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What level of public investments in irrigation is needed to make the SDGs achievable?

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Scenarios Forum: Parallel Session 4: Impact Costs: Cost of climate change impact and the use of scenario

Outline

- Objective and current situation
- Methodology
- Investment scenarios and uncertainty analysis
- Costs and impacts of irrigation investments

This study was commissioned by the World Bank Sustainable Development Practice Group and serves as a background paper for the World Bank Group's report: "Beyond the Gap: How Countries Can Afford the Infrastructure They Need While Protecting the Planet."

Analysis contributing to this study was partly conducted in partnership with the GEF/UNIDO/IIASA funded Integrated Solutions for Water, Energy and Land project.

Study objective

- Can intensification, through expanding irrigation, make progress toward ending hunger and reduce the pressure on land?

- To what extent does conversion of rainfed cropland to irrigated area or expansion of irrigated area increase water scarcity?

- What level and kind of investment cost-sharing is needed to transform rainfed cropland area or upgrade inefficient irrigation systems into productive irrigation systems?

Current situation for irrigation

- In 2010, a quarter of cropland area was irrigated (about 260 Mha globally).
  - About 25% was located in India, 25% in China, 14% in the US, 7% in Pakistan, 9% in Bangladesh and other parts of Southeast Asia, 5% in Middle Eastern and North African countries (e.g. Egypt, Morocco, Turkey, Iran, Syria, Iraq, Saudi Arabia, and Yemen)
  - Rice, wheat, maize, corn, cotton, soy, and sugarcane account for almost 90% of the total irrigated area.
- FAO estimated that more than 500 Mha of land in developing regions could be irrigated (292 Mha which is currently not irrigated).
- In 2010, about 40% of the global cereal supply was produced on irrigated land.
- Developing regions supply 72% of the global supply of irrigated cereals.

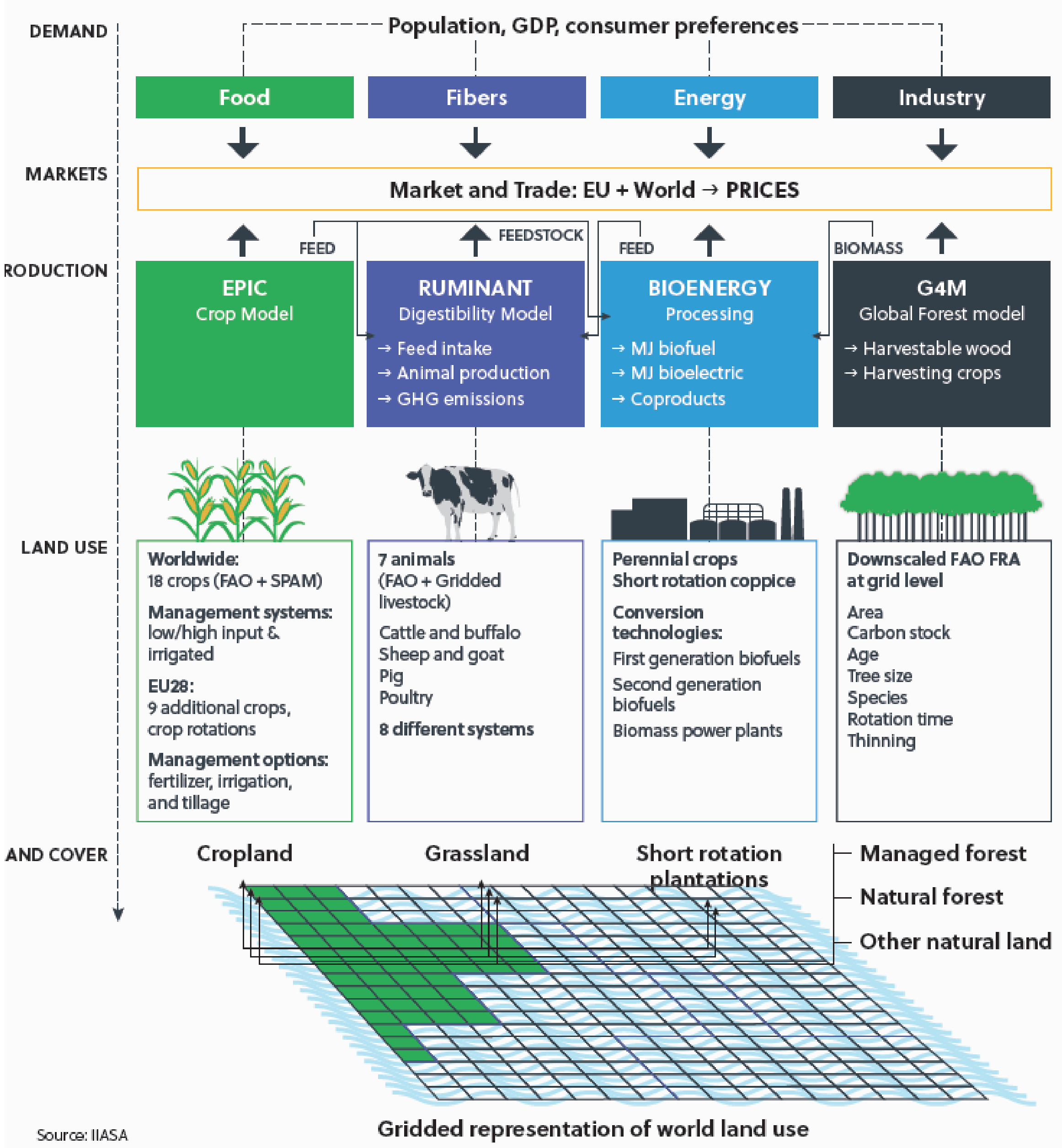
Current situation for irrigation

- Irrigation accounts for 70% of the total water withdrawals (>2500 km^3).
- Developing countries account for 86% of the total withdrawals (China and India account for ~60%)
- More than half of river basins have at least one month of unsustainable water withdrawal (Hoekstra et al. 2012).
- In China+, only 9% of the total surface water withdrawals for irrigation are considered unsustainable, however the locations where unsustainable extractions occurs account for 32% of the region's water withdrawals.

Methodology

GLOBIOM modeling framework

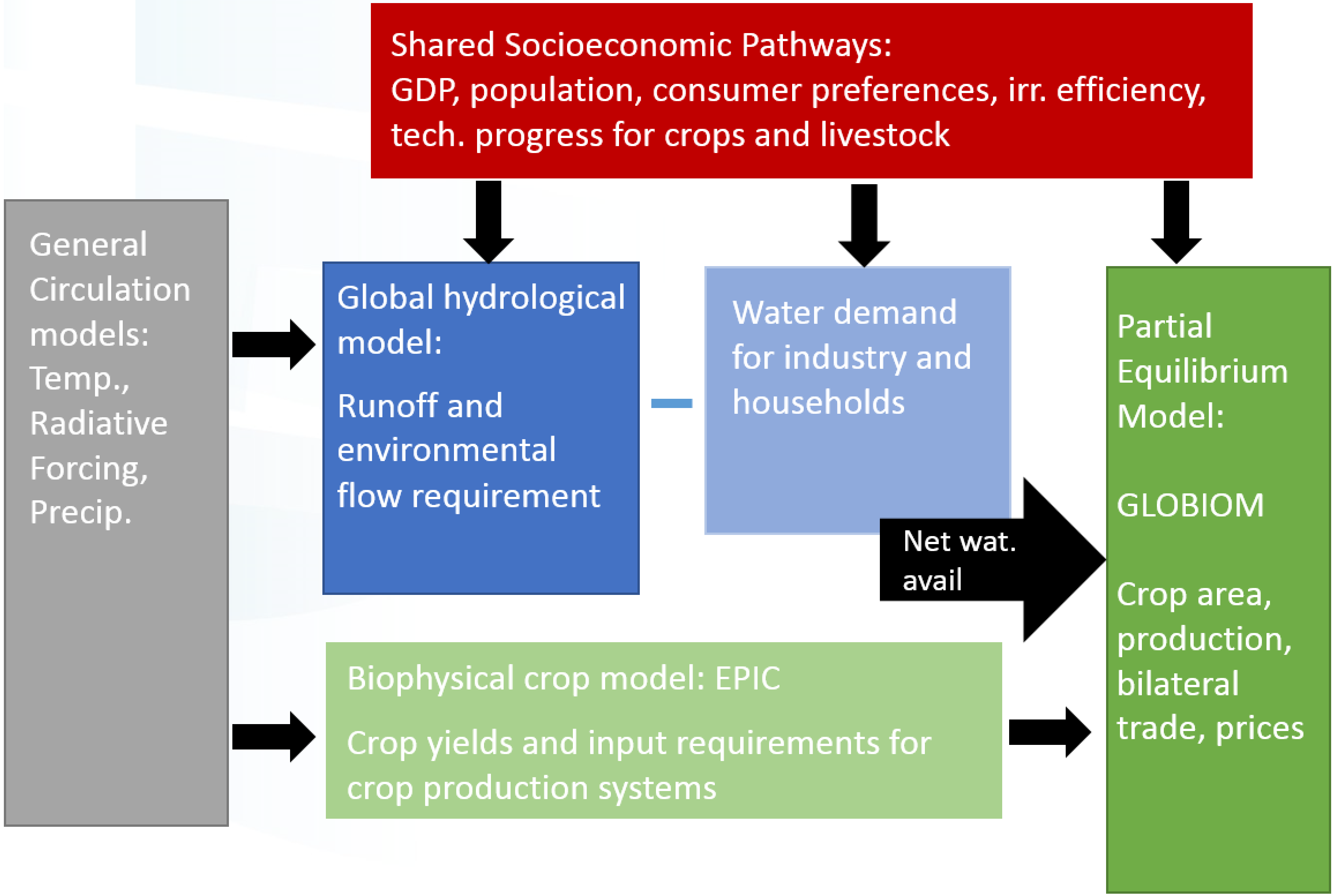
- Partial equilibrium model representing land-based activities
- Maximizes consumer and producer surplus
- Bottom-up approach with detailed gridcell information of biophysical (land and water) and technical cost information



Representation of irrigation as a crop production system

- Irrigation water demand by crop
  - Crop water requirement calculated by EPIC
    - Climate change: change in precipitation, temperature → irrigation requirement (5 GCMs)
  - Monthly water demand based on crop calendar
- Irrigated cropland area from SPAM (IFPRI) and calibrated with FAO statistics
- Irrigation by systems
  - Basin, furrow, sprinkler, drip
  - Differentiated by cost, efficiency, and crop and biophysical suitability (Sauer et al. 2010)
    - Suitability at simulation unit and homogenous response unit level

Modeling framework



Investment scenarios

Across all scenarios:

- Water withdrawals for domestic and industrial uses are used first followed by water withdrawals for irrigation.
- Water available for irrigation must be physically available in the land unit and over the growing period.
- Water available for irrigation can be sourced by groundwater or surface water.

ZeroInvest

- No new investment in irrigation and no expansion of irrigated areas beyond 2010 levels in developing regions
- No improvement in water application efficiency
- Used as a reference scenario

Investment scenarios

Invest

- Moderate public support for irrigation in developing regions
- Producers responsible for O&M
- Mixed-cost sharing approach for capital costs
- Improvement in water application efficiency of 1.5% per decade

MaxInvest

- High public support for irrigation in developing regions
- Producers are responsible for O&M
- Capital costs are fully subsided (in the interest to increase accessibly of water for irrigation)

Scenario set up

<table>
<tr><th>Type of irrigation cost</th><th colspan="2">Responsible for cost in Invest</th><th colspan="2">Responsible for costs in MaxInvest</th></tr>
<tr><td>Operations and Maintenance
Sauer et al. (2010); FAO (2008, 2016); Toan 2016</td><td colspan="2">Producer (as a production cost)</td><td colspan="2">Producer (as a production cost)</td></tr>
<tr><td rowspan="2">Capital Costs:
engineering, parts and material, training, interest and finance costs
Inocencio et al. (2005, 2007); FAO (2008, 2016); Rosegrant et al. (2017)</td><td>Large scale infrastructure</td><td>On-farm</td><td>Large scale infrastructure</td><td>On-farm</td></tr>
<tr><td>Public sector</td><td>Producer (as production costs)</td><td colspan="2">Public sector</td></tr>
<tr><td>Capital costs:
depreciation/capital cost replacement
Schmidhuber et al. (2009)</td><td colspan="2">Public sector</td><td colspan="2">Public sector</td></tr>
<tr><td>Resource costs</td><td colspan="2">Producer (as water price)</td><td colspan="2">Producer (as water price)</td></tr>
<tr><td>Environmental damages</td><td colspan="4">Quantified as a share of agricultural water use that unsustainable (not modeled with a monetary value)</td></tr>
</table>

Types of irrigation investments considered

- **Expansion** of irrigation
  - New irrigated area within a land unit
- **Upgrade** of irrigated area
  - Shift of currently irrigated area from an inefficient system to a more efficient system (basin to sprinkler, sprinkler to drip)
- **Efficiency** of irrigation system
  - Improve the application efficiency of existing basin irrigation systems that cannot be converted (through land leveling, better irrigation scheduling or improved water distribution).
- **Maintenance/depreciation**
  - Replacement capital costs

Uncertainty analysis

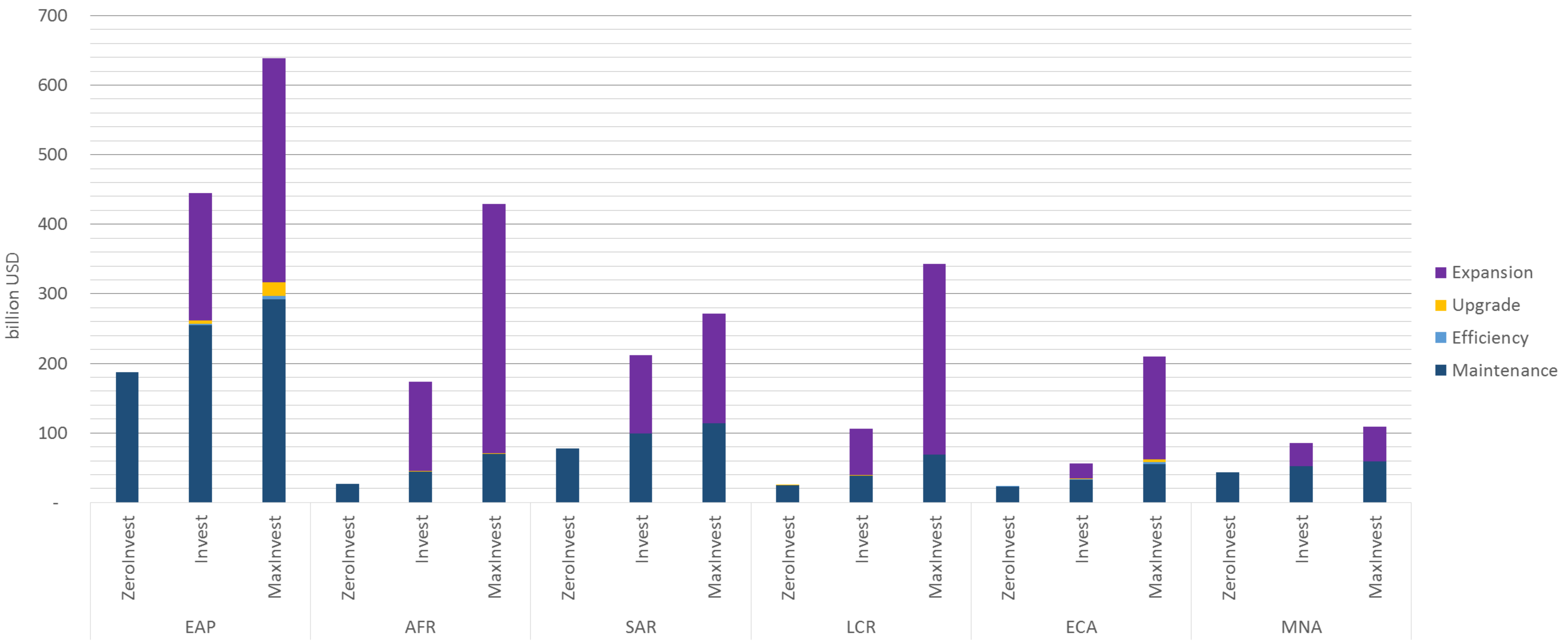
Type of modeling assumption	Change from SSP2 assumptions	Drivers considered
socioeconomic pathways (SSP)	SSP1 Sustainability SSP3 Regional Rivalry	GDP, population, water demand from other sectors, intrinsic improvement in livestock feeding efficiency and crop yields (SSP database, Wada et al. 2014, Herrero et al. 2014, Fricko et al. 2017)
climate change impact magnitude	HadGEM2-ES IPSL-CM5A-LR GFDL-ESM2M MIROC-ESM-CHEM NorESM1-M HadGEM without CO_2 fertilization	Crop yields, crop input requirements (fert, water), water available for irrigation and environmental flow requirements (Warszawski et al. 2014; Balkovič 2013; Pastor et al., 2014)
water application efficiency	High water application efficiency for irrigation Low water application efficiency for irrigation	Improvement in the application efficiency of water used by irrigation systems "crop per drop" (Based on SSP1, SSP2, and SSP3 assumptions from Hanasaki et al. 2013)

Uncertainty analysis

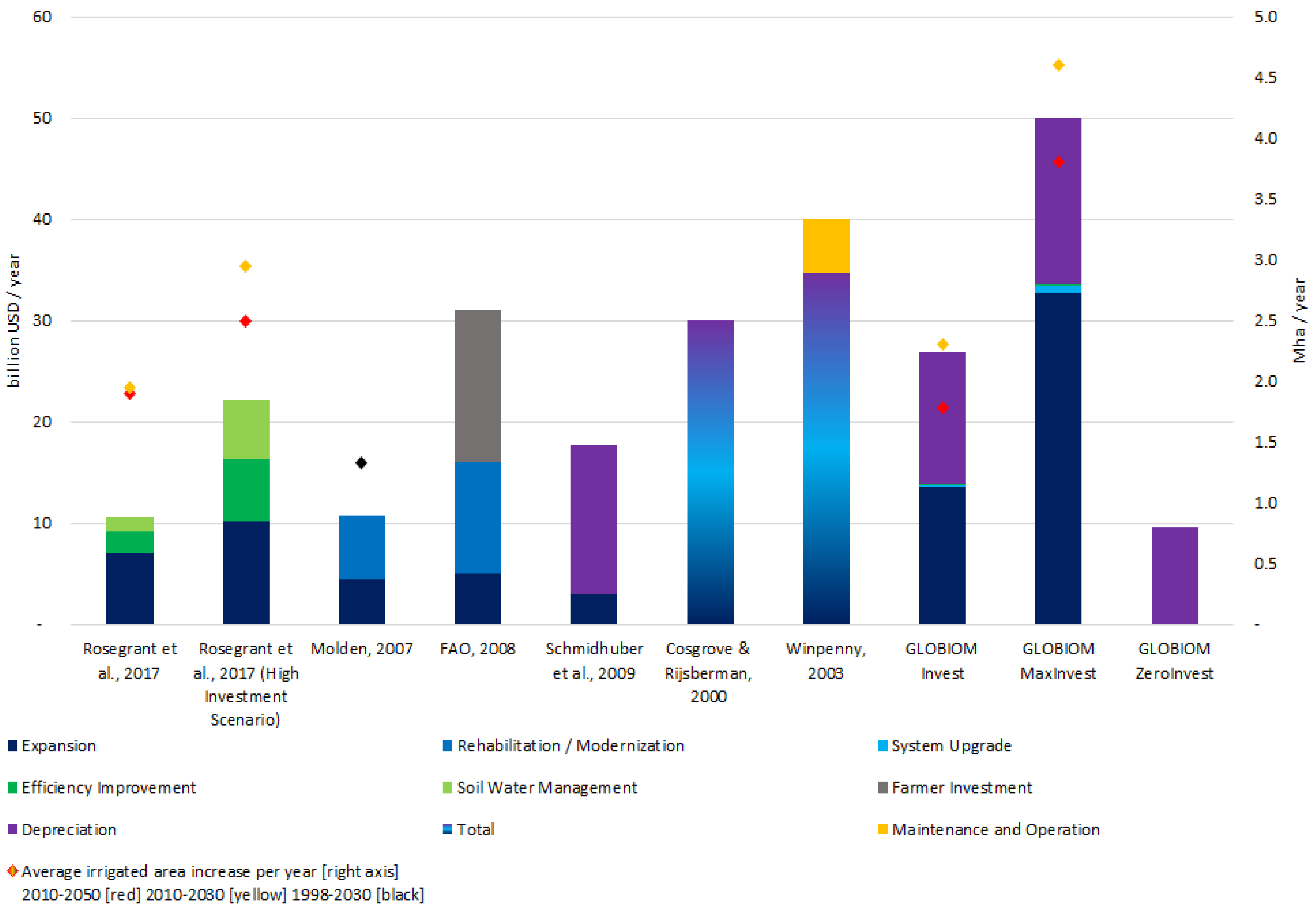
Type of modeling assumption	Change from SSP2 assumptions	Drivers considered
dietary patterns	Healthy Diets Healthy and Sustainable Diets	SSP2 assumptions (Alexandratos and Bruinsma, 2012) Healthy diet: lower meat intake in developed countries and less food waste (so-called SSP1 diets) Healthy and sustainable diet: lower meat intake in developed and BRICS country (subst. by vege cals)
trade openness	Open trade Restricted Trade	SSP5 for Open Trade represent lower international transaction costs SSP3 for Restricted reflect an increase in the barriers to trade

Main results

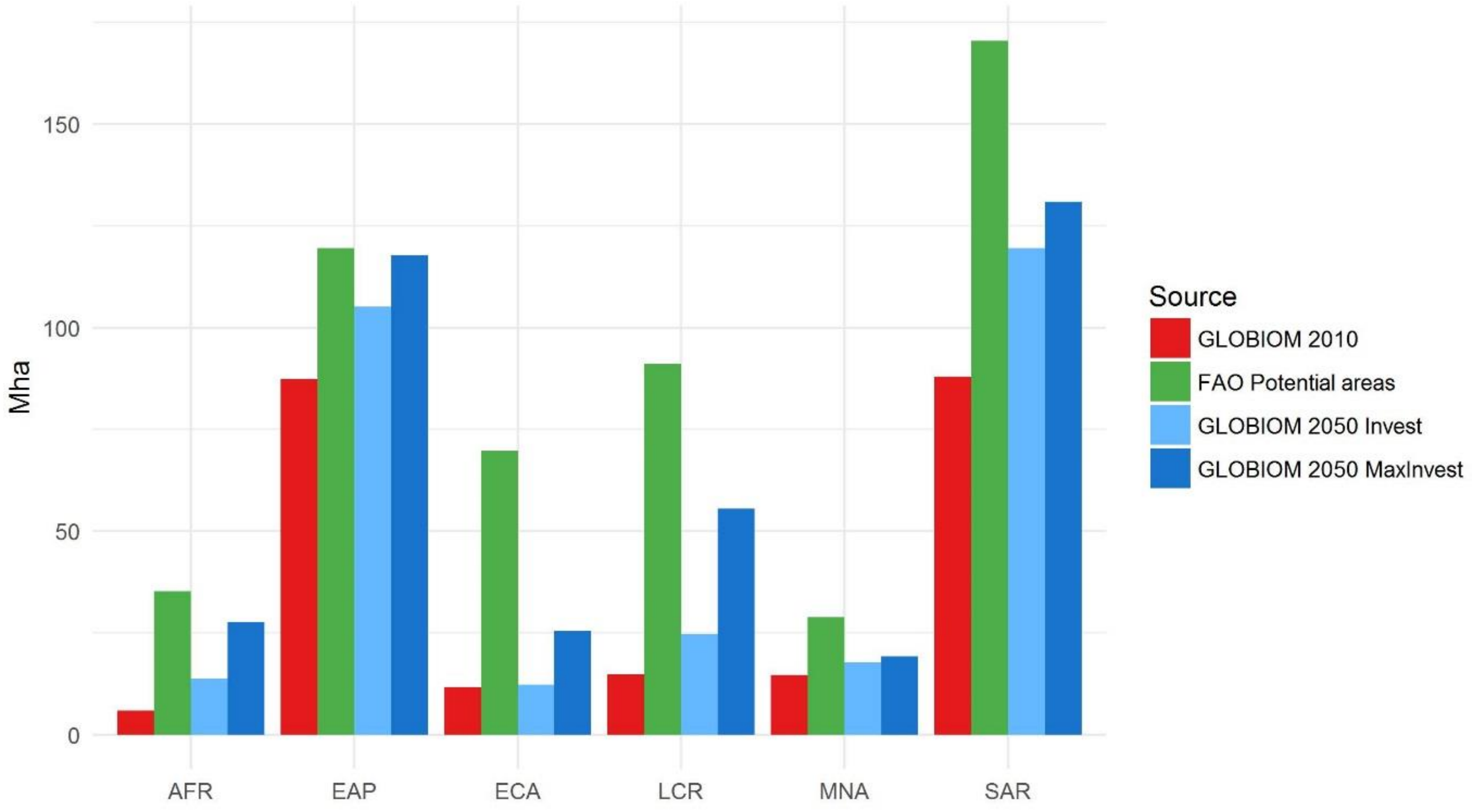
Investment costs by region and scenario from (2010 to 2050)



Irrigation expansion and costs compared to literature



FAO potentially irrigated area



In 2010: 29% of the FAO potentially irrigated area is under irrigation

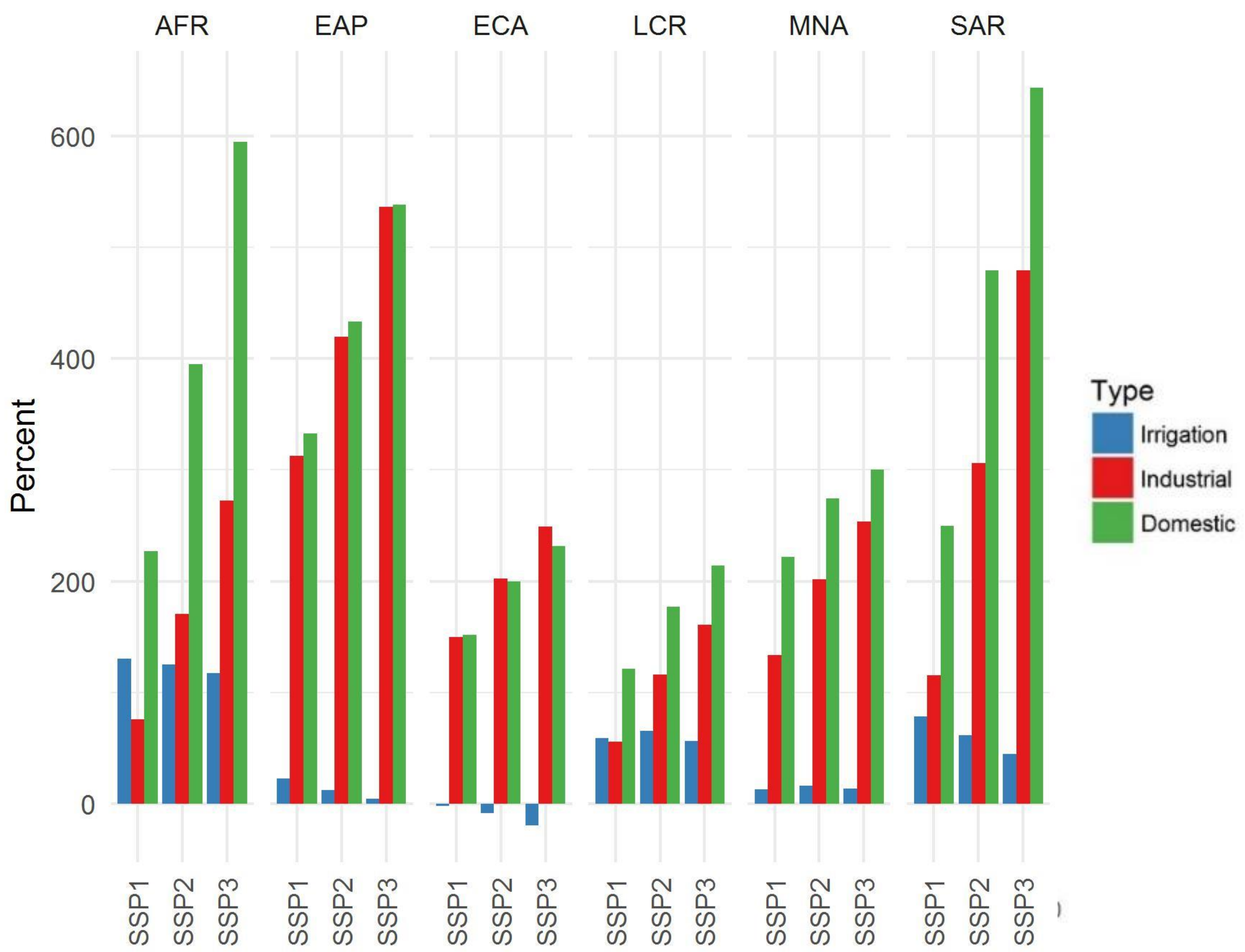
Invest in 2050: 55%

Maxinvest by 2050: 72%

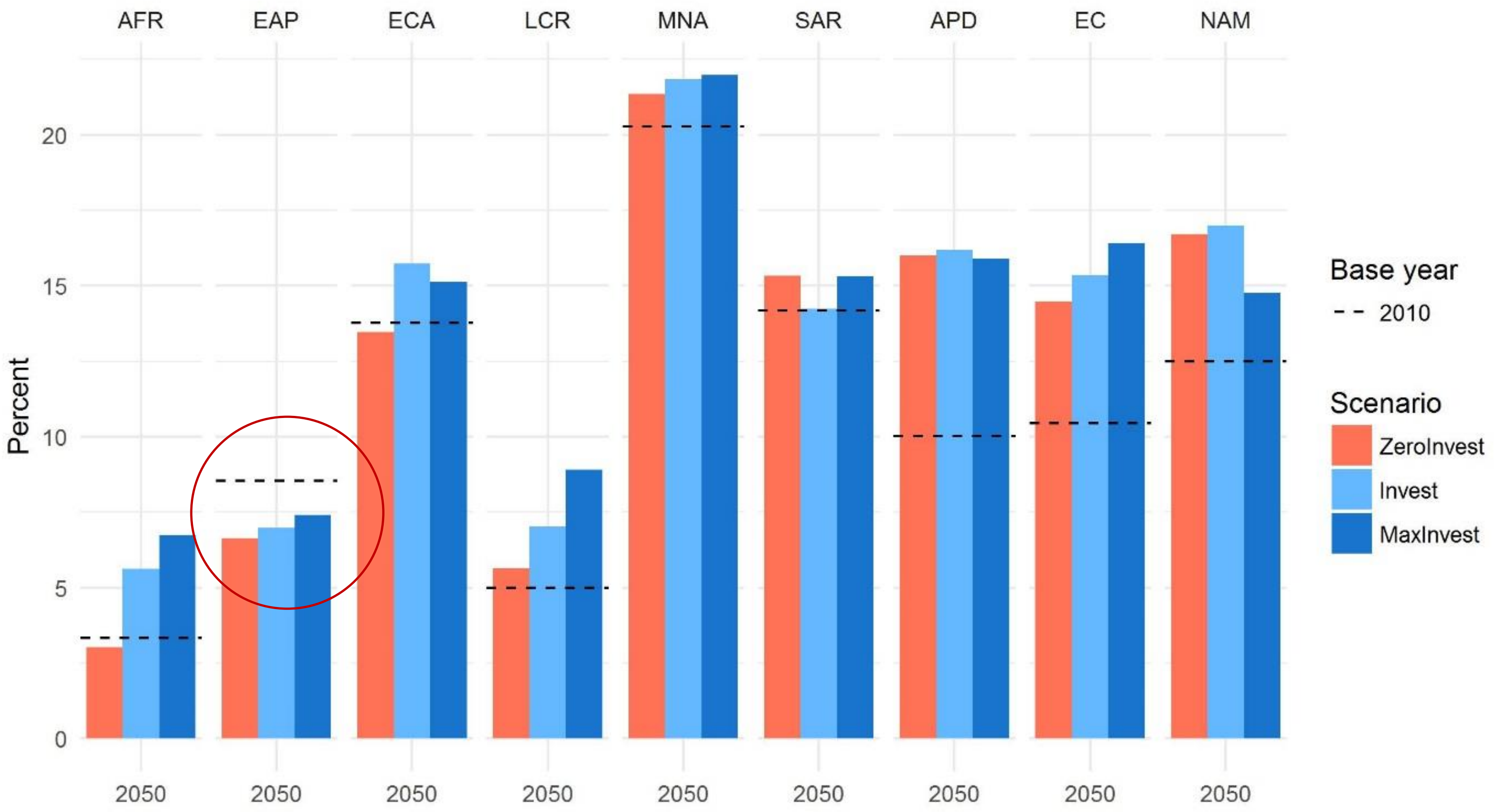
Impacts of irrigation investments in 2050 compared to no investment

	Irrig. Area	Investment Cost	Crop prices	Food availability	GHG AFOLU	Cropland	Other Nat Land	Forest	Env. Flow Requirement
MaxInvest	Mha	$ Billion/ year	% change	kcal/cap/day	$MtCO_2eq$	Mha	Mha	Mha	% of E[illegible]t
AFR	22.7	10.1	-2.2	7.7	-10.9	-1.3	2.3	-0.5	2.0
EAP	49.4	11.3	-3.3	34.9	67.9	1.6	-1.9	-1.1	2.0
ECA	18.5	4.7	-1.5	8.0	7.0	-3.7	2.8	0.0	2.6
LCR	43.5	8.0	-7.3	54.1	99.0	-5.4	8.1	-4.9	1.6
MNA	5.9	1.7	-6.5	19.7	6.9	1.0	-0.7	0.0	7.4
SAR	49.6	4.8	-5.1	71.0	71.5	5.6	-3.1	0.0	12.2
WLD	187.7	40.3	-3.8	34.2	221.4	-4.9	10.1	-6.5	2.1

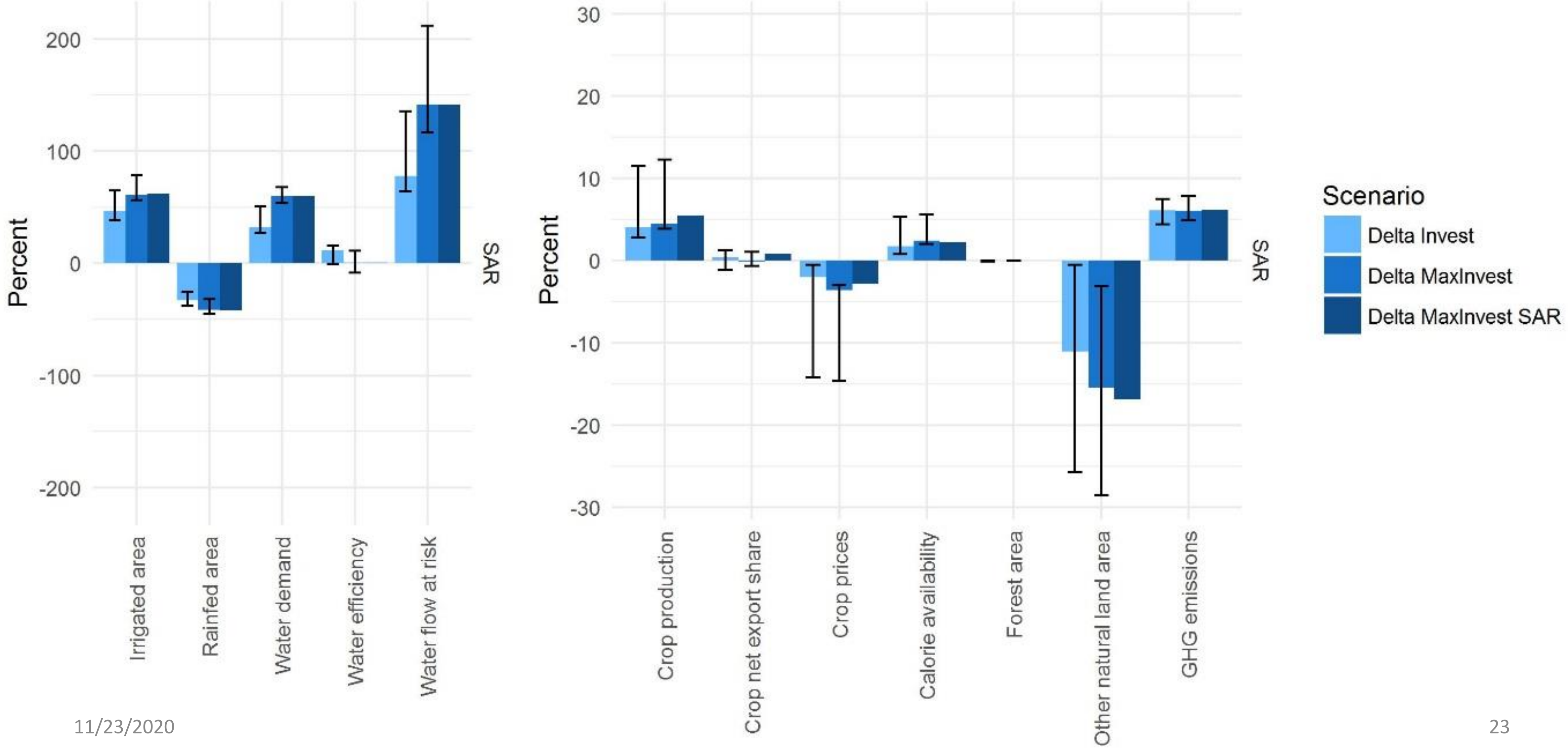
Water withdrawals by sector in *Invest*



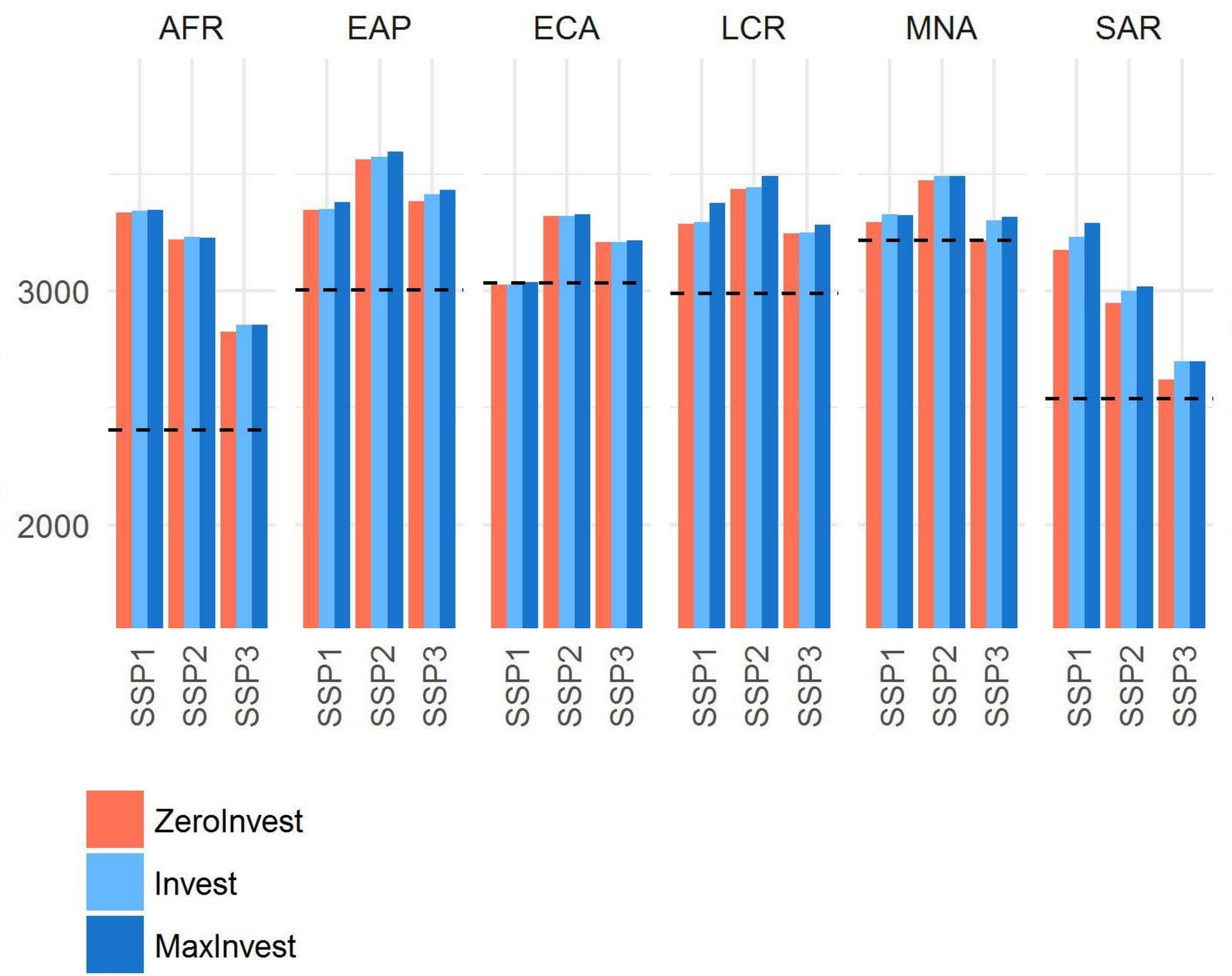
Share of irrigation water withdrawals considered unsustainable



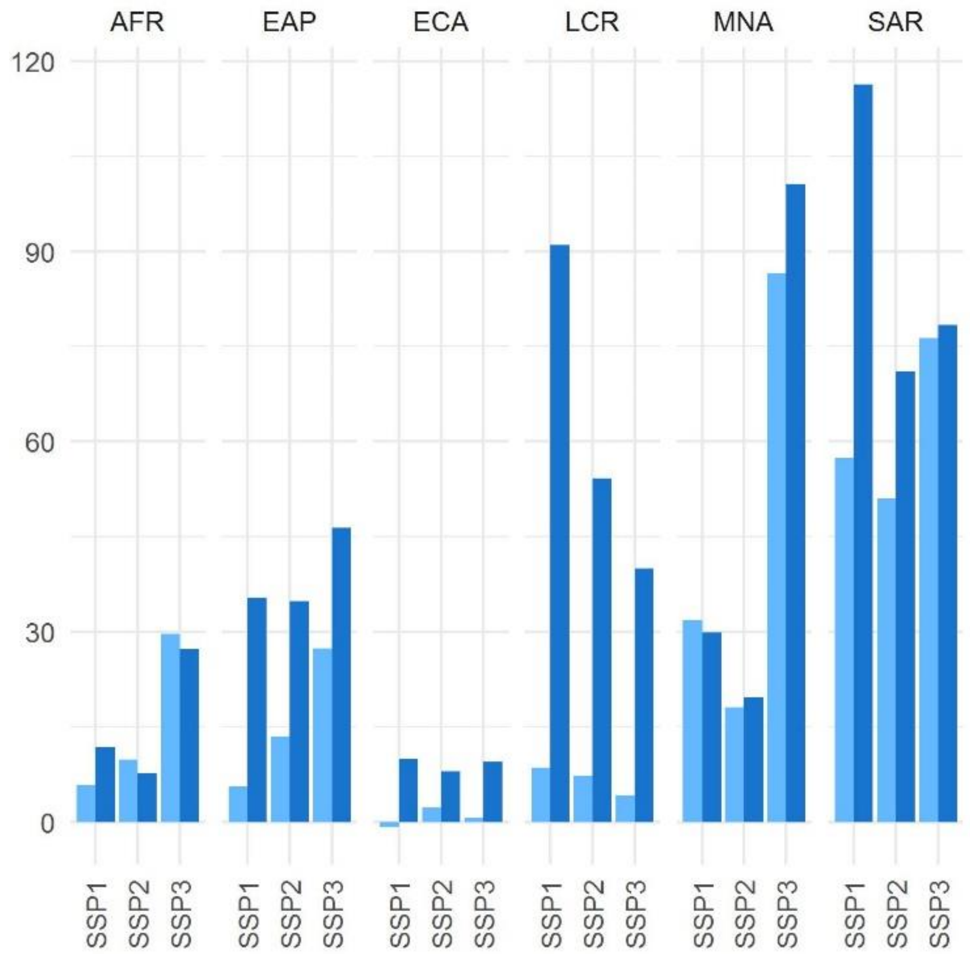
Impacts of irrigation investment depend on regional context



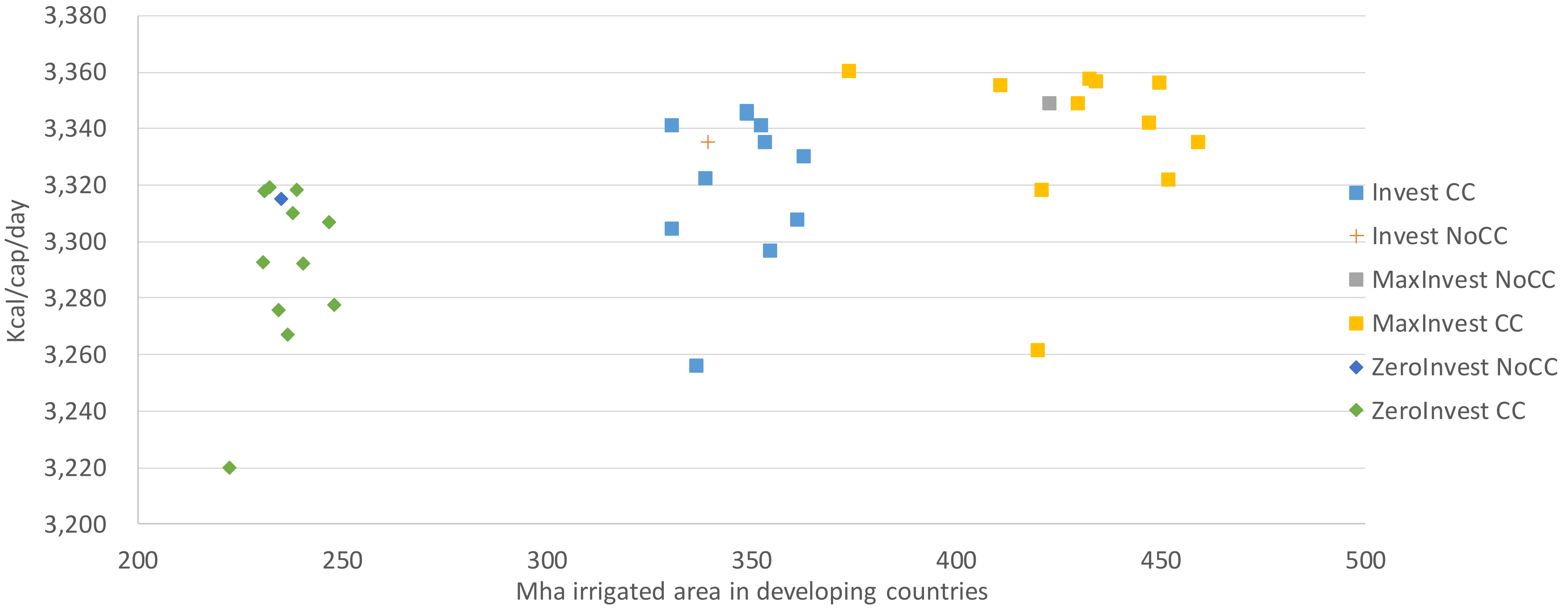
Uncertainty analysis: SSPs calorie availability



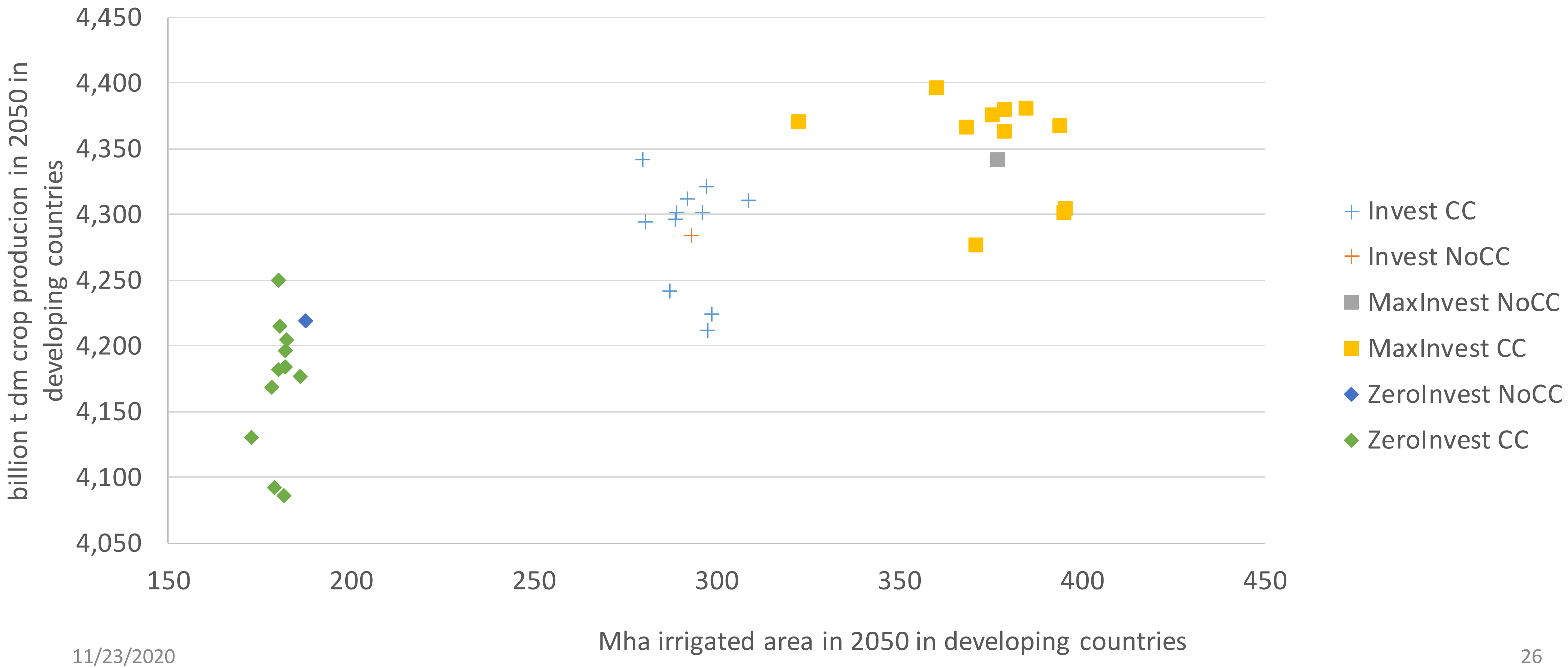
Compared to ZeroInvest in 2050



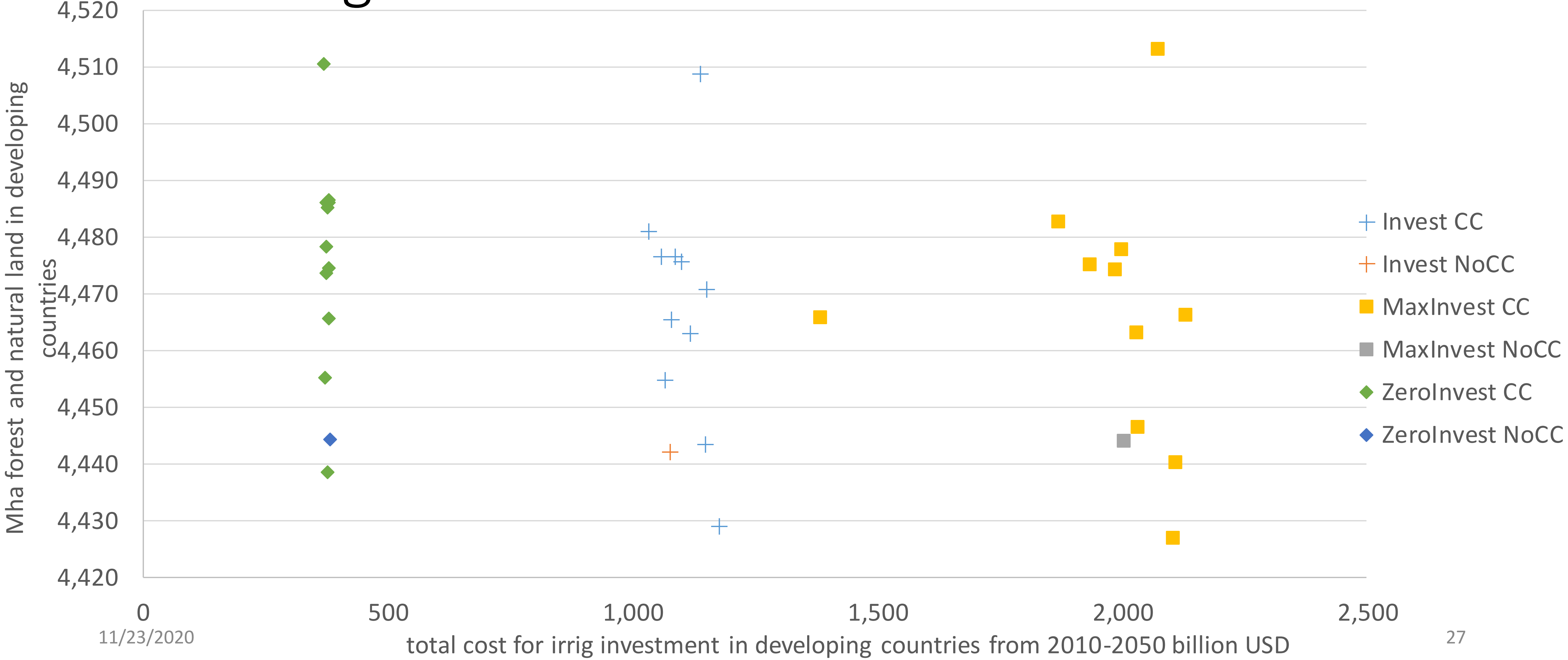
Uncertainty analysis: Climate change
Can investment in irrigation help improve food security under climate change?



Uncertainty analysis: Climate change
Can irrigation help to adapt to impacts from climate change even under changing water availability?



Uncertainty analysis: What are the impacts of irrigation investments on land sparing under climate change?

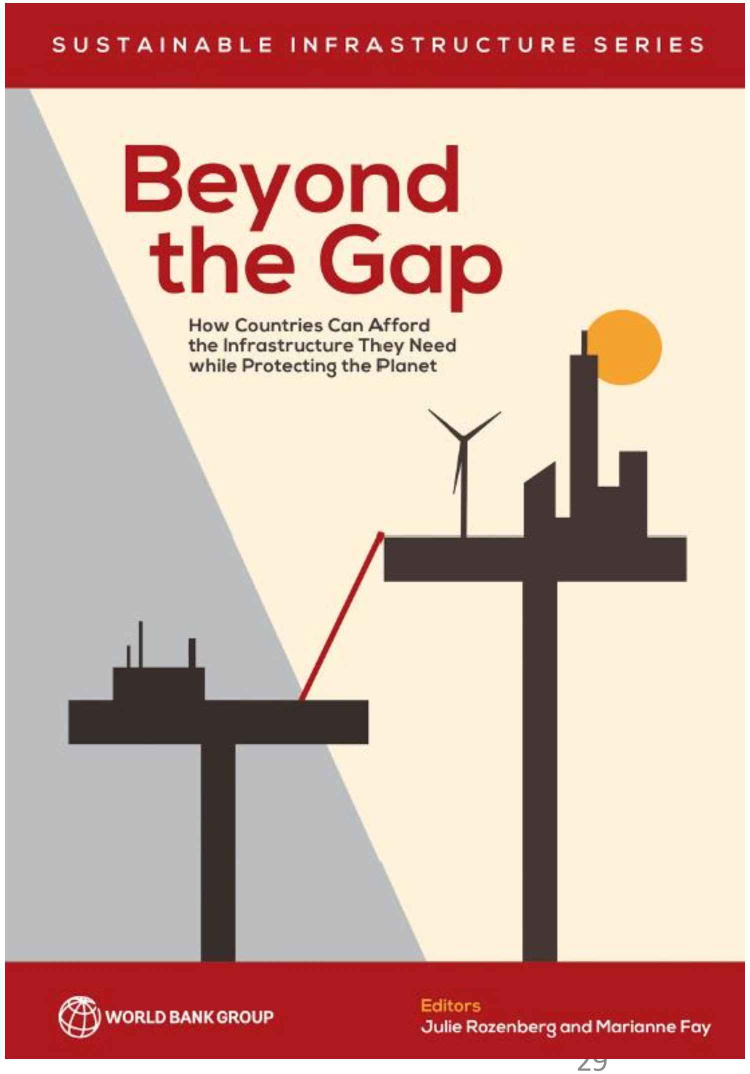


Conclusions

- With ambitious public support irrigated area could expand by 70% over the next 40 years.
- Benefits from irrigation investments depend on the how costs associated with large-scale infrastructure and on-farm capital costs are shared with farmers.
- Irrigation investments can have multiple benefits (food security, land sparing) though not across all regions.
- The regional context is important to in determining the benefits and costs for irrigation investments.
- Irrigation has a role to play in adaptation to climate impacts but water scarcity (from other users) may limit adaptation potential.
- Irrigation investments may increase unsustainable water extractions and should therefore be connected with policies to protect the environmental stream flows

Analysis contributed to WB report *Beyond the Gap*

	Electricity	Transport	Water supply and sanitation	Flood protection	Irrigation	Total
Minimum spending scenario: less ambitious goals, high efficiency						
	Strongly reduce demand for energy through energy efficiency measures; invest now in renewable energy and energy efficiency; gradually ramp up access in poorest areas	+ Increase the utilization rate of rail and public transport; densify cities; reduce demand for transport	+ Provide only basic water and sanitation	+ Keep coastal flood risk constant in relative terms; accept increased risks from river floods based on cost-benefit analysis	+ Subsidize irrigation infrastructure only; promote low-meat diets	= **2.0% of GDP (US$640 billion)**
	US$298 billion 0.90% of GDP	**US$157 billion 0.53% of GDP**	**US$116 billion 0.32% of GDP**	**US$23 billion 0.06% of GDP**	**US$43 billion 0.12% of GDP**	
Preferred scenario: ambitious goals, high efficiency						
	Invest now in renewable energy and energy efficiency; gradually ramp up access to electricity in poorest areas	+ Increase the utilization rate of rail and public transport; densify cities; promote electric mobility	+ Provide safe water and sanitation using high-cost technology in cities and low-cost technology in rural areas	+ Adopt Dutch standards of coastal flood protection for cities; accept increased risks from river floods based on cost-benefit analysis	+ Subsidize irrigation infrastructure only	= **4.5% of GDP (US$1.5 trillion)**
	US$778 billion 2.2% of GDP	**US$417 billion 1.3% of GDP**	**US$198 billion 0.55% of GDP**	**US$103 billion 0.32% of GDP**	**US$50 billion 0.13% of GDP**	
Maximum spending scenario: ambitious goals, low efficiency						
	Do not invest in energy efficiency or demand management; provide high access to electricity using fossil energy for 10 years and early-scrap these capacities to switch to low carbon	+ Let cities sprawl; favor rail investments without accompanying policies to increase the utilization rate of rail	+ Provide safe water and sanitation using high-cost technology everywhere	+ Adopt Dutch standards of coastal flood protection for cities; keep river flood risk constant in absolute terms	+ Subsidize both irrigation infrastructure and electricity for water extraction	= **8.2% of GDP (US$2.7 trillion)**
	US$1,020 billion 3.0% of GDP	**US$1,060 billion 3.3% of GDP**	**US$229 billion 0.65% of GDP**	**US$335 billion 1.0% of GDP**	**US$100 billion 0.20% of GDP**	



Presented by Julie Rosenburg SF Parallel Session 3: Infrastructure

Thank you!

Questions?

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Policy Research Working Paper 8744

Beyond the Gap
How Countries Can Afford the Infrastructure They Need While Protecting the Planet

Background Paper

Investment Needs for Irrigation Infrastructure along Different Socioeconomic Pathways

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Petr Havlík

WORLD BANK GROUP
Sustainable Development Practice Group
Office of the Chief Economist
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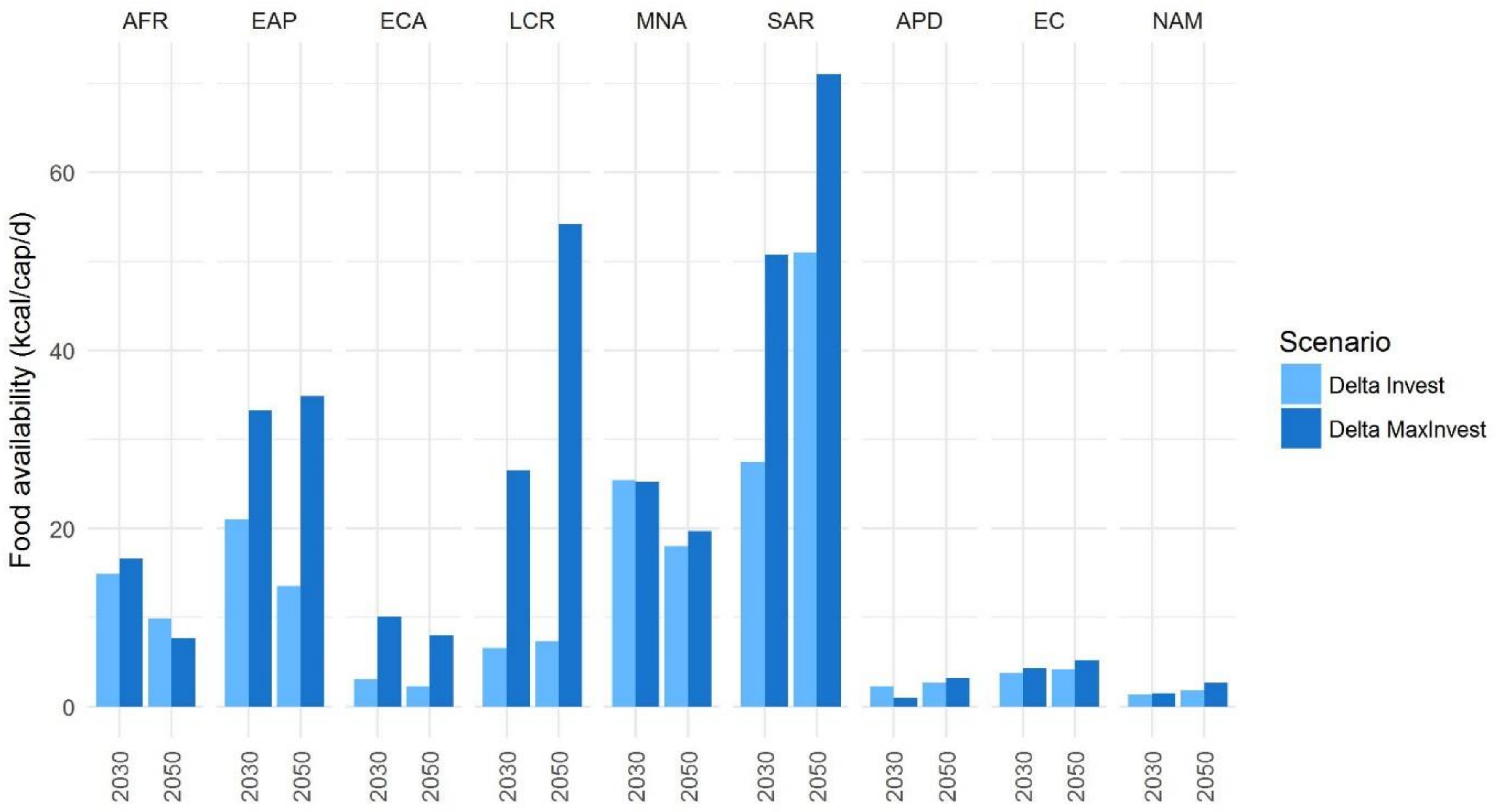
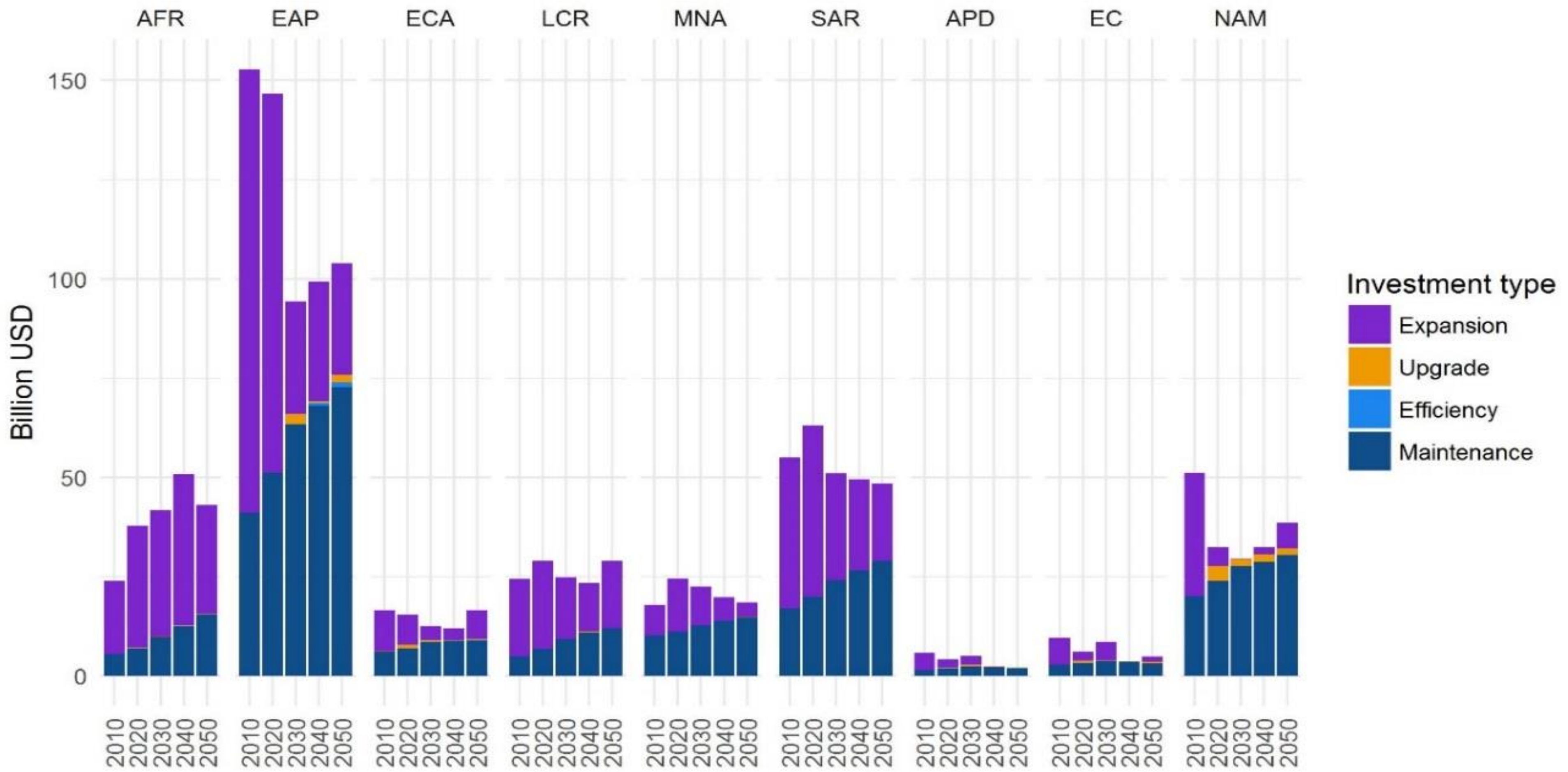
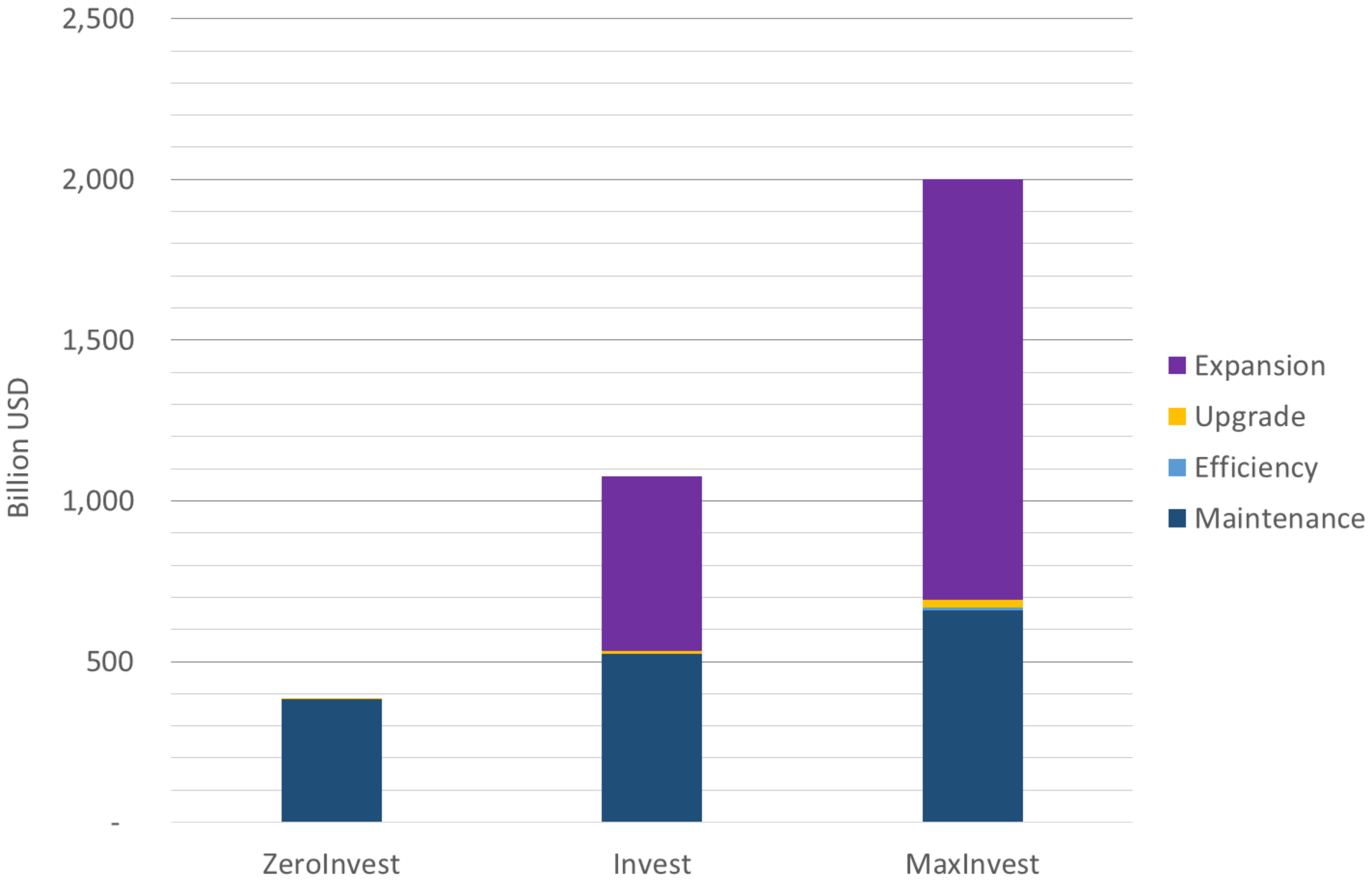
Impacts of irrigation on food security compared to no investment in 2050



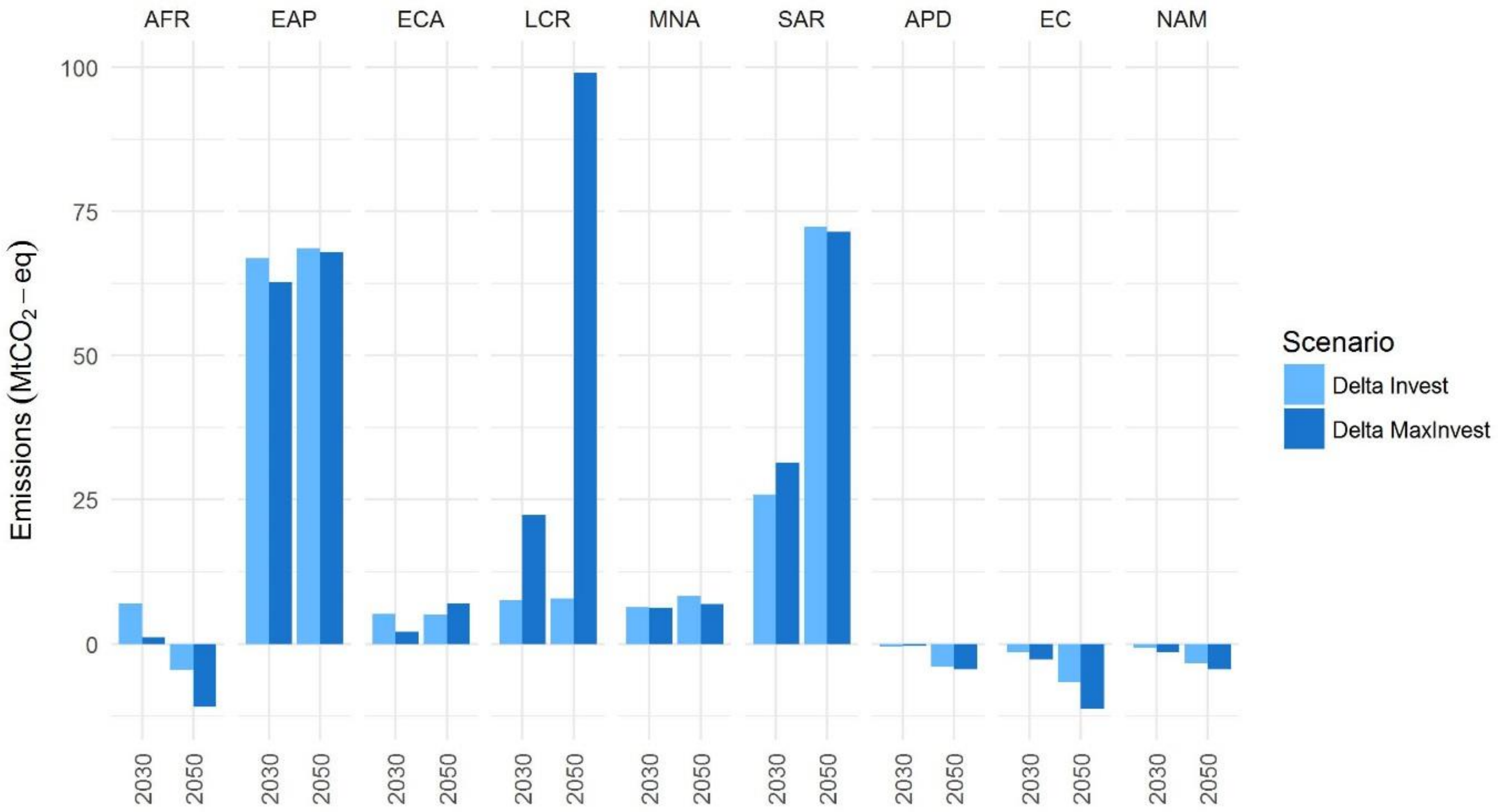
Investment costs per decade by region for Invest scenario



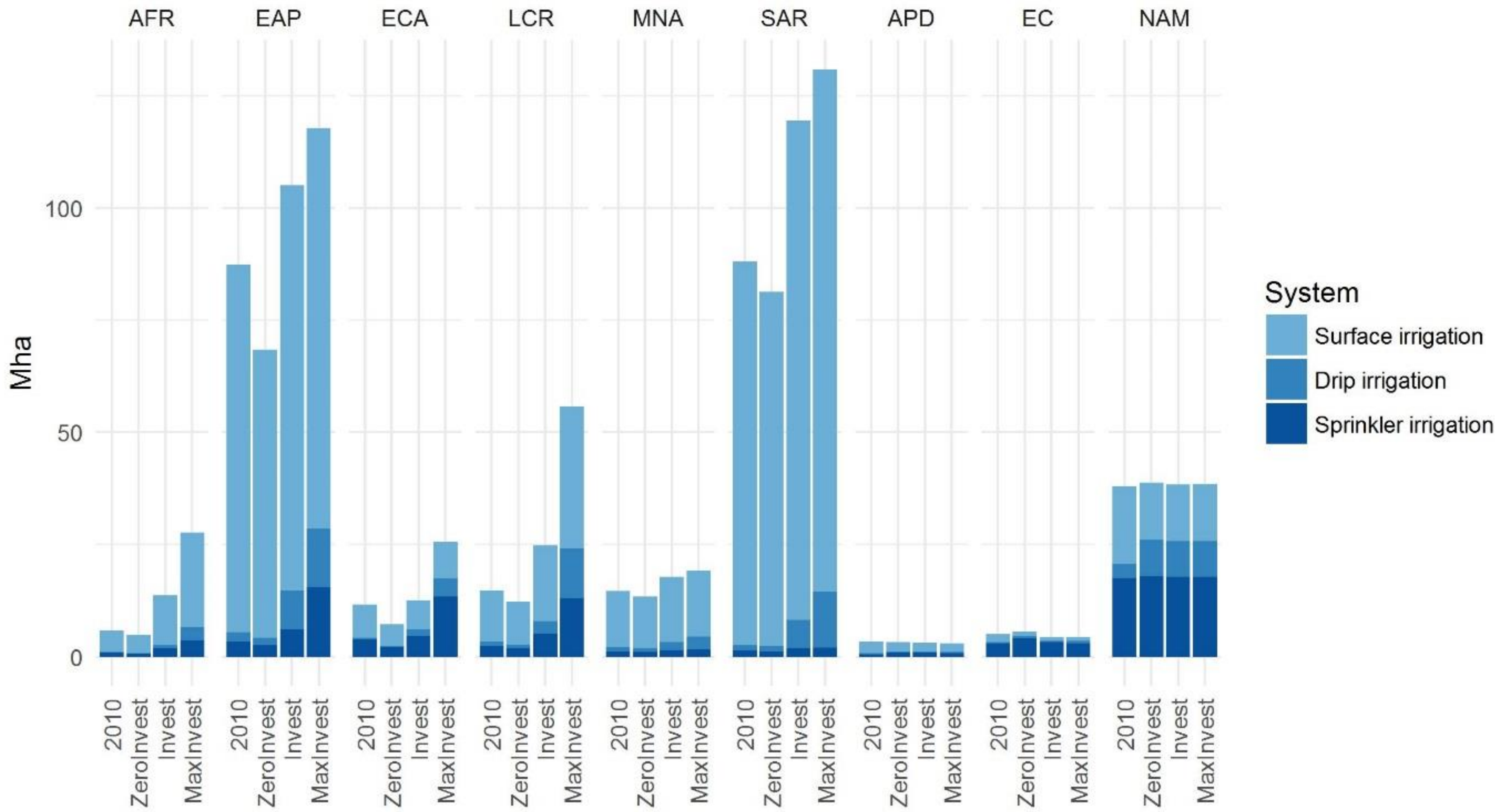
Irrigation costs by scenario by type (2010 to 2050)



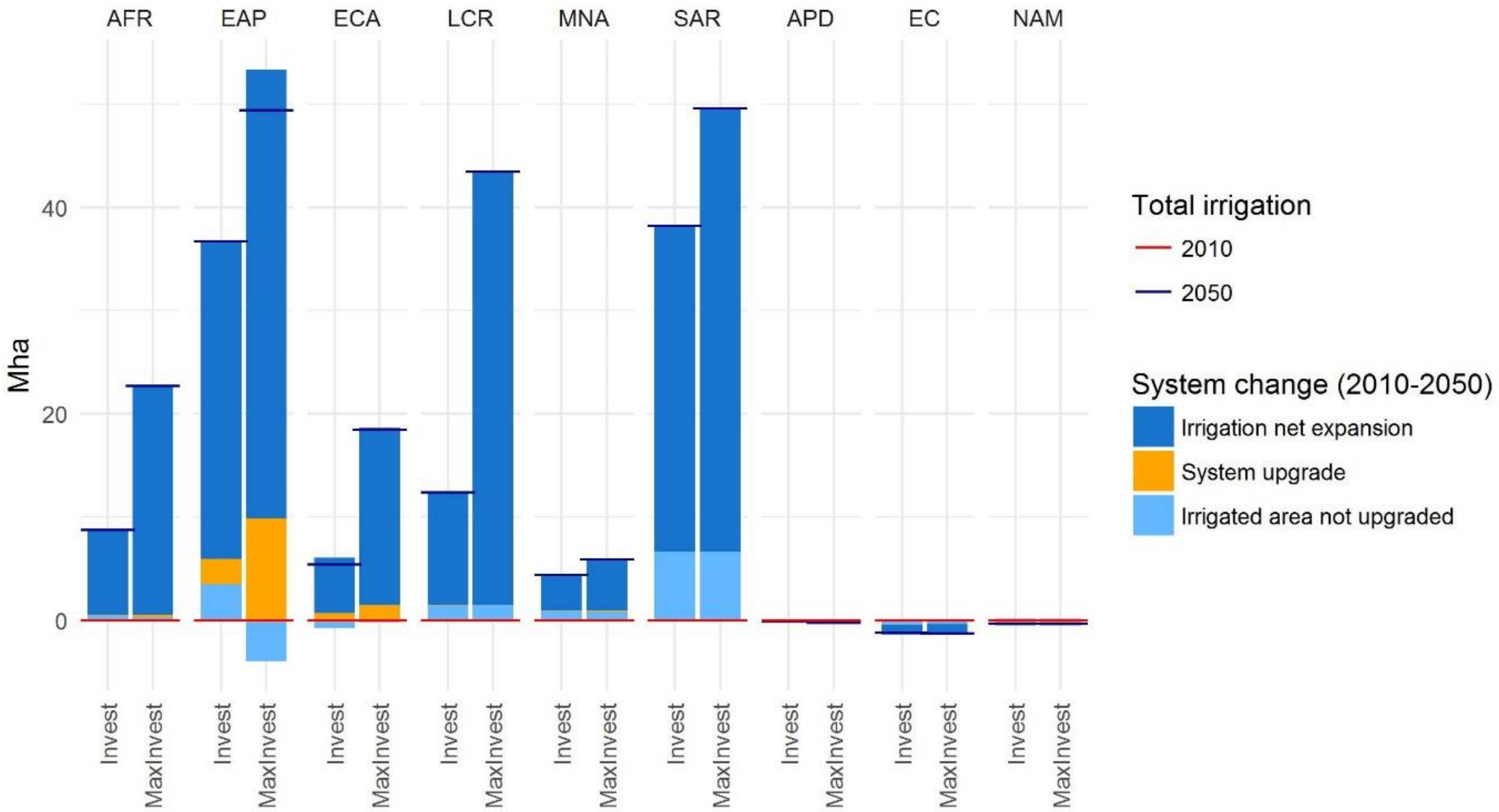
GHG emissions from increased crop and livestock production compared to no investment



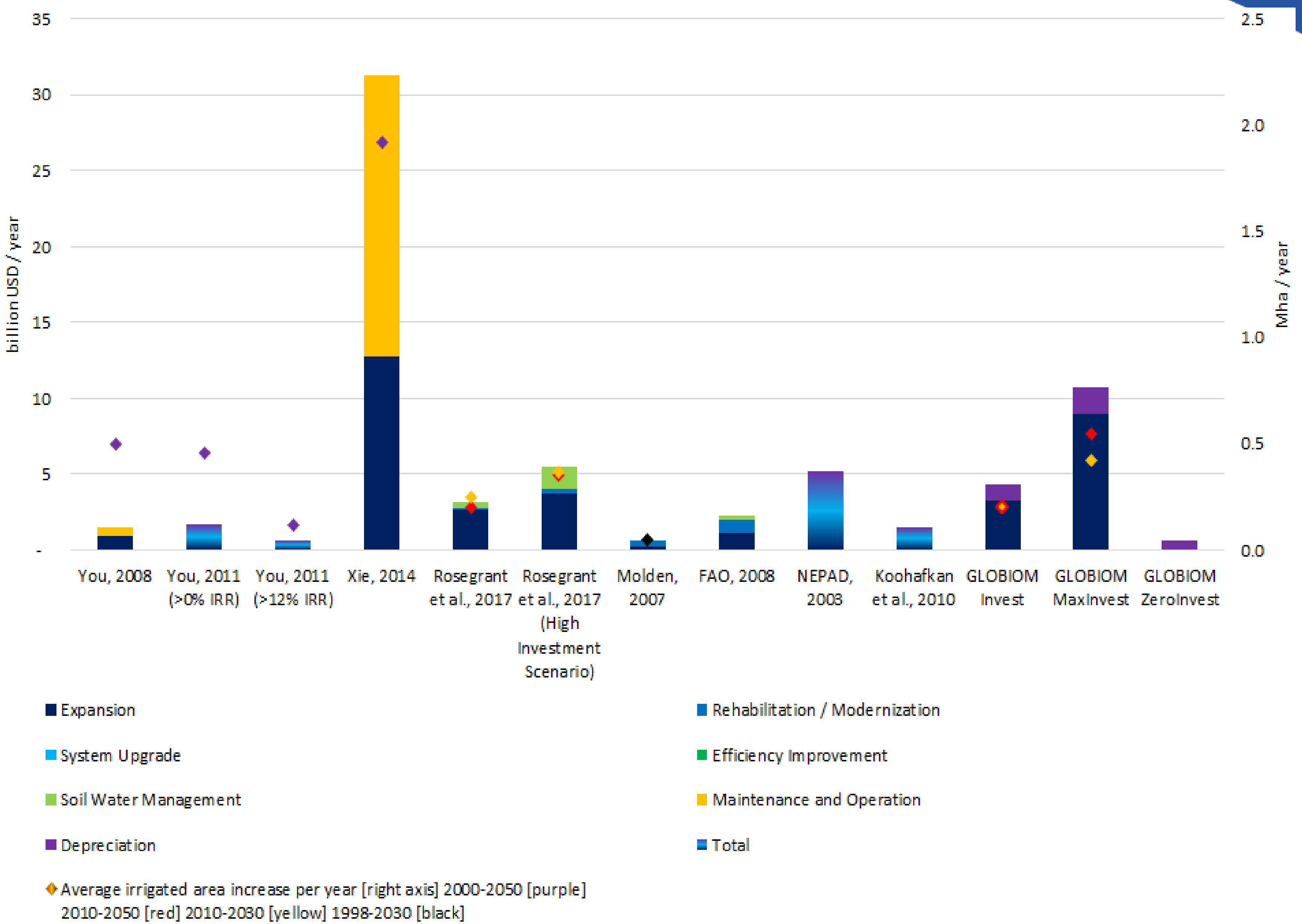
Irrigation system composition



Cumulative irrigated area expansion and upgrade in 2050



Irrigation expansion and costs compared to literature in SSA



Impacts of irrigation investments in 2050 compared to no investment

	Irrig. Area	Investment Cost	Crop prices	Food availability	GHG AFOLU	Cropland	Other Nat Land	Forest	Env. Flow Requirement
Invest	Mha	$ Billion/ year	% change	kcal/cap/day	$MtCO_2eq$	Mha	Mha	Mha	% of EFRs at risk
AFR	8.8	3.7	-2.0	9.9	-4.6	1.5	0.1	-0.3	0.7
EAP	36.7	6.4	-2.3	13.5	68.6	1.5	-0.8	-1.2	0.8
ECA	5.4	0.8	-0.5	2.3	5.1	-0.7	0.6	0.0	0.4
LCR	12.4	2.0	-0.5	7.3	7.9	-4.0	2.0	0.4	0.3
MNA	4.4	1.1	-5.1	18.0	8.3	1.0	-0.7	0.0	7.1
SAR	38.2	3.4	-2.9	51.0	72.4	3.2	-2.2	0.0	6.7
WLD	104.3	17.2	-1.8	20.2	143.7	1.0	0.4	-1.1	0.8