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Water and Food Security under Climate Change: Integrated Global Water and Food Modeling

Tingju Zhu, Claudia Ringler, Gerald Nelson, Mark W. Rosegrant

International Food Policy Research Institute

Washington, DC

IGIM CMIP Meeting, October 3-4, 2012

Appendix 2 The IMPACT Development Team

The IMPACT model has had many contributors over the years and remains in active development today.

Current Contributors

Miroslav Batka
Prapti Bhandary
Elizabeth Bryan
Nicola Cenacchi
Alex de Pinto
Dolapo Enahoro
Laetitia Leroy
Man Li
Nicholas Magnan
Daniel Mason-D'Croz
Siwa Msangi
Gerald Nelson
Claudia Ringler
Richard Robertson
Sherman Robinson
Mark W. Rosegrant
Timothy B. Sulser
Timothy Thomas
Simla Tokgoz
Rowena Valmonte-Santos
Liangzhi You
Wei Zhang
Tingju Zhu
Ulrich Kleinwechter

Past Contributors

Mercedita C. Agcaoili-Sombilla
Mahfuzuddin Ahmed
Ximing Cai
Sarah A. Cline
Claude Courbois
Christopher Delgado
Simeon Ehui
Robert E. Evenson
Mandy Ewing
Ian Gray
Christina Ingersoll
Puja Jawahar
David R. Lee
Weibo Li
Marilia Magalhaes
Alyssa McCluskey
Siet Mejier
Naoko Nakagawa
Michael S. Paisner
Amanda Palazzo
Nicostrato D. Perez
Gregory J. Scott
Pascale Sabbagh
Henning Steinfeld
Kenneth Strzpek
Nikolas Wada
Julie Witcover

Rosegrant et al. 2012. International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model Description. International Food Policy Research Institute (IFPRI), Washington, D.C.

Motivation: ***Climate Change is likely to Adversely Affect Water Supply and Agricultural Water Use***

- Climate change is expected to alter hydrological regimes
  - Affecting freshwater availability – quantity and timing
- Crop ET requirements are likely to increase under warming
- Existing assessments focus on natural processes, with less attention being paid to the human dimension
- Past hydroclimatic experience is no longer a good guide for the future
  - Need timely assessments to aid decision-making
  - Especially for irreversible investments with long-term consequences in climate-sensitive sectors

Motivation: Agriculture – the Single Largest Water User Globally in the Foreseeable Future

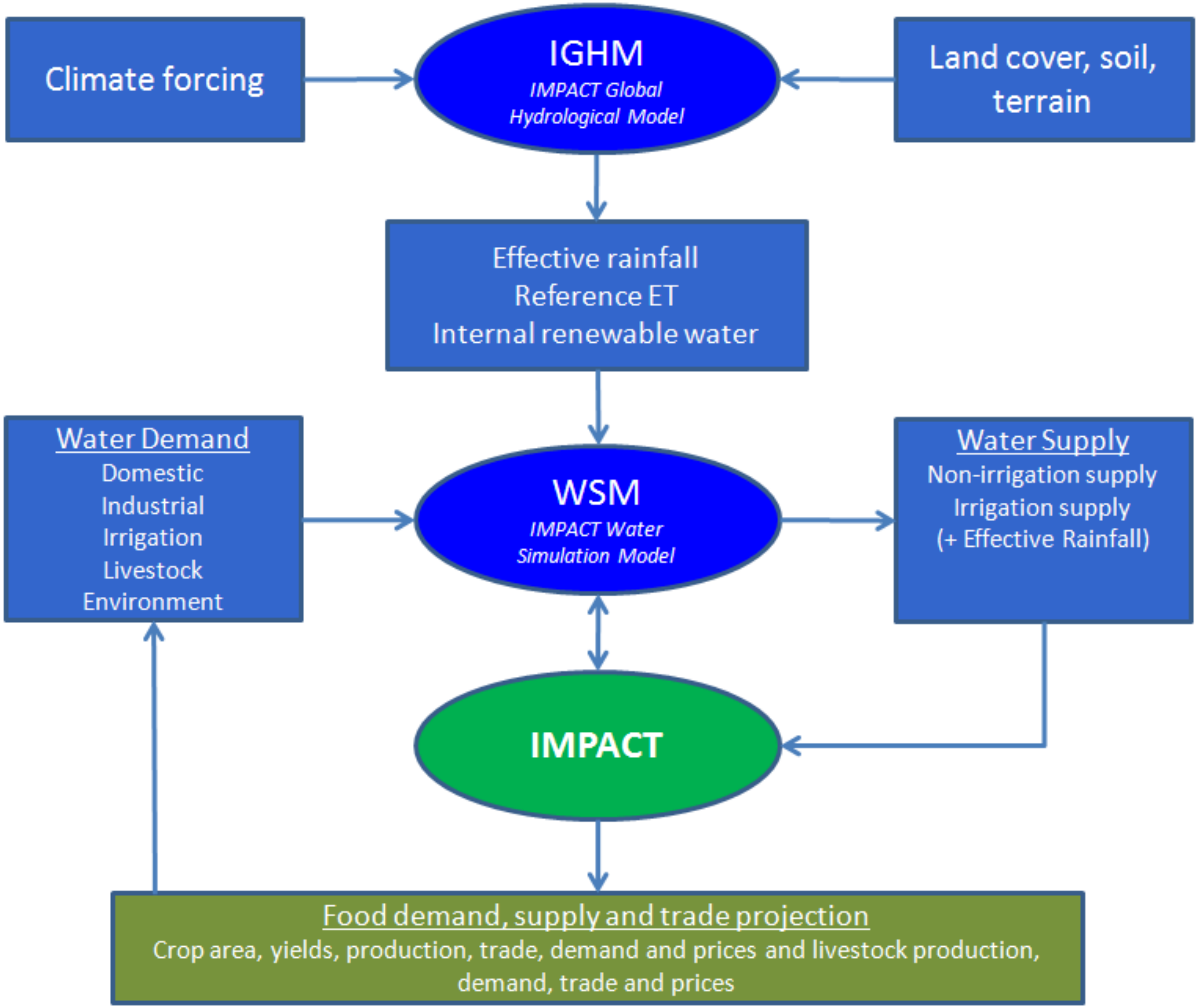
- Irrigation is key for securing future food supply
  - Accounting for less than 20% of global cropland
  - Contributing ~40% of global cereal production
- Irrigation is the largest water user, accounting for
  - 70% global water withdrawals
  - 90% global water consumption
- Usually seen as the major driver of water scarcity
- But improvement of agricultural water use efficiency is a slow and difficult process

Motivation: *Food Security Challenges are Unprecedented*

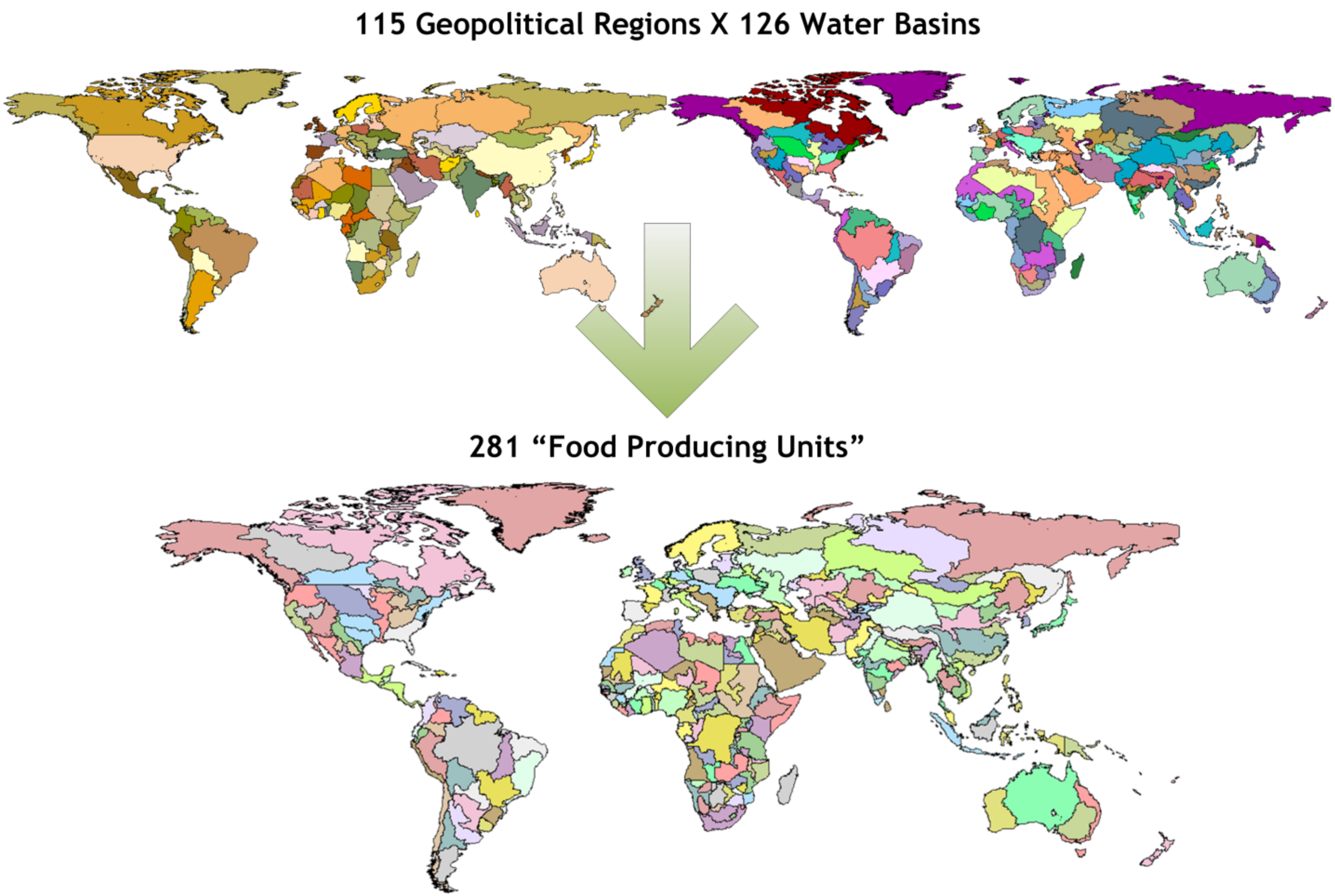
- Population growth
  - 50 percent more people between 2000 and 2050
  - Almost all growth in developing countries—particularly Africa
- Income growth in developing countries
  - More demand for high valued food (meat, fish, fruits, vegetables)
- Climate change – a threat multiplier
  - Reduced productivity of existing varieties, cropping systems

Part I:
Linked Modeling System for Global Water & Food Projections

Data Flow and Modeling Strategy (IMPACT-Water)



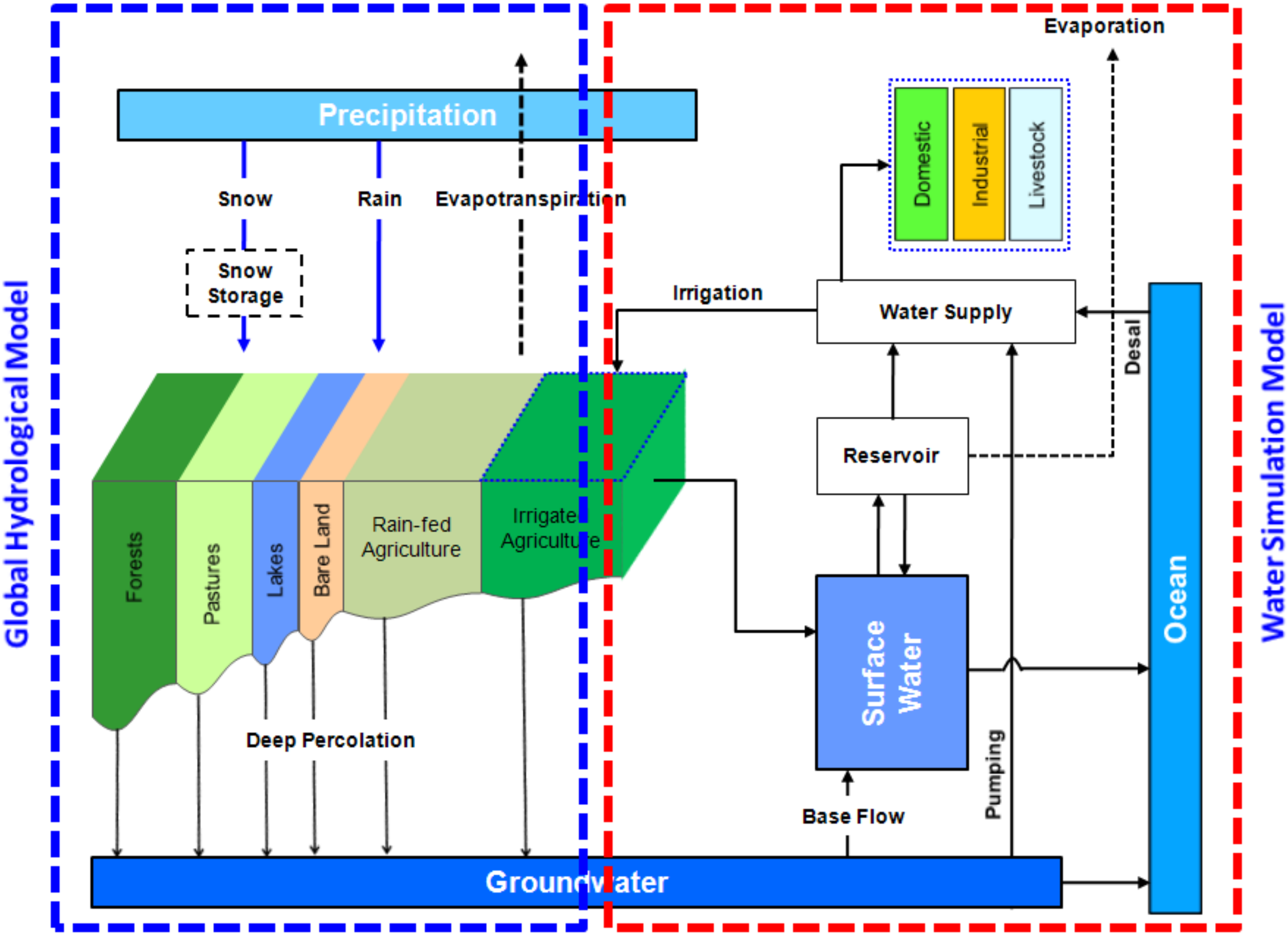
IMPACT Model's Spatial Disaggregation



IMPACT Commodities

1	Beef	24	Rice
2	Cassava et al.	25	Sheep and Goats
3	Chickpeas	26	Sorghum
4	Cotton	27	Soybean Meal
5	Eggs	28	Soybean Oils
6	Groundnut Meal	29	Soybeans
7	Groundnut Oils	30	Sugar
8	Groundnuts	31	Sugar beets
9	Maize	32	Sugarcane
10	Milk	33	Sunflower
11	Millet	34	Sunflower Meal
12	Other Grains	35	Sunflower Oil
13	Palm	36	Sweet Potatoes and Yams
14	Palm Kernel	37	Sweeteners
15	Palm Kernel Meal	38	Temperate Fruits
16	Palm Kernel Oil	39	Total Other Meals
17	Pigeonpeas	40	Total Other Oils
18	Pork	41	Total Other Oilseeds
19	Potato	42	Tropical and Sub-Tropical Fruits
20	Poultry	43	Vegetables
21	Rapeseed	44	Wheat
22	Rapeseed Meal	45	Other Crops
23	Rapeseed Oil		

Representation of Hydrology & Water Uses



IGHM Main Structure and Major Assumption

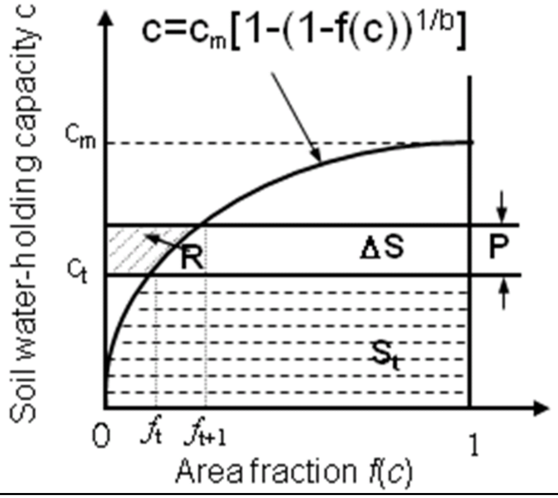
- ***Spatial Resolution***: 0.5° latitude x 0.5° longitude grid cells covering the entire global land surface except the Antarctic
- ***Temporal Resolution***: Monthly simulation over multi-decadal period

Potential Evapotranspiration - Priestley-Taylor equation

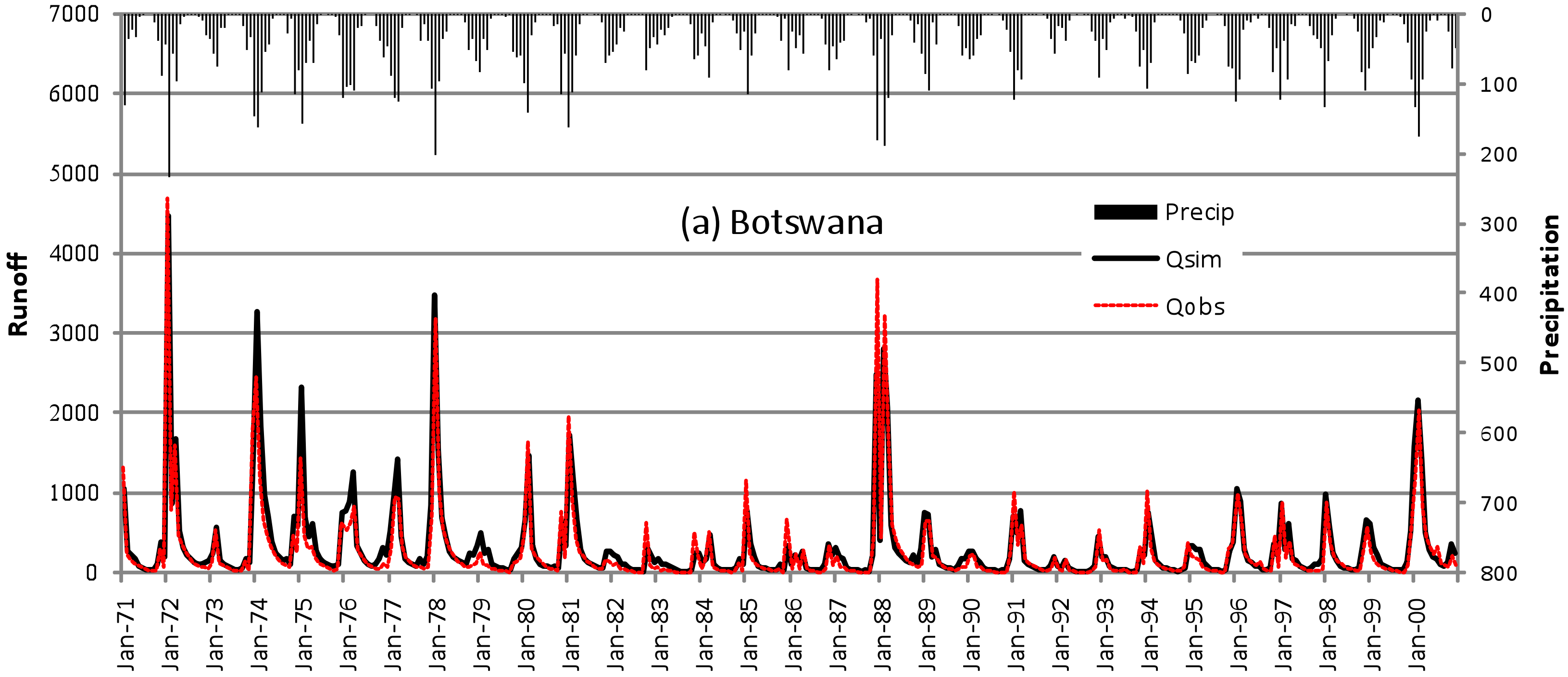
$$PET = \alpha \frac{\Delta}{\Delta + \gamma}(R_n - G)$$

Runoff Generation

- *Variable soil moisture holding capacity within a grid cell*
- *Linear reservoir representing groundwater modulation of base flow*



IGHM Model Runoff Calibration and Validation for Botswana Catchment of the Limpopo River Basin

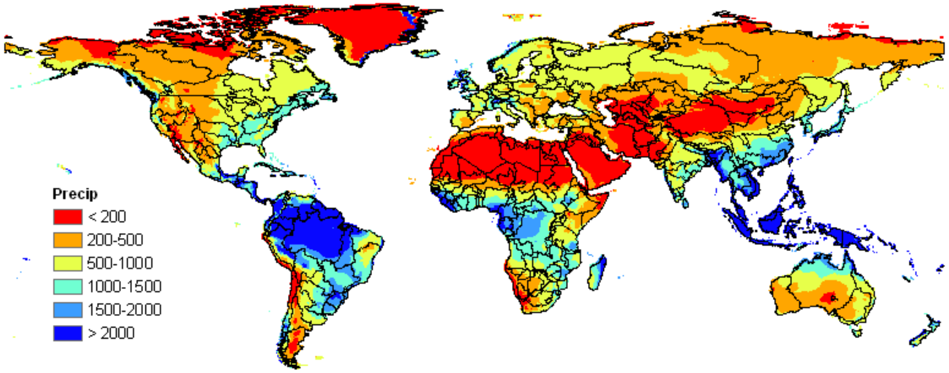


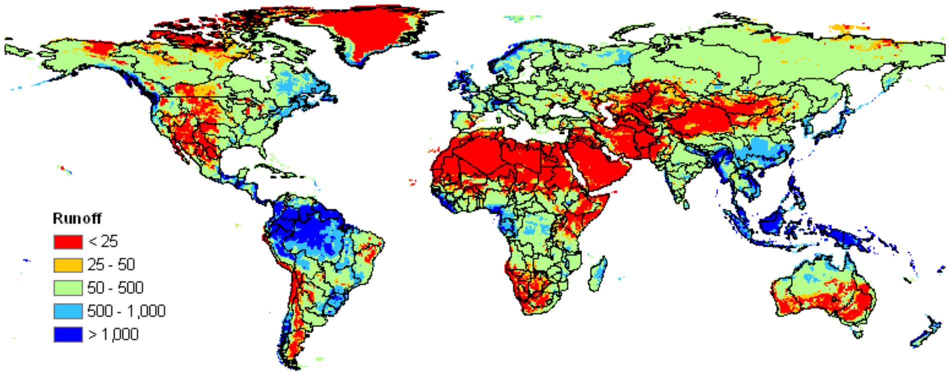
$$NSE = 1 - \frac{\sum_t (Q_t - q_t)^2}{\sum_t (Q_t - \bar{Q}_t)^2}$$

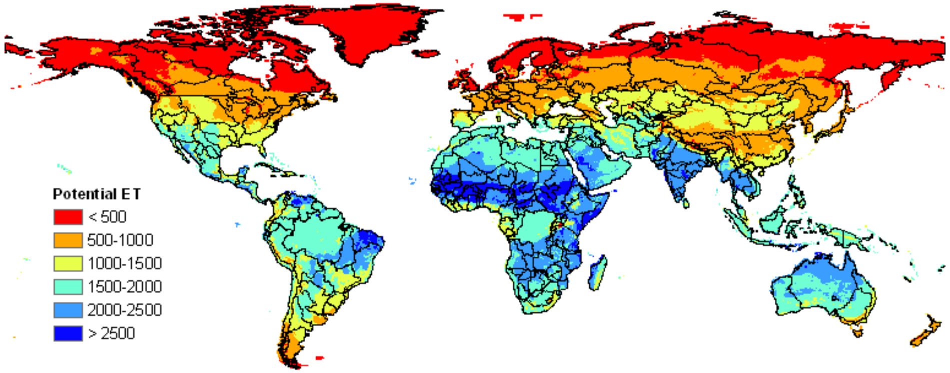
Nash-Sutcliffe model efficiency coefficient is 0.913 in the calibration period (1971-85) and is 0.906 in the validation period (1986-2000).

Mean Annual Precipitation, Potential ET and Runoff

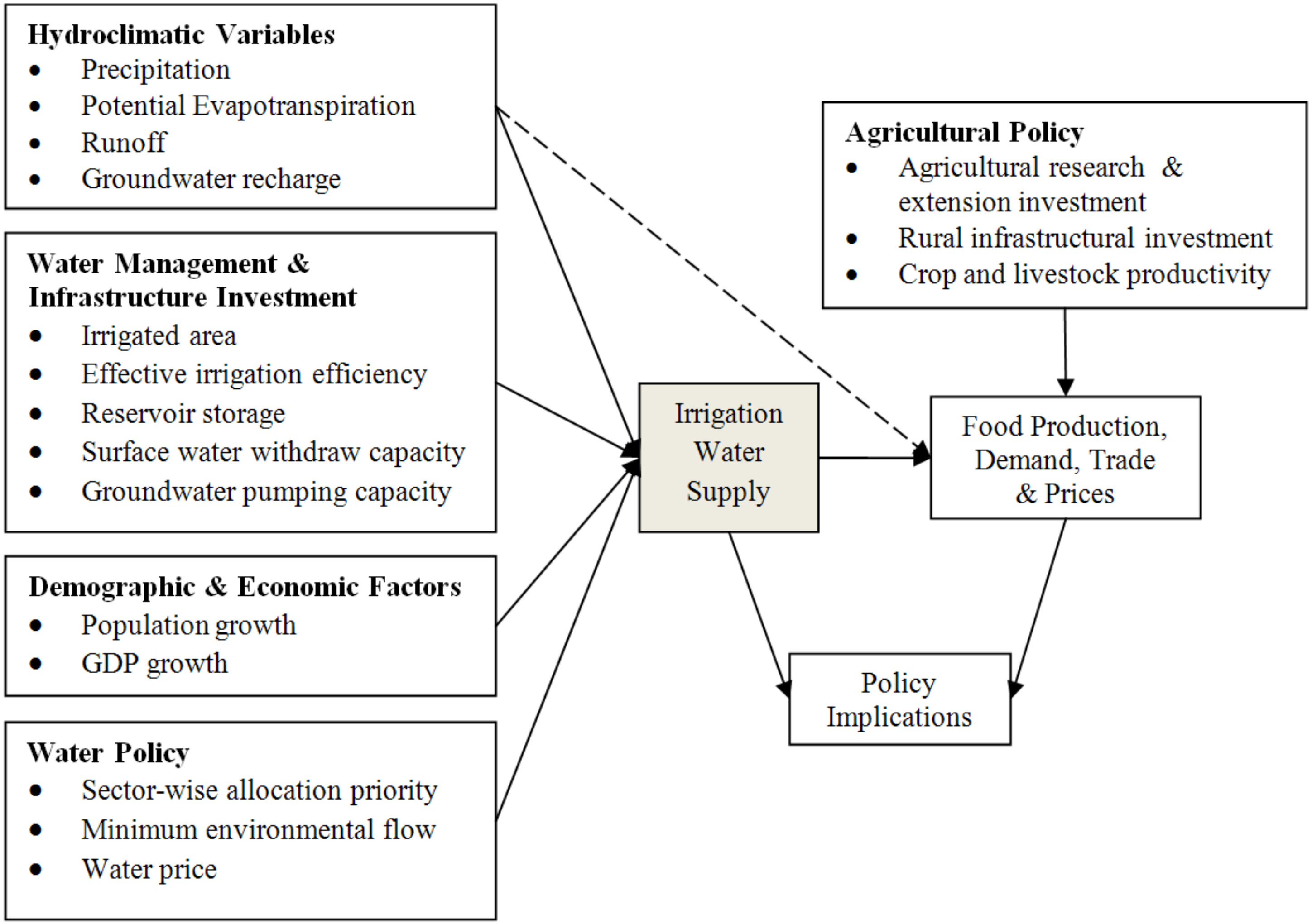
1971-2000



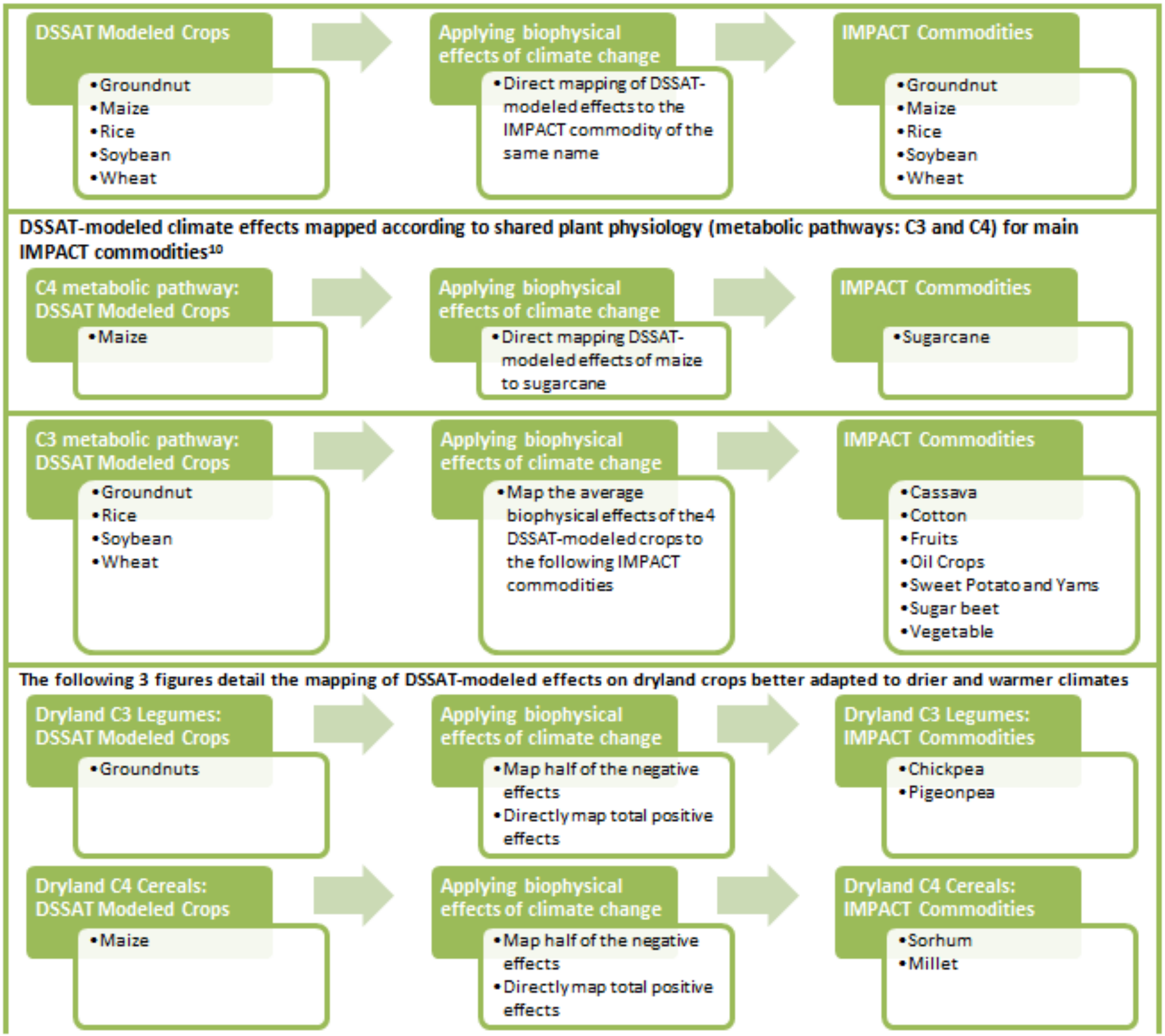




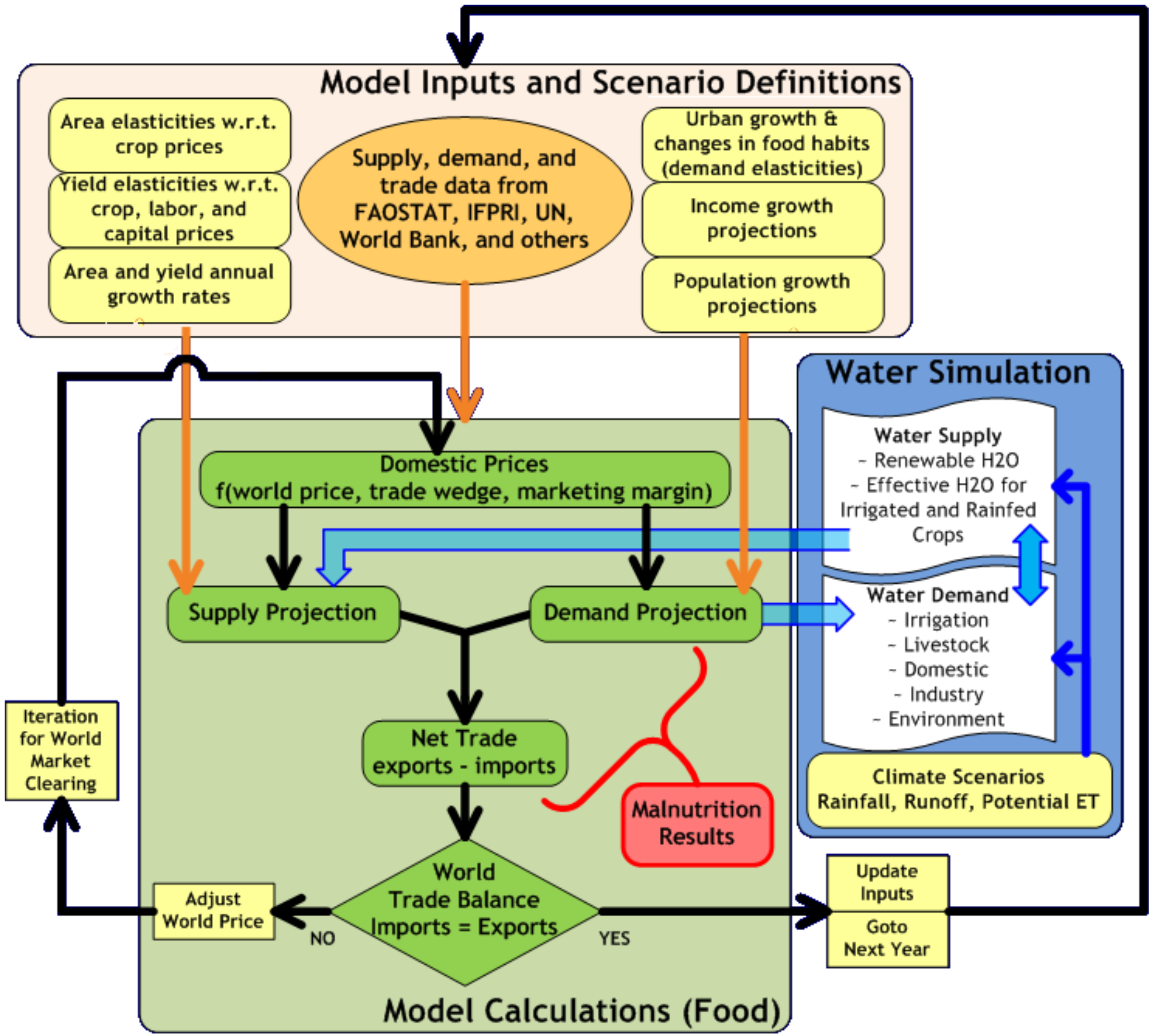
IWSM Data Flow and Policy Scenario Framework



Applying DSSAT-simulated Crop Yield Impacts of Climate Change in IMPACT Model



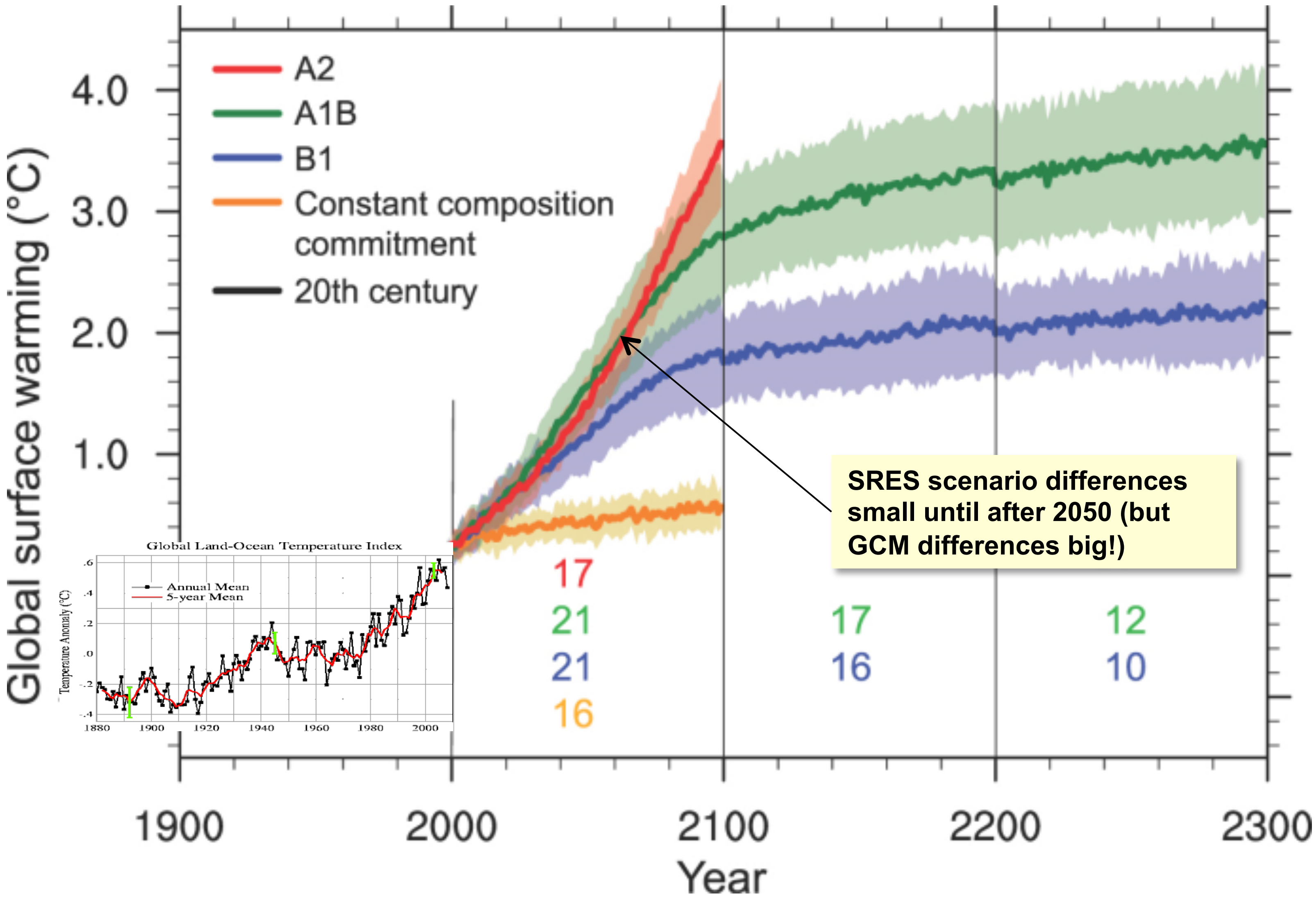
IMPACT – Partial Equilibrium Agricultural Sector Model



Part II:
Climate Change and Socioeconomic Scenarios

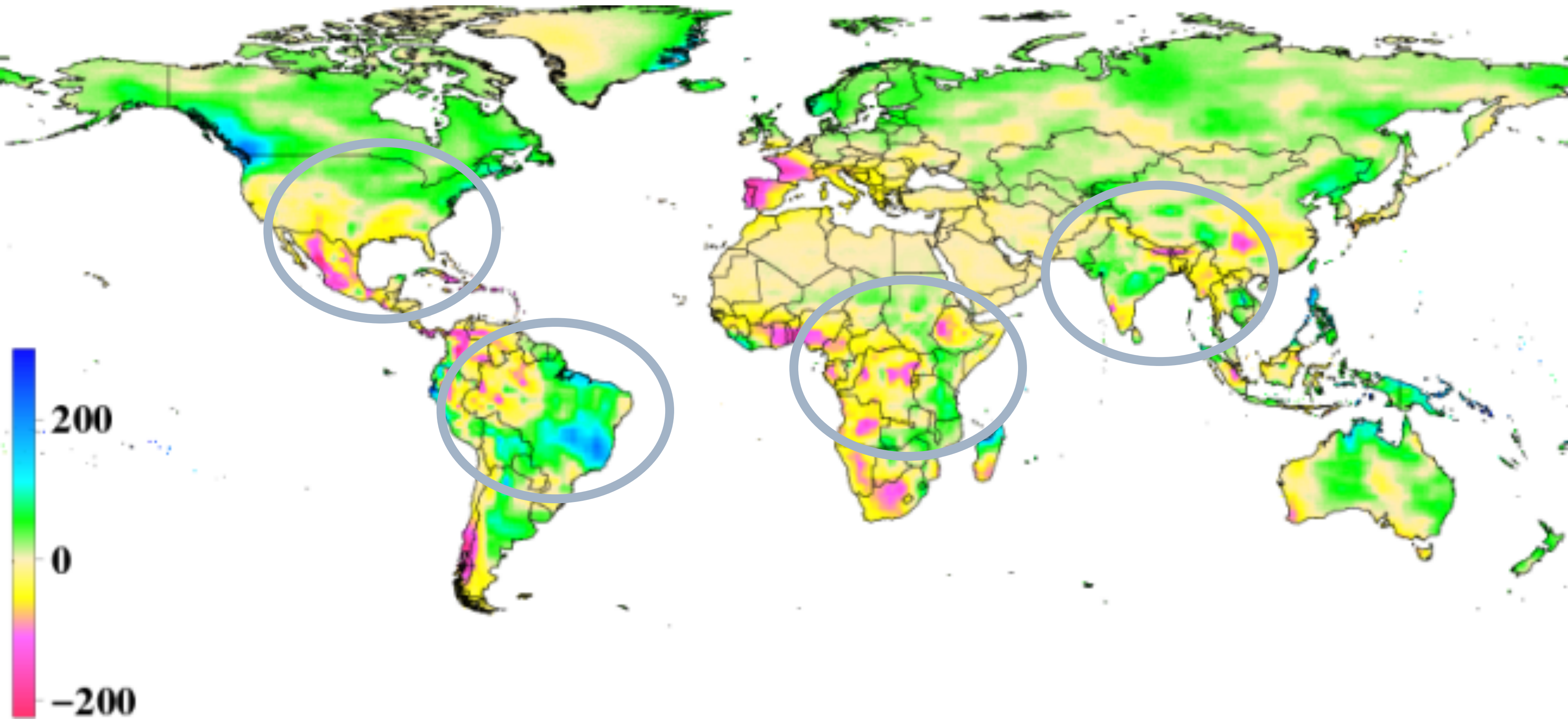
Source: Nelson et al. (2010); Zhu and Ringler (2011)

Average temperatures could increase substantially



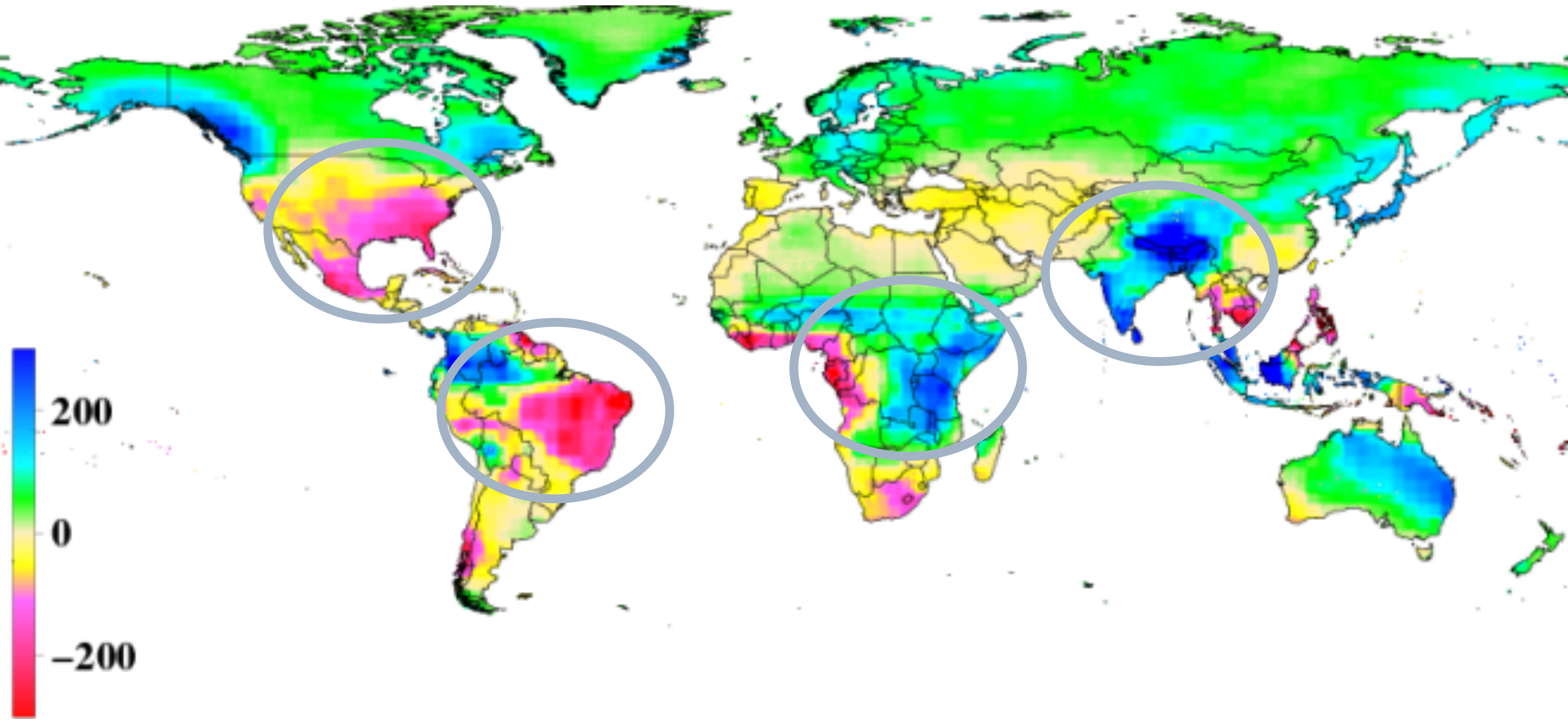
Source: Figure 10.4 in Meehl, et al. (2007)

Change in average annual precipitation, 2000-2050, CSIRO GCM, A1B (mm)



Source: Nelson et al. (2010)

Change in average annual precipitation, 2000-2050, MIROC GCM, A1B (mm)



Source: Nelson et al. (2010)

Socioeconomic Scenarios - Plausible futures for population and GDP growth

- **Optimistic**
  - High GDP and low population growth
- **Baseline**
  - Medium GDP and medium population growth
- **Pessimistic**
  - Low GDP and high population growth

Global and regional GDP per-capita growth scenarios

Global growth rate assumptions, annual average 2010-2050 (%)

	Pessimistic	Baseline	Optimistic
Population	1.04	0.70	0.35
GDP	1.91	3.21	3.58
GDP per capita	0.86	2.49	3.22

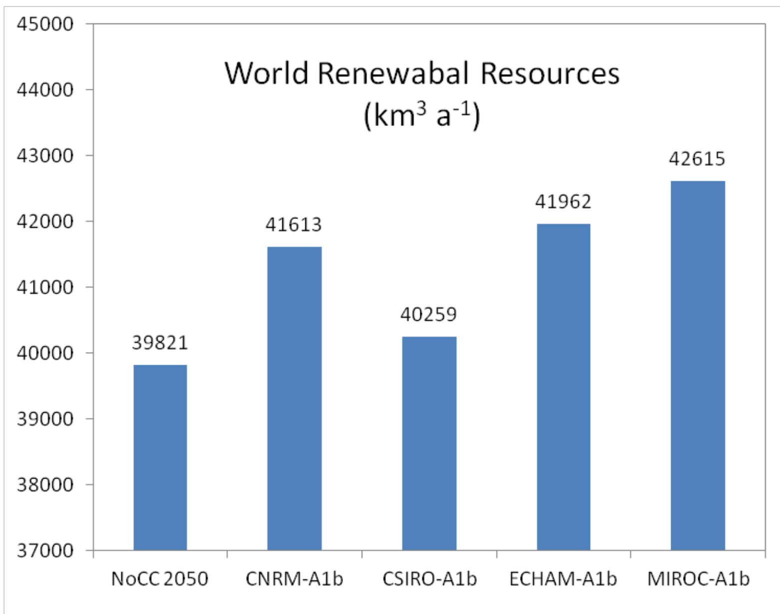
African GDP per capita growth rate assumptions, annual average 2010-2050 (%)

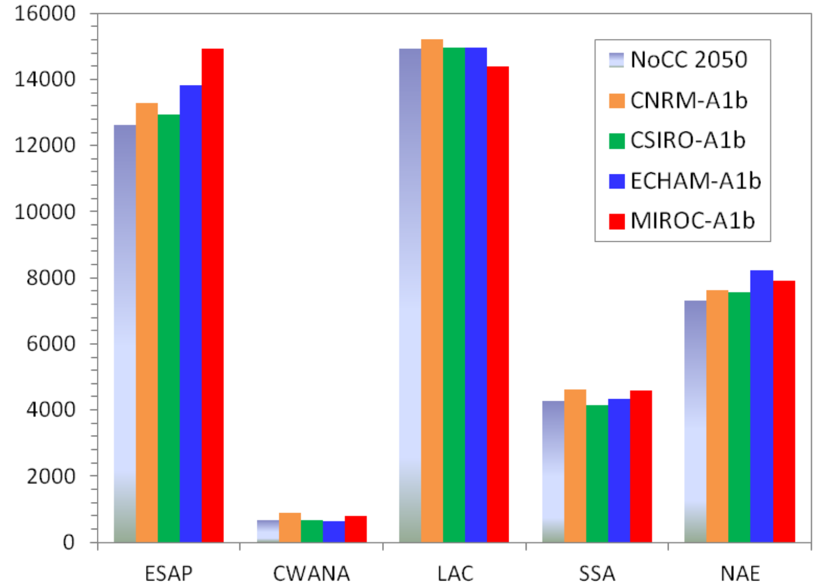
	Pessimistic	Baseline	Optimistic
Central Africa	2.42	3.92	4.85
Western Africa	2.04	3.63	4.03
Eastern Africa	2.72	4.18	4.97
Northern Africa	1.78	2.60	3.49
Southern Africa	0.55	2.98	3.44

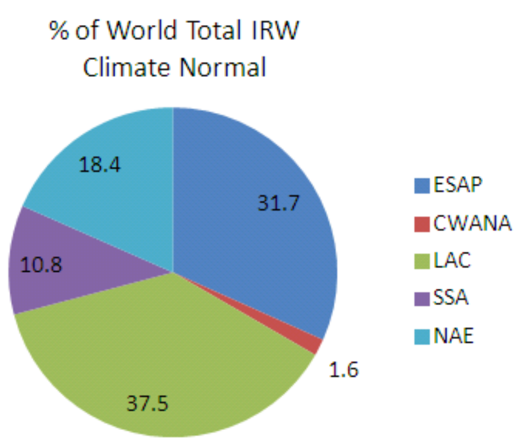
Part III:

Water and Food Security Implications of Global Climatic and Socioeconomic Changes

Internal Renewal Water Resources (IRW) under Climate Normal and Climate Change: 2050







Region Grouping

ESAP - East -South Asia and Pacific

CWANA - Central-West Asia and North Africa

LAC - Latin America and Caribbean

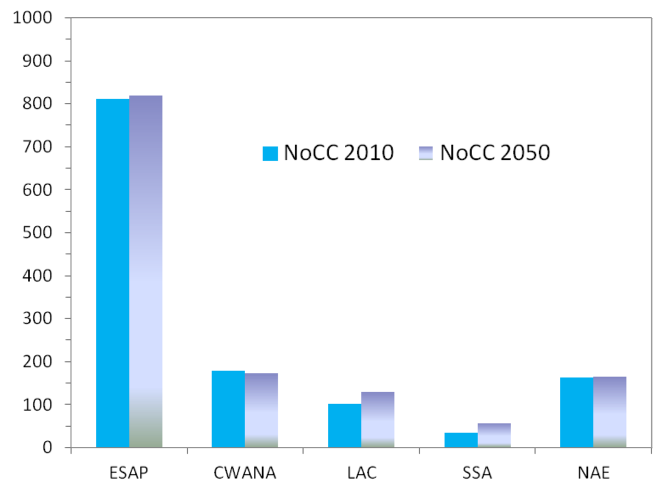
SSA - Sub-Saharan Africa

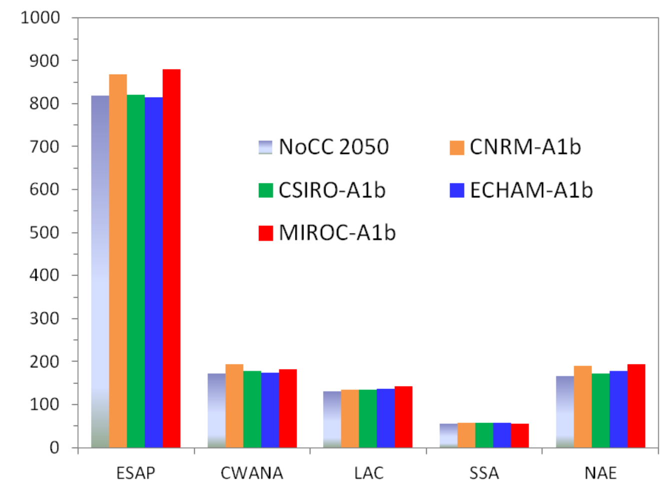
NAE - North America and Europe

Source: Authors' calculation with **IGHM** Global Hydrological Model (2011)

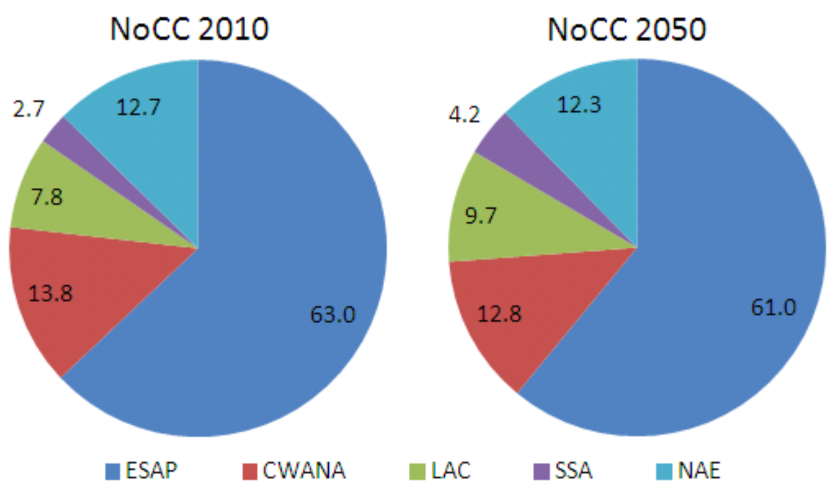
Irrigation Water Consumption under Climate Normal and Climate Change: 2010-2050

Estimated Consumption in $km^3\ a^{-1}$





As % of Global Total Irrigation Consumption



Region Grouping

ESAP - East -South Asia and Pacific

CWANA - Central-West Asia and N. Africa

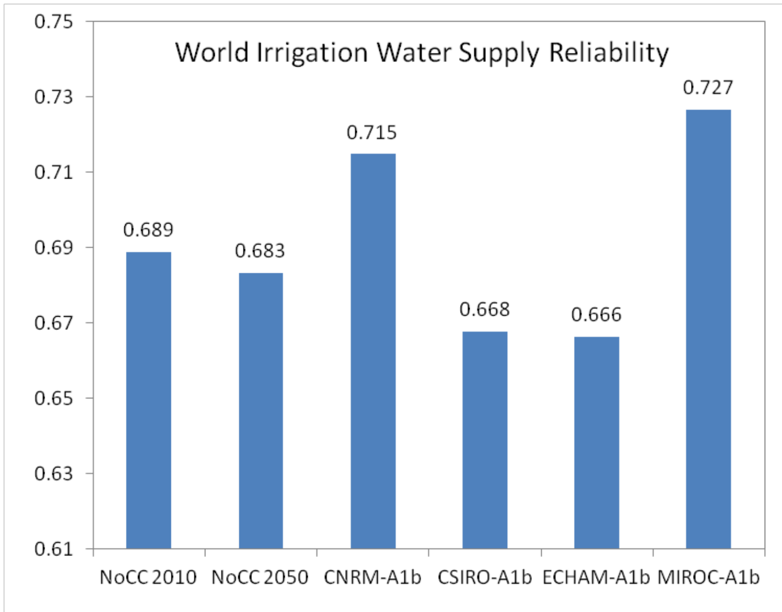
LAC - Latin America and Caribbean

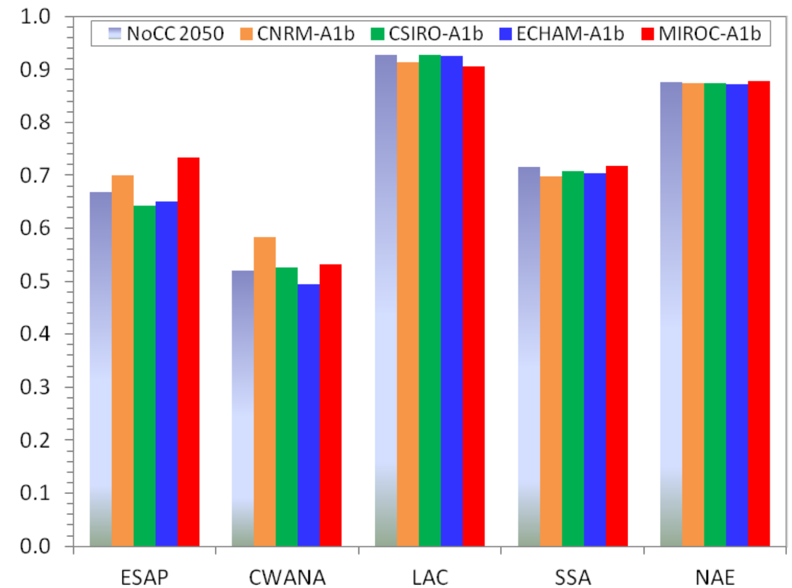
SSA - Sub-Saharan Africa

NAE - North America and Europe

Source: Authors' calculation with **IWSM** Global Water Simulation Model (2011)

Irrigation Water Supply Reliability (IWSR) under Climate Normal and Climate Change: 2010 & 2050





Concept Definition

IWSR = Irrigation Water Requirement / Irrigation Water Supply

Water accounting considers consumptive use

Region Grouping

ESAP - East -South Asia and Pacific

CWANA - Central-West Asia and North Africa

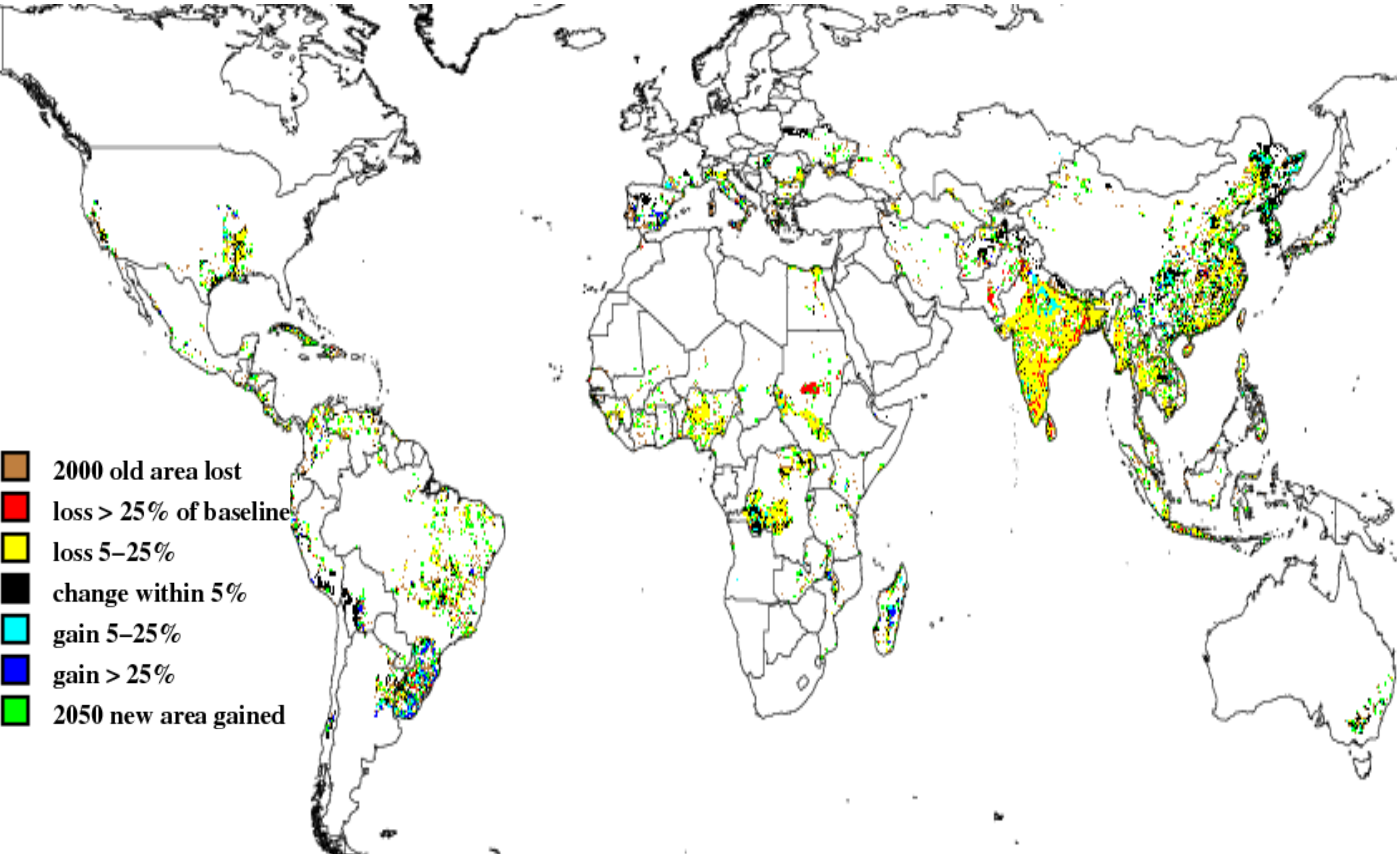
LAC - Latin America and Caribbean

SSA - Sub-Saharan Africa

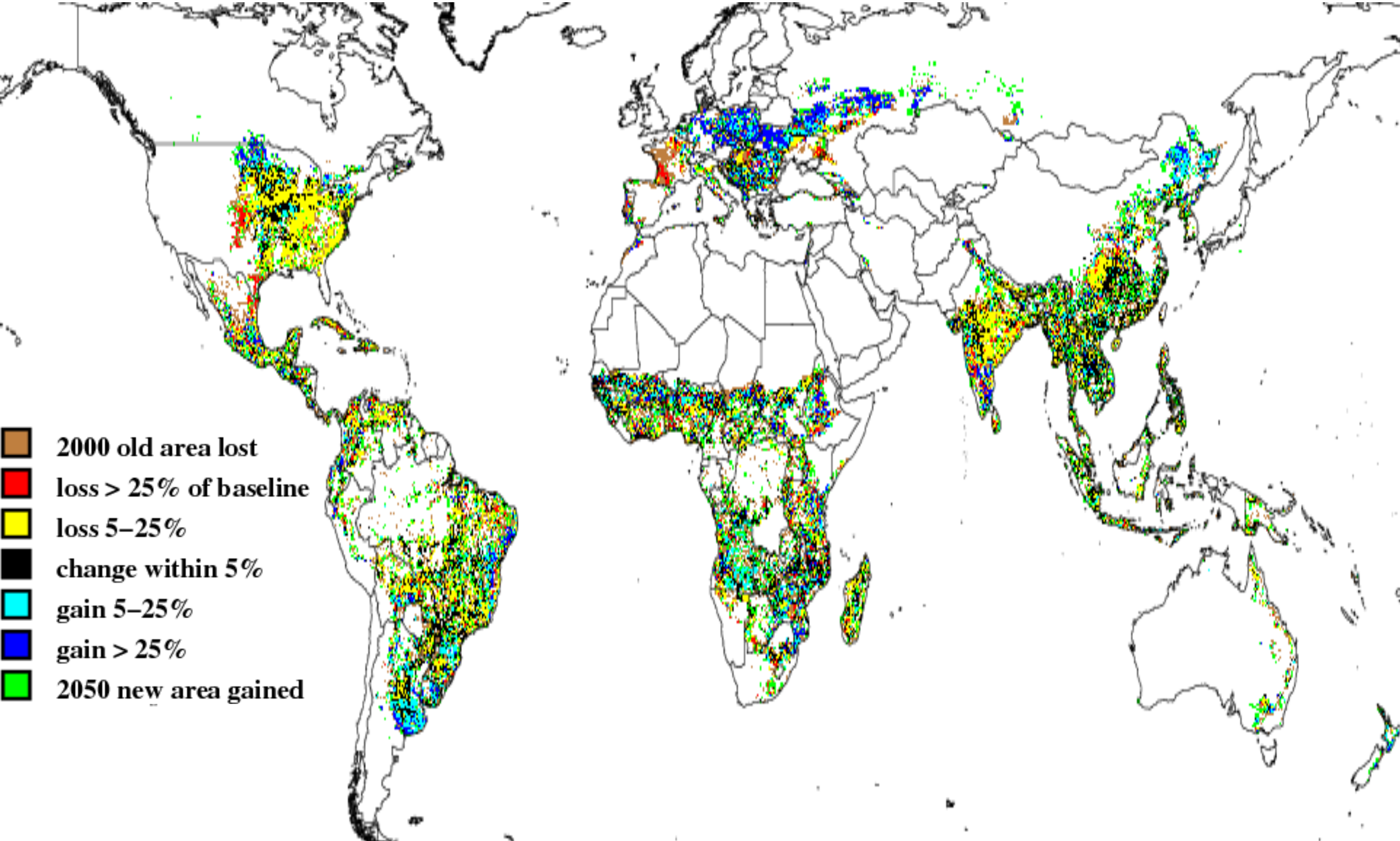
NAE - North America and Europe

Source: Authors' calculation with **IGHM** Global Hydrological Model (2011)

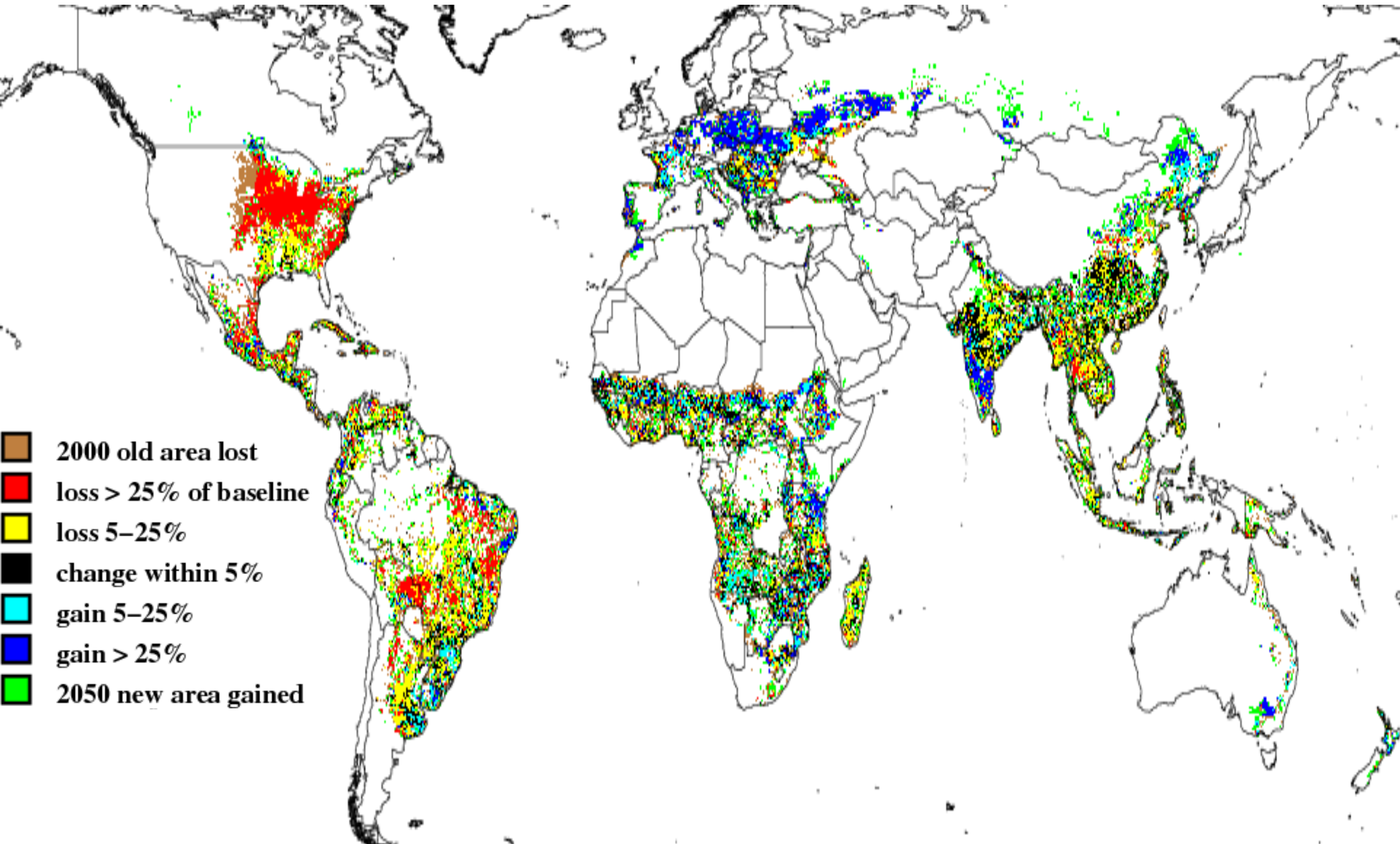
Yield Effects, Irrigated Rice, CSIRO A1B (% change 2000 climate to 2050 climate)



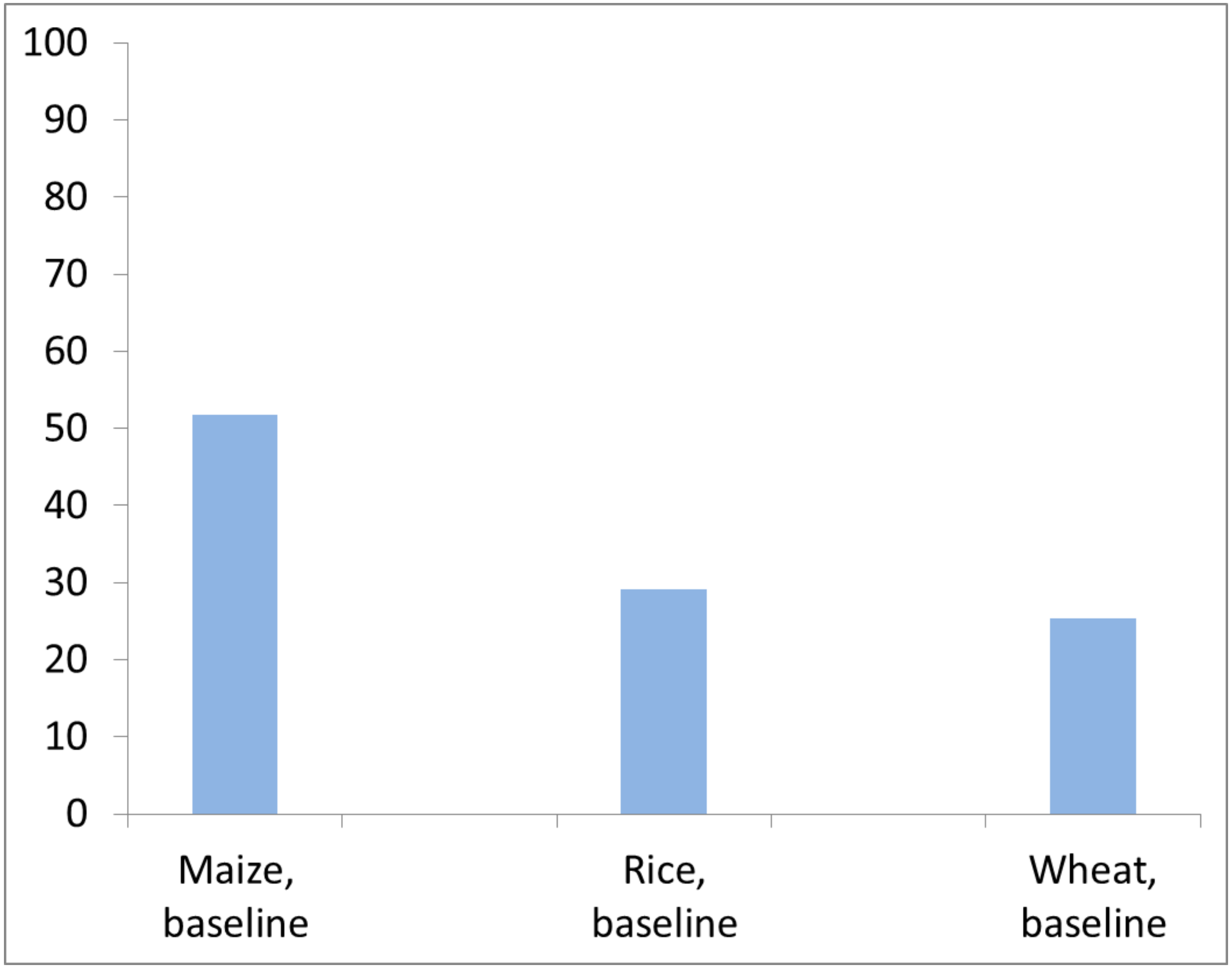
Yield Effects, Rainfed Maize, CSIRO A1B (% change 2000 climate to 2050 climate)



Yield Effects, Rainfed Maize, MIROC A1B
(% change 2000 climate to 2050 climate)



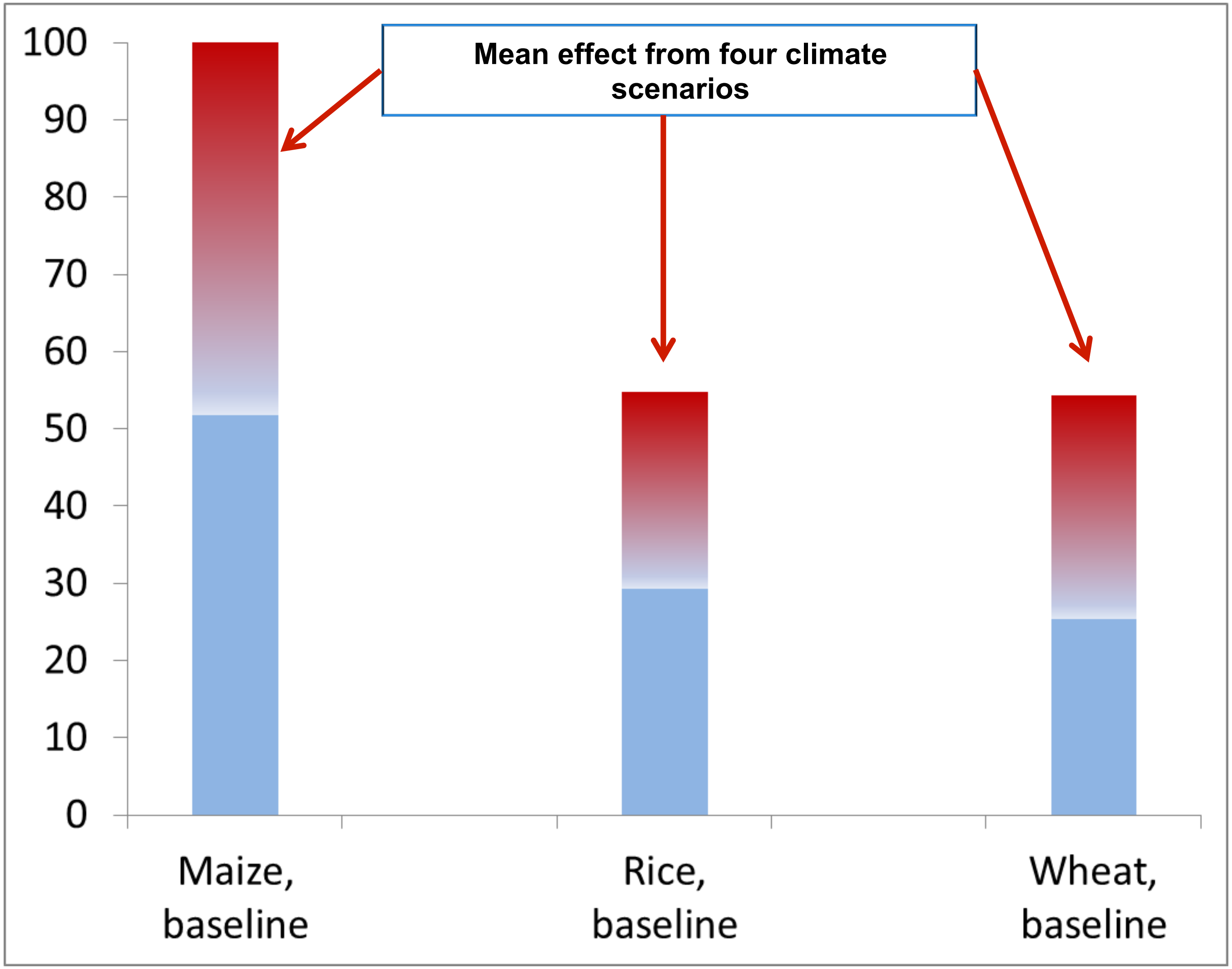
Income and population growth drive prices higher (price increase (%), 2010 – 2050, Baseline economy and demography)



Source: Nelson et al. (2010)

Climate change adds to price increases

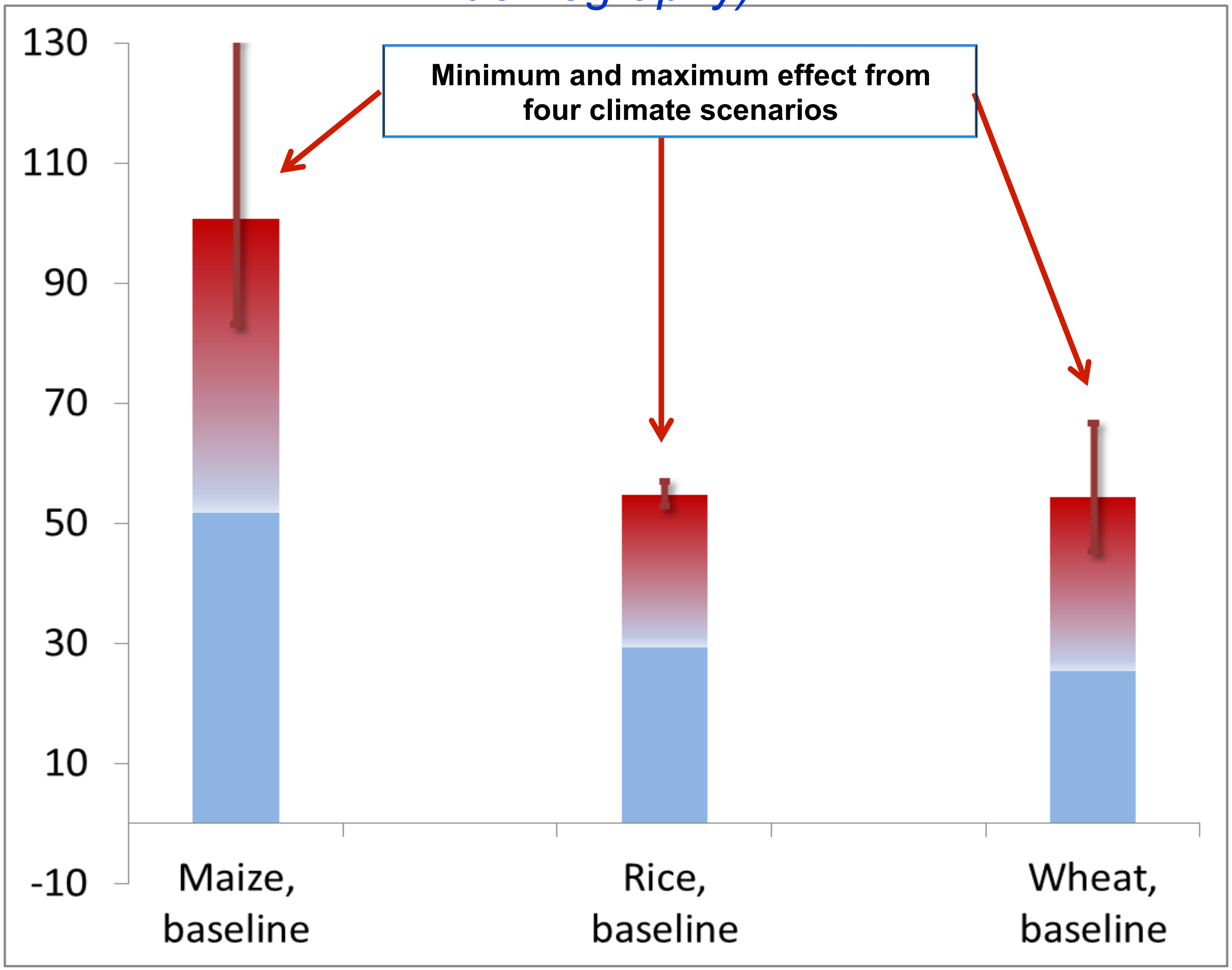
(price increase (%), 2010 – 2050, Baseline economy and demography)



Source: Nelson et al. (2010)

Climate change scenario effects differ

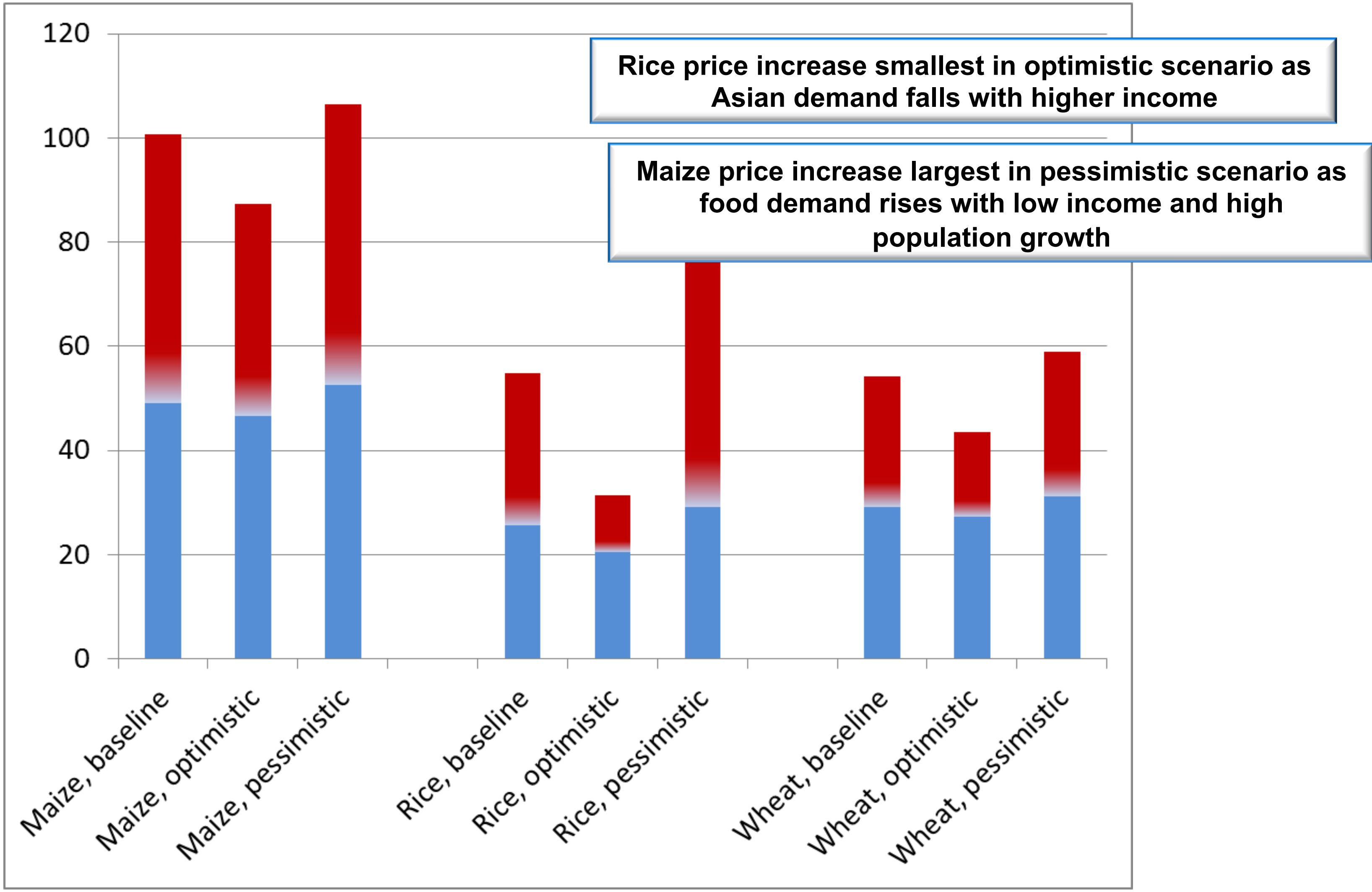
(price increase (%), 2010 – 2050, Baseline economy and demography)



Source: Nelson et al. (2010)

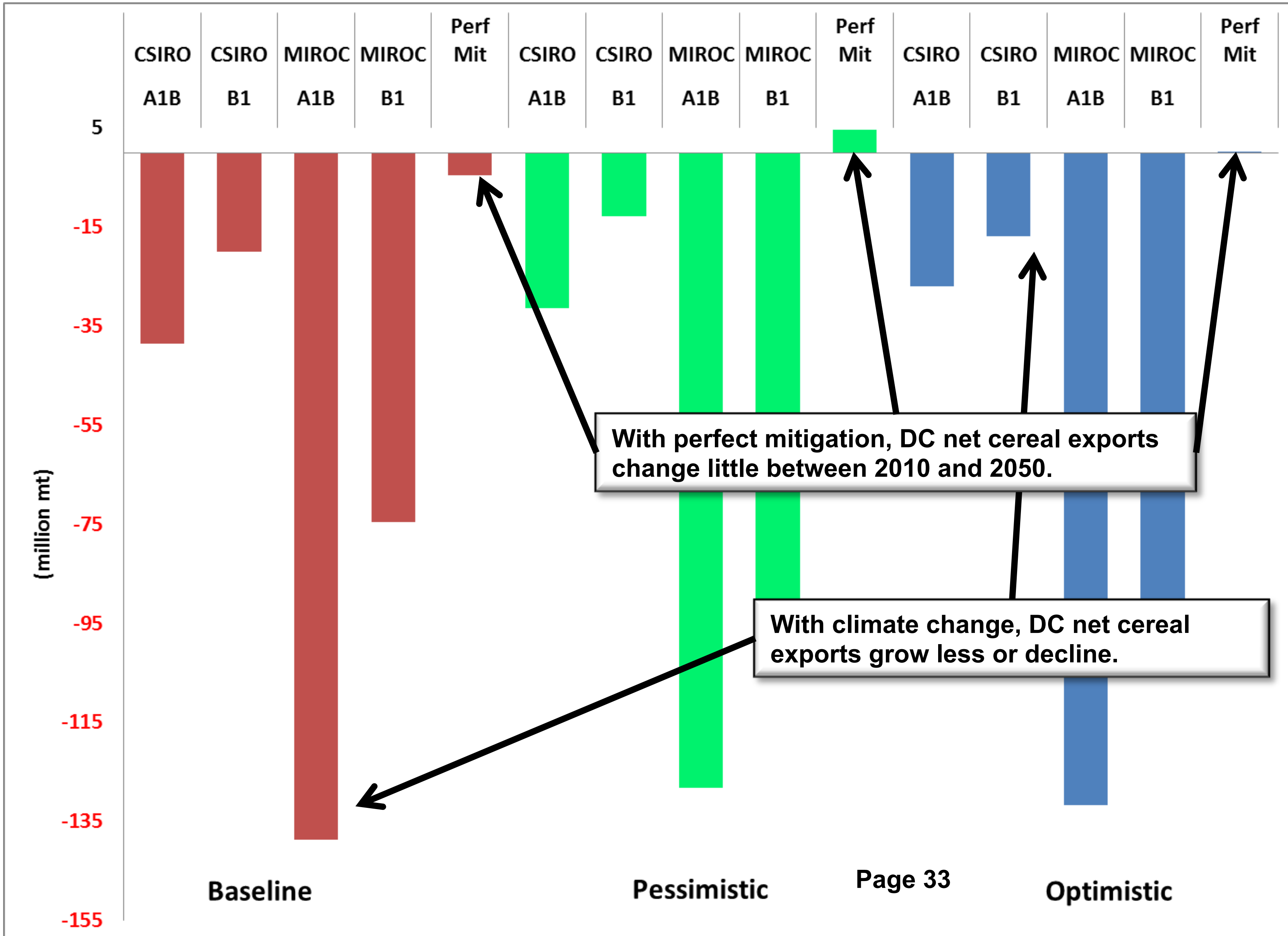
Economy and population scenarios alter price outcomes

(price increase (%), 2010 – 2050, Changing economy and demography)



Source: Nelson et al. (2010)

Developed Country, Change in Net Exports of Cereals, 2010-2050 (million mt)



Conclusions

- Agricultural water use is considerably affected by climate change, but the impacts will be region-specific and hidden beneath natural climate variability
- Climate change can affect food production, trade, prices, and consumption, with broad socioeconomic implications
- Sustainable economic growth is a powerful form of climate change adaptation
- Adaptations for agriculture and water management will benefit from progress in climate modeling and improved quantification of climate projection uncertainties