the AgMIP global economic modeling team

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Overview

- AgMIP Global Economic Modeling Team
  - Agricultural Model Intercomparison and Improvement Project
  - Models/Institutions
  - Model Types
- Global Analysis During 2012-2013
  - Nine participating models
  - Reference scenario to 2050 (SSP2 "middle of the road")
  - Economic responses to biophysical shocks (RCP 8.5)
- Global and Regional Analysis During 2014
  - Five participating models
  - Scenarios
    - SSP1 and RCP 4.5
    - SSP2 and RCP 6.0
    - SSP3 and RCP 8.5

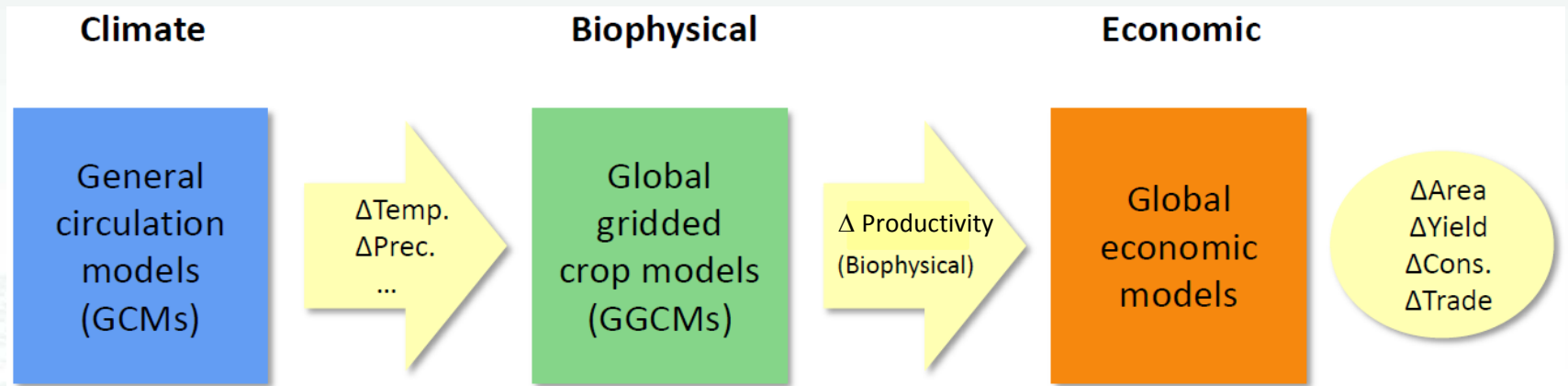# Key characteristics of participating economic models

Model	Institution	Type	Economy coverage	Agr. sectors*	Regions**	Base year	Agr. Policies	Bioenergy	Global numeraire	Agric. supply	Final demand	Trade
AIM	NIES, Japan	CGE	Full economy	8 / 1	89 / 17	2005	Implicitly assumed unchanged	Endogenous 1st and 2nd generation	US CPI	Nested CES	LES utility	Non-spatial; Armington gross-trade
ENVISAGE	FAO/World Bank/ Purdue	CGE	Full economy	10 / 5	11 / 9***		Price wedges (based on GTAP)	None explicitly represented	Price index high-inc. manuf'ed exports	Nested CES	LES utility (with dynamic shifters)	Armington spatial equilibrium
FARM	USDA, USA	CGE	Full economy	12 / 8	5 / 8***	2004 & 2007	Price wedges (based on GTAP)	Little for electricity and heating	Price Index of European Service Sector	Nested CES	LES utility	Armington spatial equilibrium
GTEM	ABARE, Australia	CGE	Full economy	7 / 7	5 / 8***	2004	Implicitly assumed unchanged	Endogenous 1st generation	Average price of capital goods	Nested Leontief and CES	CDE utility	Armington spatial equilibrium
MAGNET	LEI-WUR, The Nether-lands	CGE	Full economy	10 / 9	29 / 16	2004 & 2007	Price wedges (adjusted from GTAP); milk quotas	Biofuel targets w/ endogenous allocation	World GDP Deflator	Nested CES	CDE private demand and Cobb-Douglas utility	Armington spatial equilibrium
GCAM	PNNL, USA	PE	Agriculture, Energy	18 / 0	7 / 9***	2005	Implicitly assumed unchanged	Endogenous 1st and 2nd generation	n.a.	Leontief	Demand elasticities adjusted over time	Heckscher-Ohlin non-spatial, net-trade
GLOBIOM	IIASA, Austria	PE	Agriculture, forestry, Bioenergy	31 / 6	10 / 20	2000	Implicitly assumed unchanged	Exogenous demand	n.a.	Leontief	Demand elasticities adjusted over time	Enke-Samuelson-Takayama-Judge spatial equilibrium
IMPACT	IFPRI, USA	PE	Agriculture	32 / 14	101 / 14	2000	Price wedges (based on PSE/CSE)	Exogenous demand for feedstock crops	n.a.	Supply elasticities adjusted over time	Demand elasticities adjusted over time	Heckscher-Ohlin non-spatial, net-trade
MAgPIE	PIK, Germany	PE	Agriculture	21 / 0	0 / 10	1995	Implicitly assumed unchanged	Exogenous Bioenergy demand	n.a.	Leontief	exogenous	Based on historical self-sufficiency rates

* Figures indicate the number of raw and processed agricultural products represented, respectively.
** Figures indicate the number of individual countries and multi-country aggregates represented, respectively.
*** Regional breakout specific for this application.

The climate modeling chain: From biophysical to socioeconomic

Climate → **Biophysical** → **Economic**

General circulation models (GCMs) → ΔTemp. ΔPrec. ... → Global gridded crop models (GGCMs) → Δ Productivity (Biophysical) → Global economic models → ΔArea ΔYield ΔCons. ΔTrade

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4

AgMIP Agricultural Productivity Growth

Land-augmenting agricultural productivity index (2005 = 1)
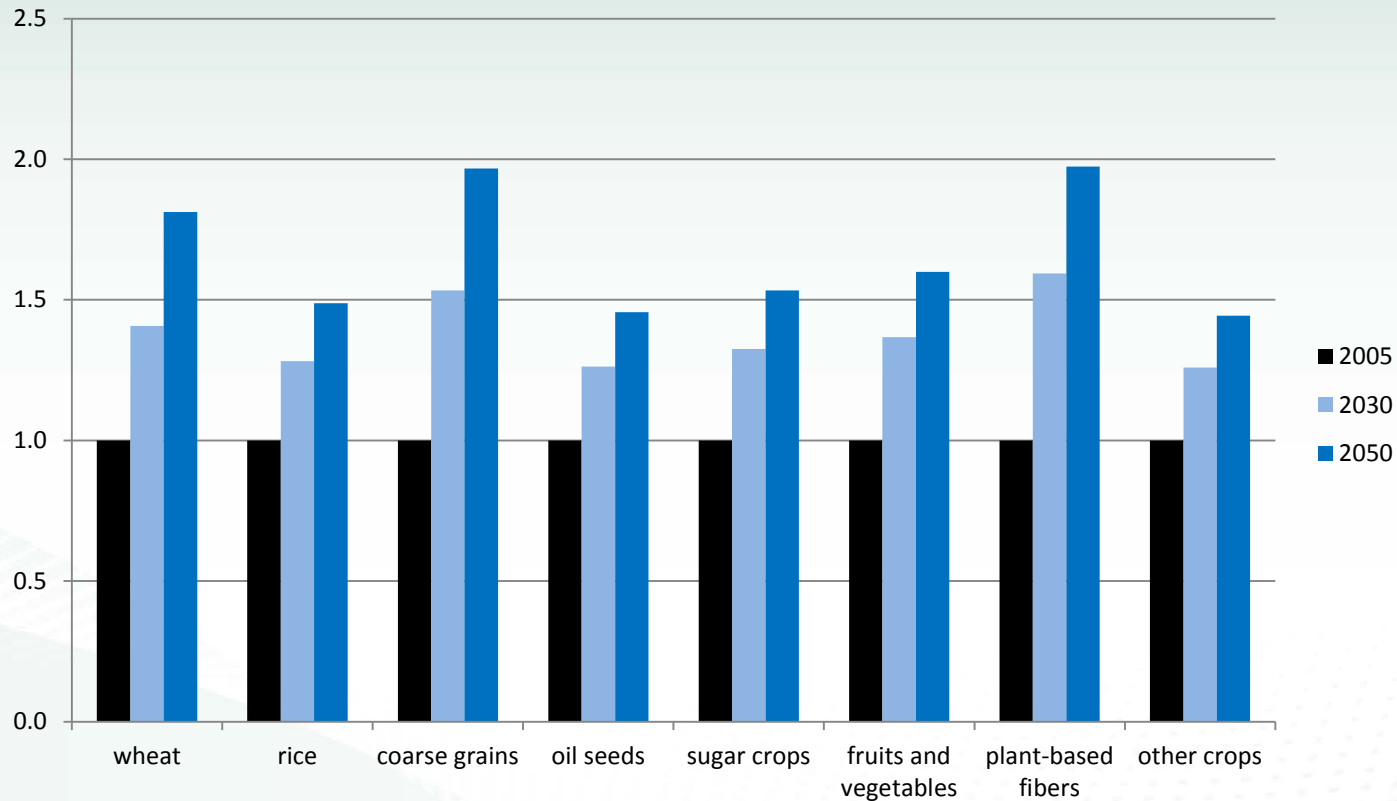
Source: IMPACT model maintained by the International Food Policy Research Institute. IMPACT values are based on expert opinion about potential biological yield gains for crops in individual countries based on historical yield gains and expectations about future private and public sector research and extension efforts.

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Economic Responses to a Decline in Agricultural Productivity Due to Climate Change (SSP2 and RCP 8.5)
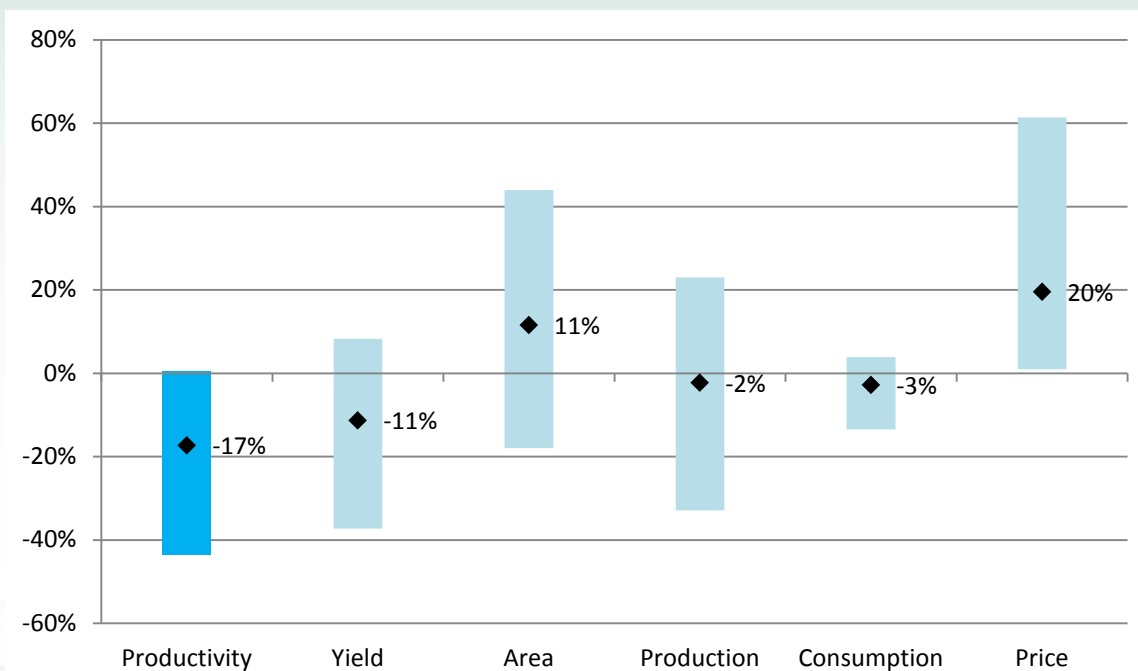
The black diamond is the average (mean) percent change with climate change compared to no climate change in year 2050; the height of a column is the range across climate models, crop models, and economic models. Results are a world average across major field crops: wheat, rice, coarse grains, and oil seeds.

Source: Nelson et al. (2014) *Proceedings of the National Academy of Sciences*, Vol. 111(9): 3274-3279.

AgMIP Scenarios

Radiative forcing	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
RCP 8.5		AgMIP Phase 1	HadGEM (3.1) IPSL (3.2) MIROC (3.3)		
RCP 6.0		HadGEM (2.1) IPSL (2.2) MIROC (2.3)			
RCP 4.5	HadGEM (1.1) IPSL (1.2) MIROC (1.3)				
RCP 2.6					
No climate change	Reference (1.0)	Reference (2.0) AgMIP Phase 1	Reference (3.0) AgMIP Phase 1		

Shared Socio-economic Pathways (SSPs)
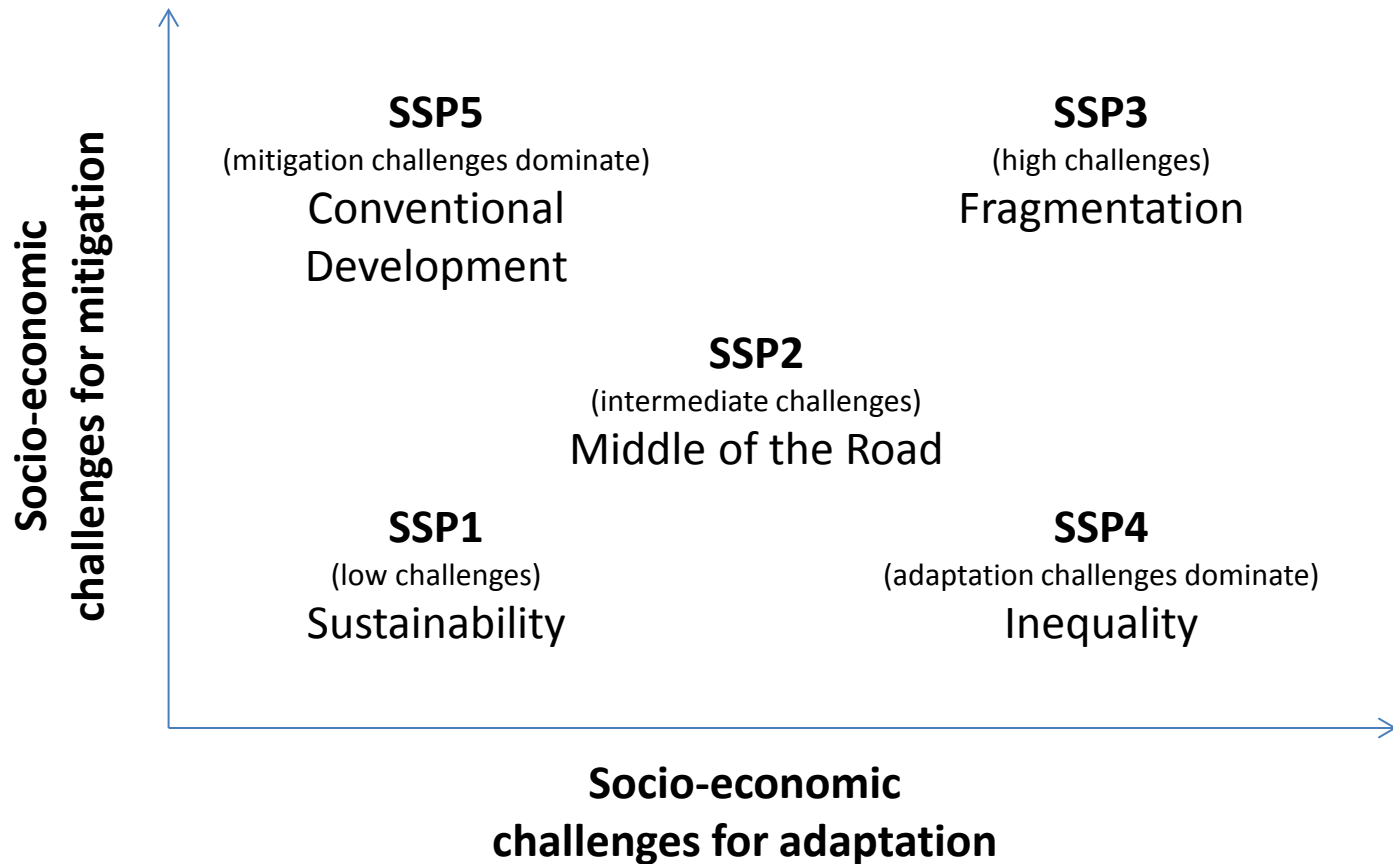
Source: O'Neill, B.C., E. Kriegler, K. Riahi, K. Ebi, S. Hallegatte, T.R. Carter, R. Mathur, D.P. van Vuuren. February 2014. "A New Scenario Framework for Climate Change Research: The Concept of Shared Socio-Economic Pathways," Special Issue on "A Framework for the Development of New Socioeconomic Scenarios for Climate Change Research," *Climatic Change* 122(3): 387-400.

Regional aggregations

Code	Region name	Comments
USA	United States of America	
CAN	Canada	
BRA	Brazil	
OSA	Other South America, Central America & Caribbean	
EUR	Europe	Excl. Turkey
FSU	Former Soviet Union	European and Asian
MEN	Middle-East North Africa	Incl. Turkey
SSA	Sub-Saharan Africa	
CHN	China	
IND	India	
SEA	South-East Asia	Incl. Japan
OAS	Other Asia	Incl. Other Oceania
ANZ	Australia/New Zealand	

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Figure 1. Percent change in economic indicators from 2005 through 2050 for the 5-commodity aggregate <u>without climate change</u>, across three SSPs (reference scenarios)
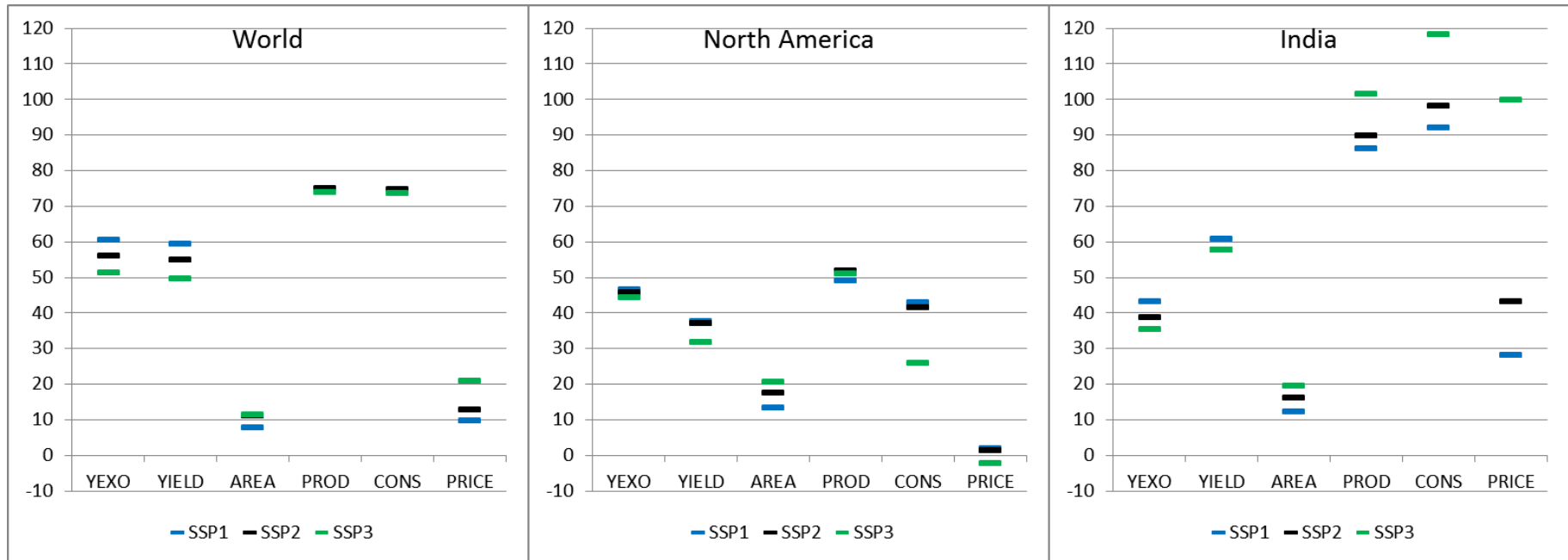

At the world level, change in production equals change in consumption; but they differ at regional level.

YEXO reflects income-related capacity for agricultural research.

For SSP 3 relative to SSP 2, greater population and lower income are partially offsetting.

Figure 2. Percent change in economic indicators from 2005 through 2050 by crop <u>without climate change</u>, for <u>SSP2</u> (reference scenario 2.0)
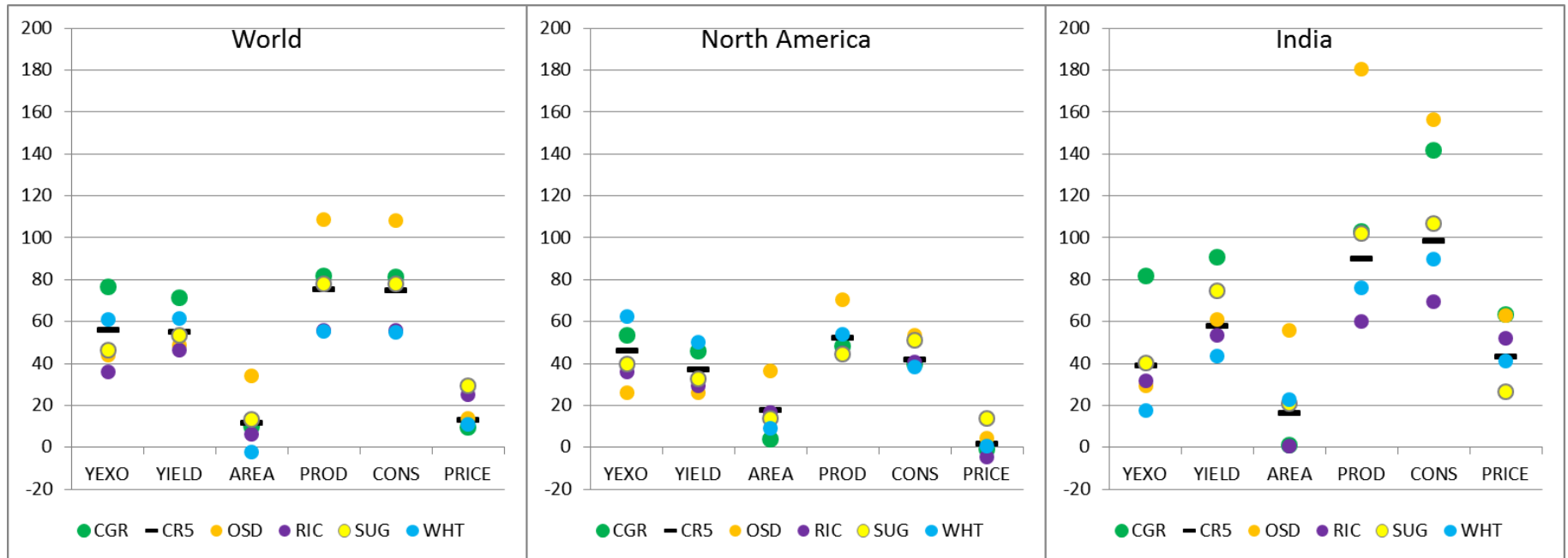
CGR = coarse grains
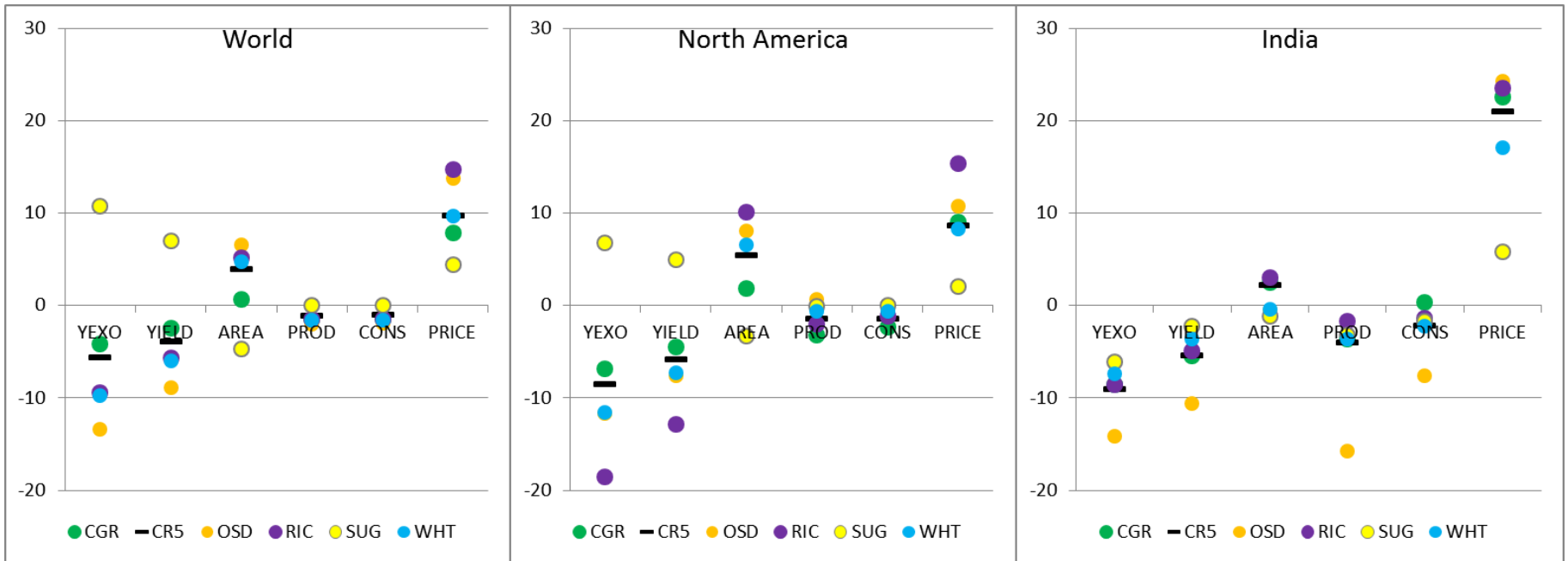OSD = oil seeds
RIC = rice
SUG = sugar
WHT = wheat

Figure 3. Percent change in USA economic indicators for the 5-commodity aggregate <u>with climate change</u>, across three climate models
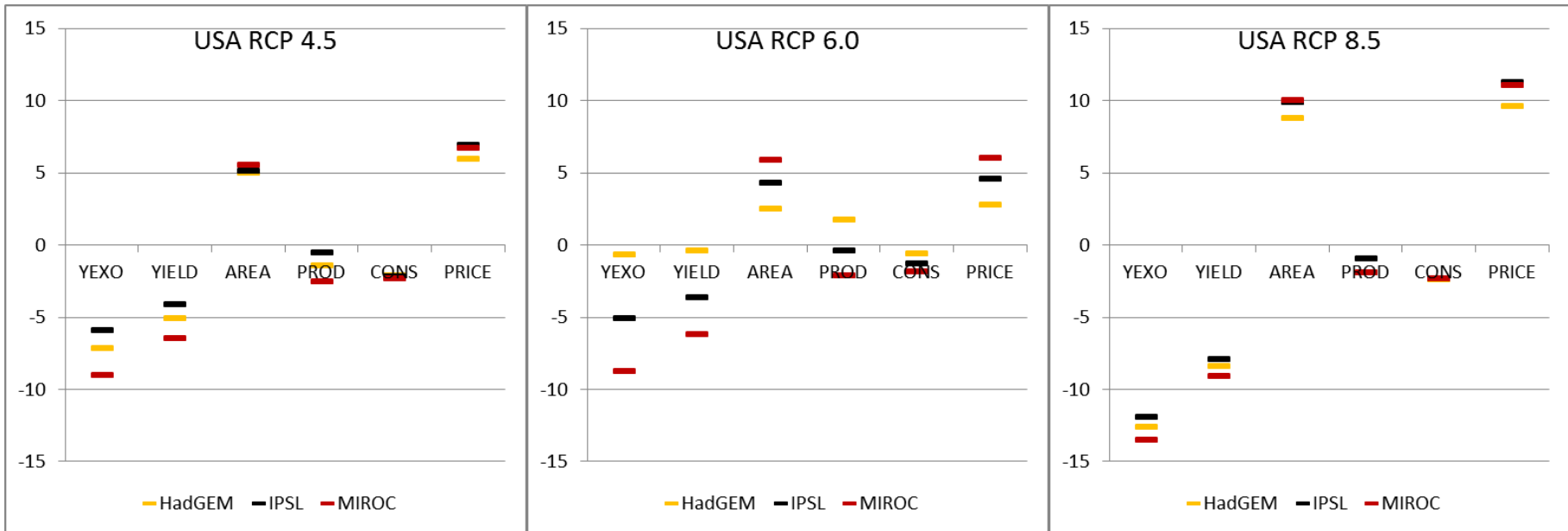
Small decline in consumption across climate scenarios and climate models.

Figure 4. Percent change in economic indicators by crop for SSP 2 and RCP 6.0 using the MIROC climate model (scenario 2.3)

CGR = coarse grains
OSD = oil seeds
RIC = rice
SUG = sugar
WHT = wheat

In some parts of the world, yield for sugar crops increases with climate change. In India, the yield for sugar crops decreases.

Figure 5. Percent change in imports and exports for <u>SSP 2</u> and <u>RCP 6.0</u> with HadGEM (average of FARM, ENVISAGE, and MAGNET models; scenario 2.1)
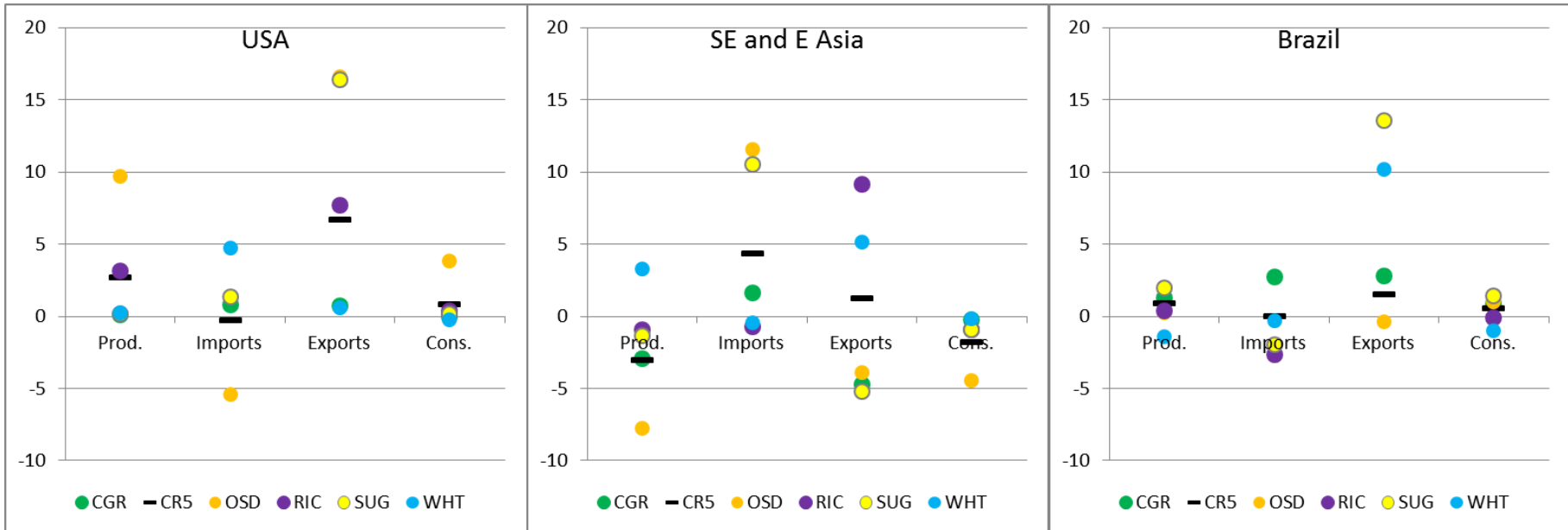
CGR = coarse grains
OSD = oil seeds
RIC = rice
SUG = sugar
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USA: increase in exports with climate change
SE and E Asia: increase in imports
Brazil: increase in exports

Outstanding Issues

- How to apply output from crop process models to global economic models

- Response of food consumption to increasing per-capita income
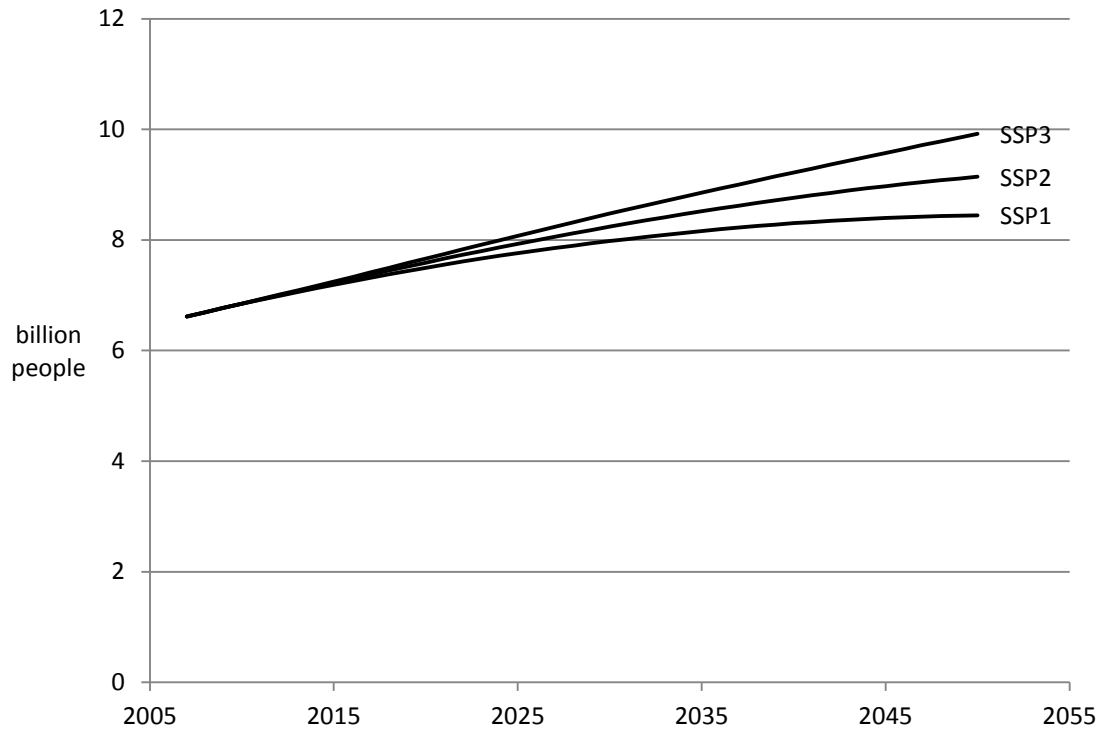
- Link to analysis at sub-national level

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Further Reading

- **Special issue** of *Agricultural Economics* on AgMIP global economic scenarios (January 2014)

- Nelson, G.C., H. Valin, R.D. Sands, P. Havlik, H. Ahammad, D. Deryng, J. Elliott, S. Fujimori, T. Hasegawa, E. Heyhoe, P. Kyle, M. von Lampe, H. Lotze-Campen, D. Mason d'Croz, H. van Meijl, D. van der Mensbrugghe, C. Müller, A. Popp, R. Robertson, S. Robinson, E. Schmid, C. Schmitz, A. Tabeau, and D. Willenbockel, 4 March 2014, "Climate change effects on agriculture: Economic responses to biophysical shocks," *Proceedings of the National Academy of Sciences* (**special feature**) 111(9): 3274-3279.
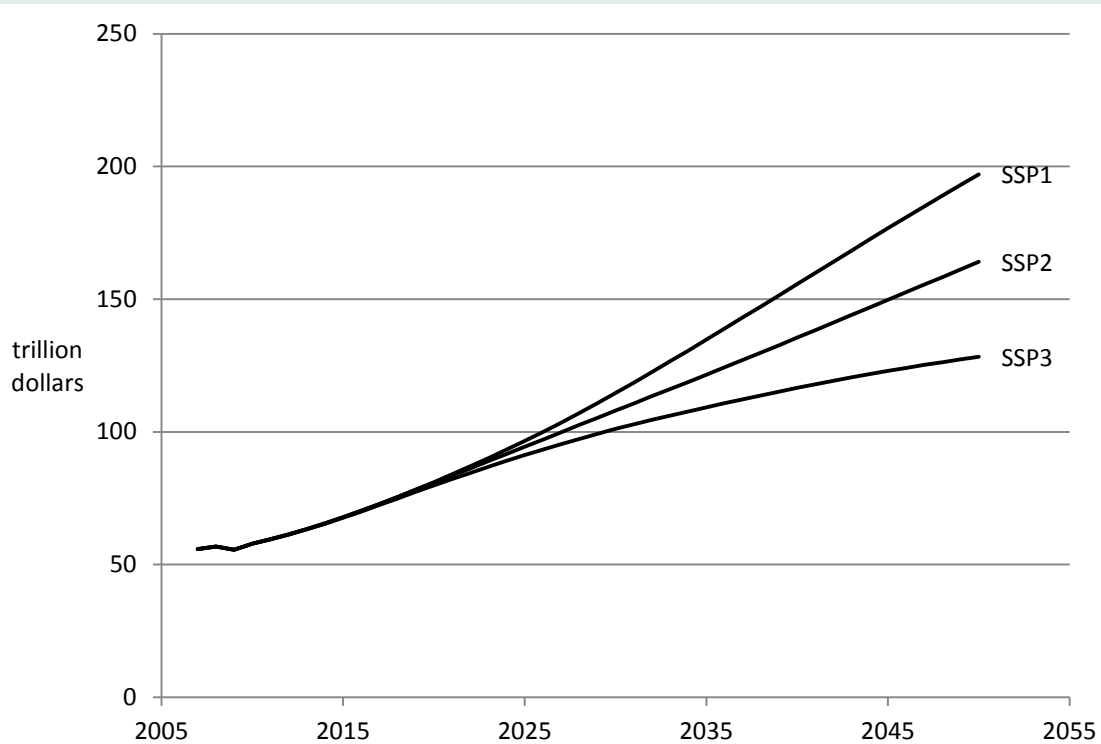
World Population Projections

Source: OECD

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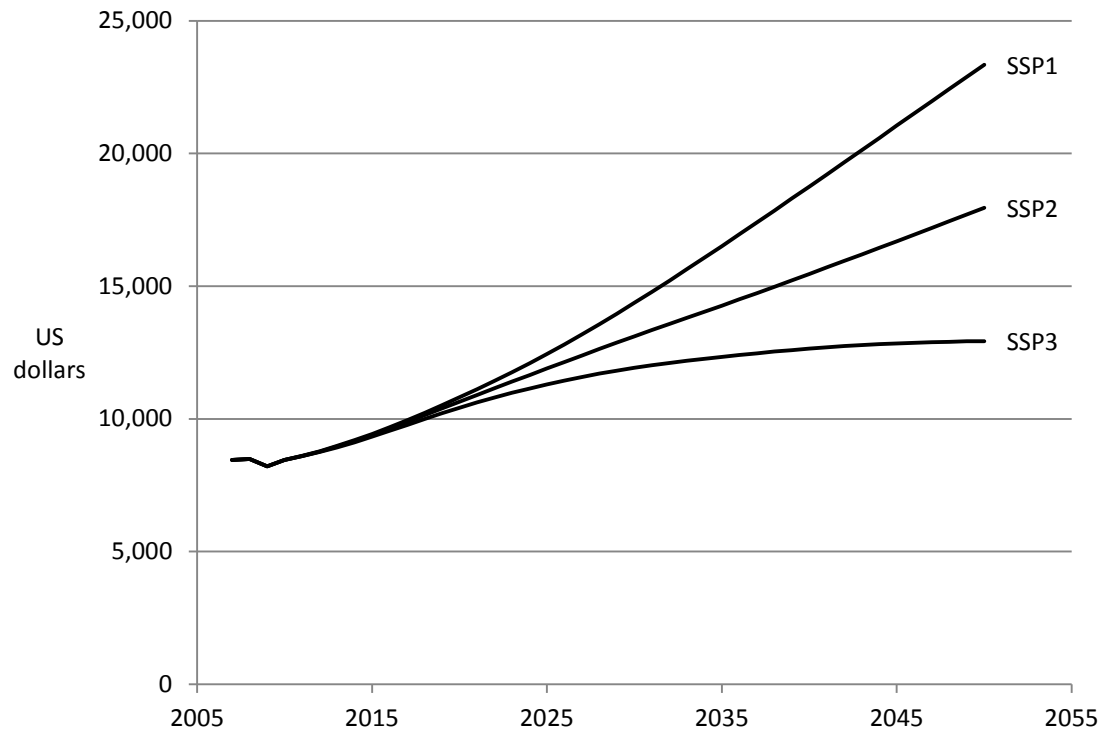
World Projections of Total GDP

Source: OECD

World Projections of Average GDP Per Capita

Source: OECD