

Water scarcity in the context of growing food demands and climate change

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Snowmass, July 28, 2011



OUTLINE

1. Drivers of Change Affecting Water and Food
2. Climate, Water and Food Linkages
3. Economic Growth, Water and Food
4. Other relevant water work
5. How to Move Forward

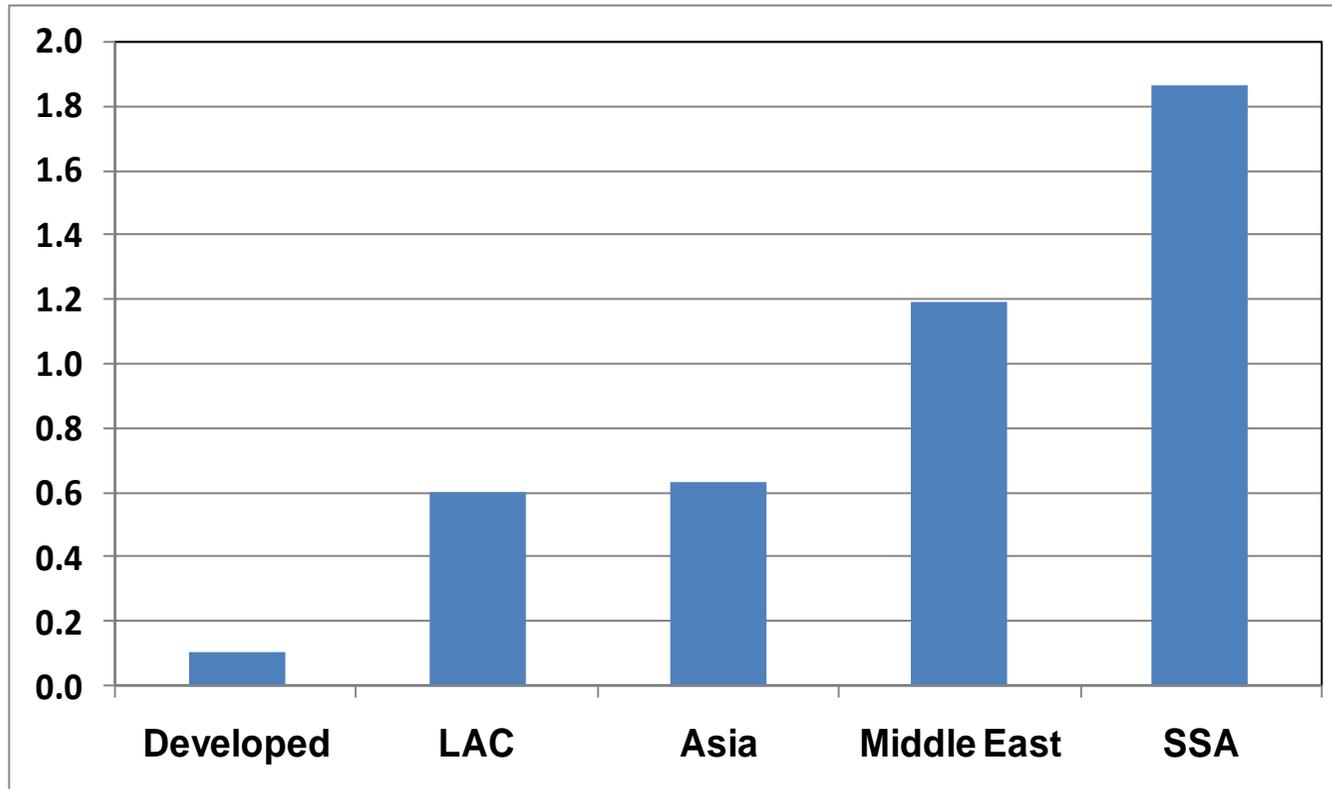
DRIVERS OF CHANGE AFFECTING WATER & FOOD



Water & Food Availability are (Adversely) Affected by a Series of Global Drivers

1. Population growth & urbanization
2. Economic growth and changing diets
3. Higher energy prices (increased HP demand)
4. Growing demand for non-food crops (biofuels)
5. Growing water demand for domestic/ industrial/ environmental uses, affecting irrigation water supply (~80% of withdrawals)
6. Declining water quality
7. Climate variability and climate change
8. Slowing investments in agriculture & water (some change in Sub-Saharan Africa)
9. Unsustainable use & poor management

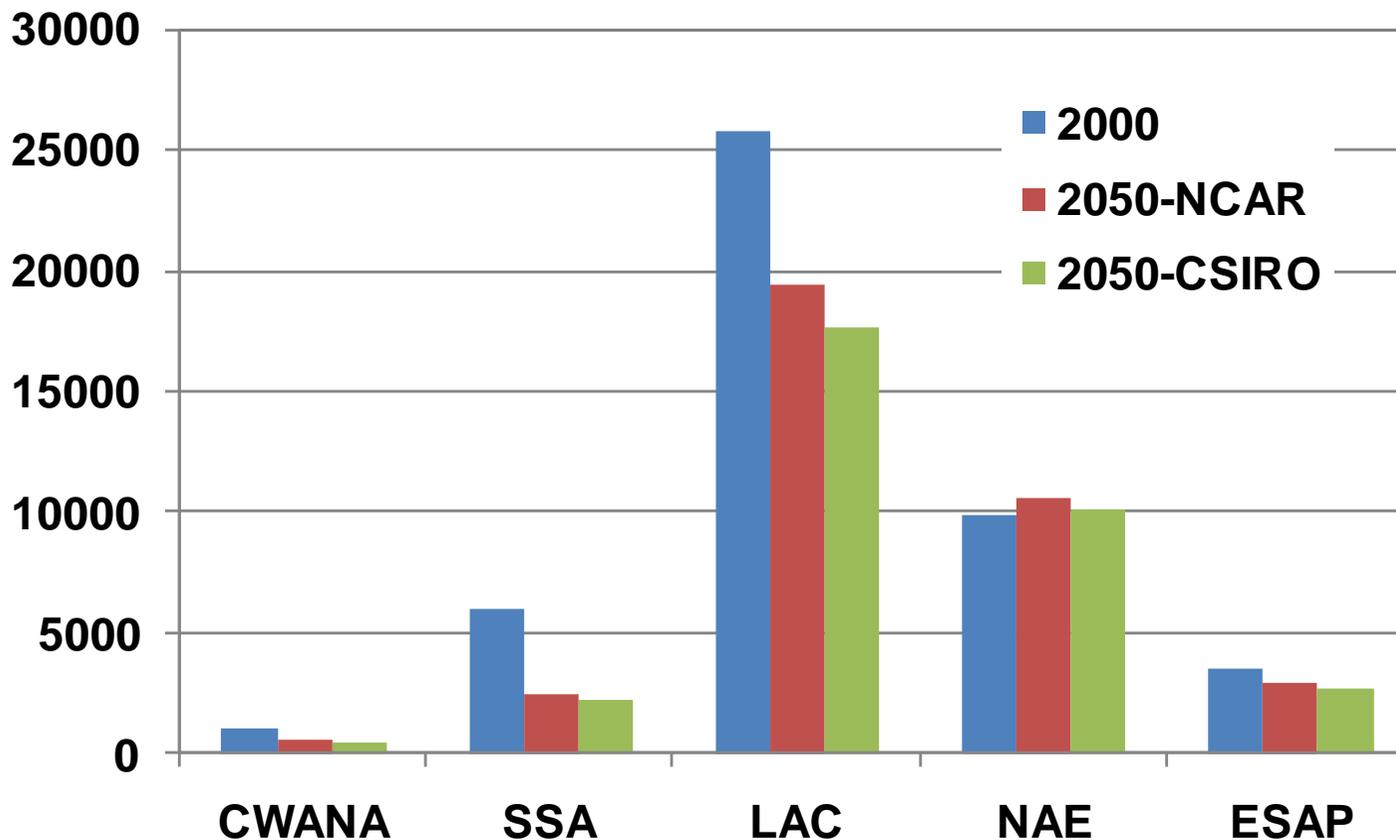
Population growth (%/yr), by region (2000-2050)



Source: UN (2009).

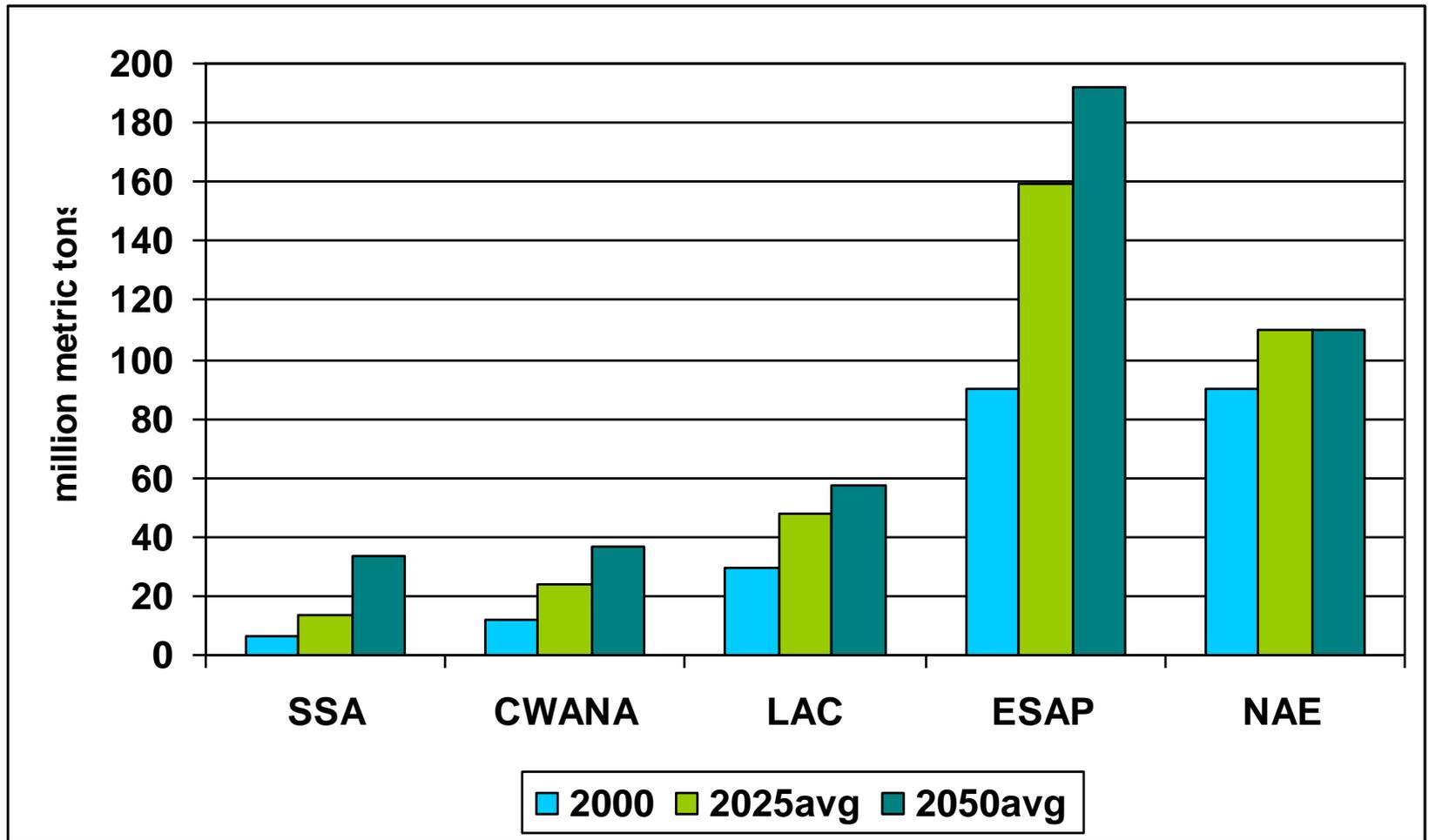
9.2 bn (or 10 bn) people by 2050, 86% of whom will live in less developed countries and 70% in rapidly growing urban areas

Projected changes in per capita water supply (m³/cap)



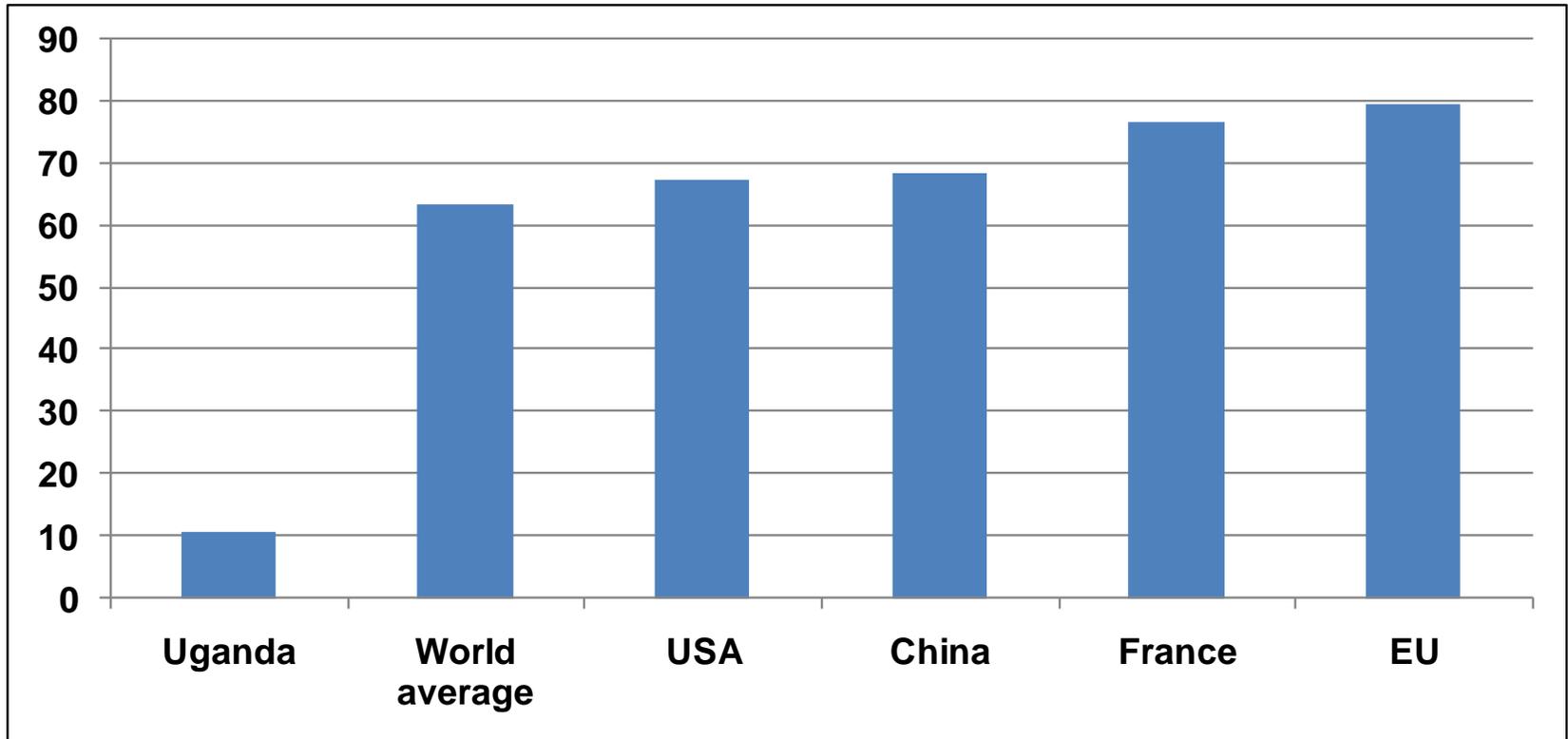
Source: IFPRI IMPACT (2009)

Growing Meat Demand, *mostly outside NA & Europe*



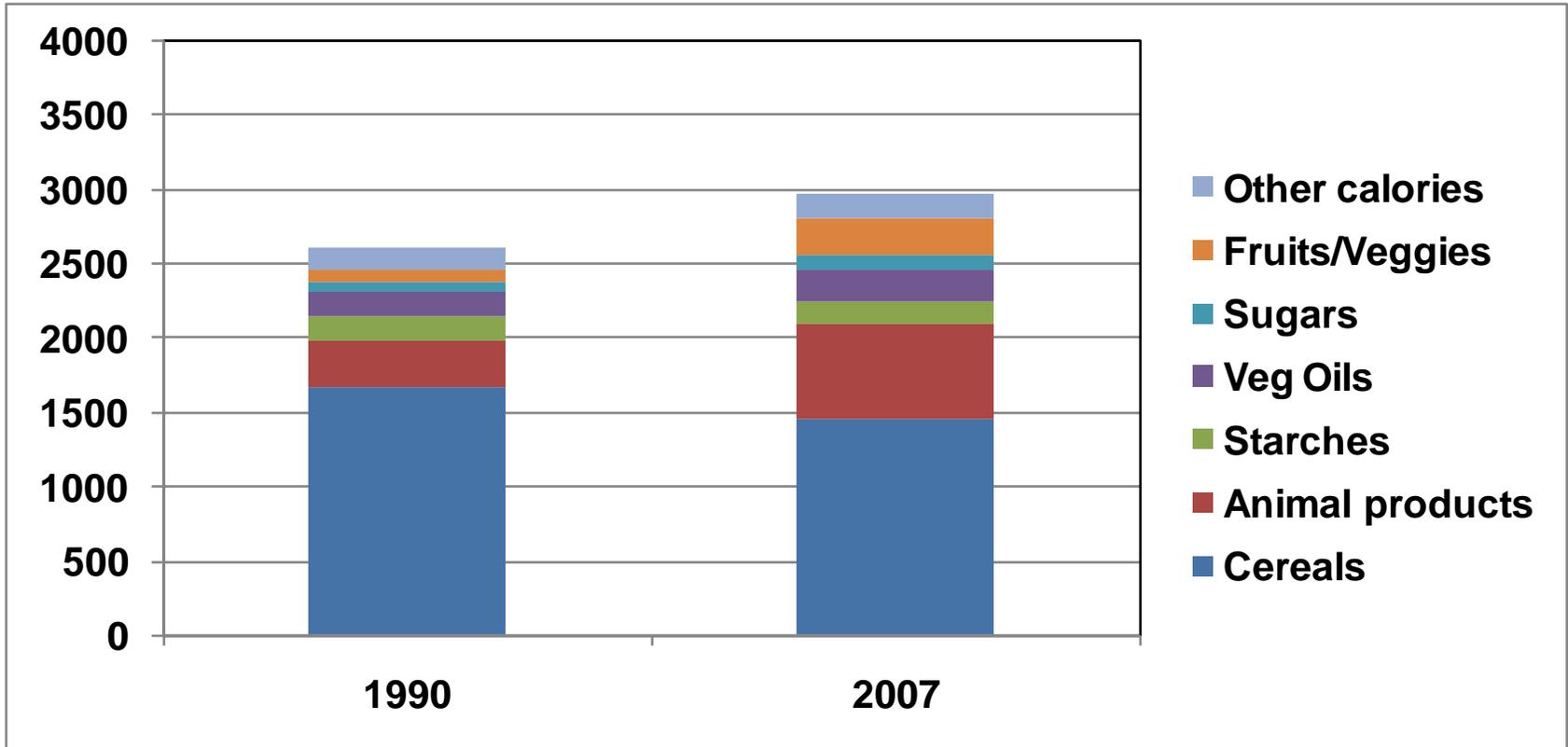
Source: IFPRI (2010).

Share of maize production used as animal feed



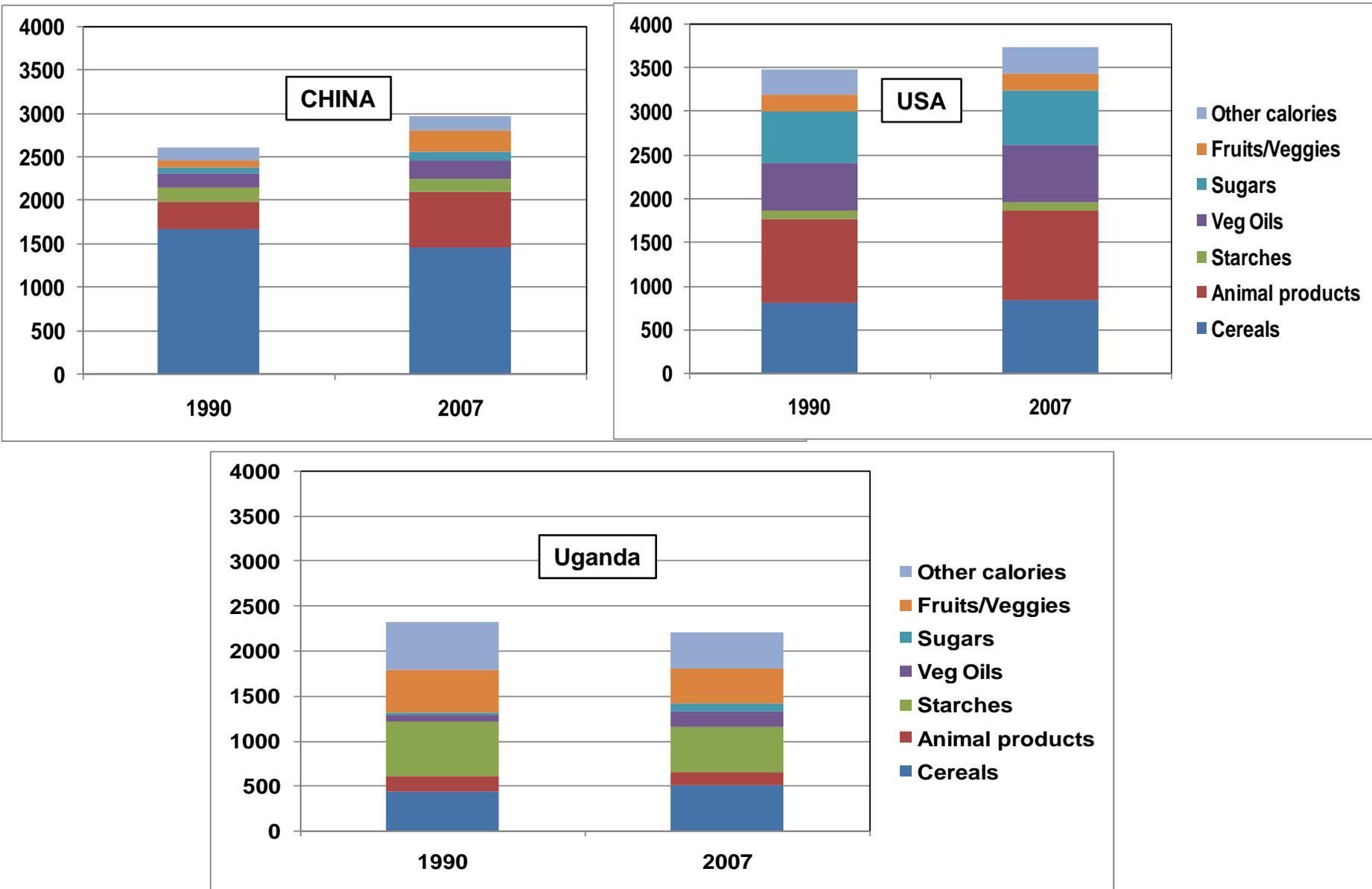
Source: FAOSTAT

Changes in calorie availability per capita/day, example China



Source: FAOSTAT (2010).

Changes in calorie availability per capita/day

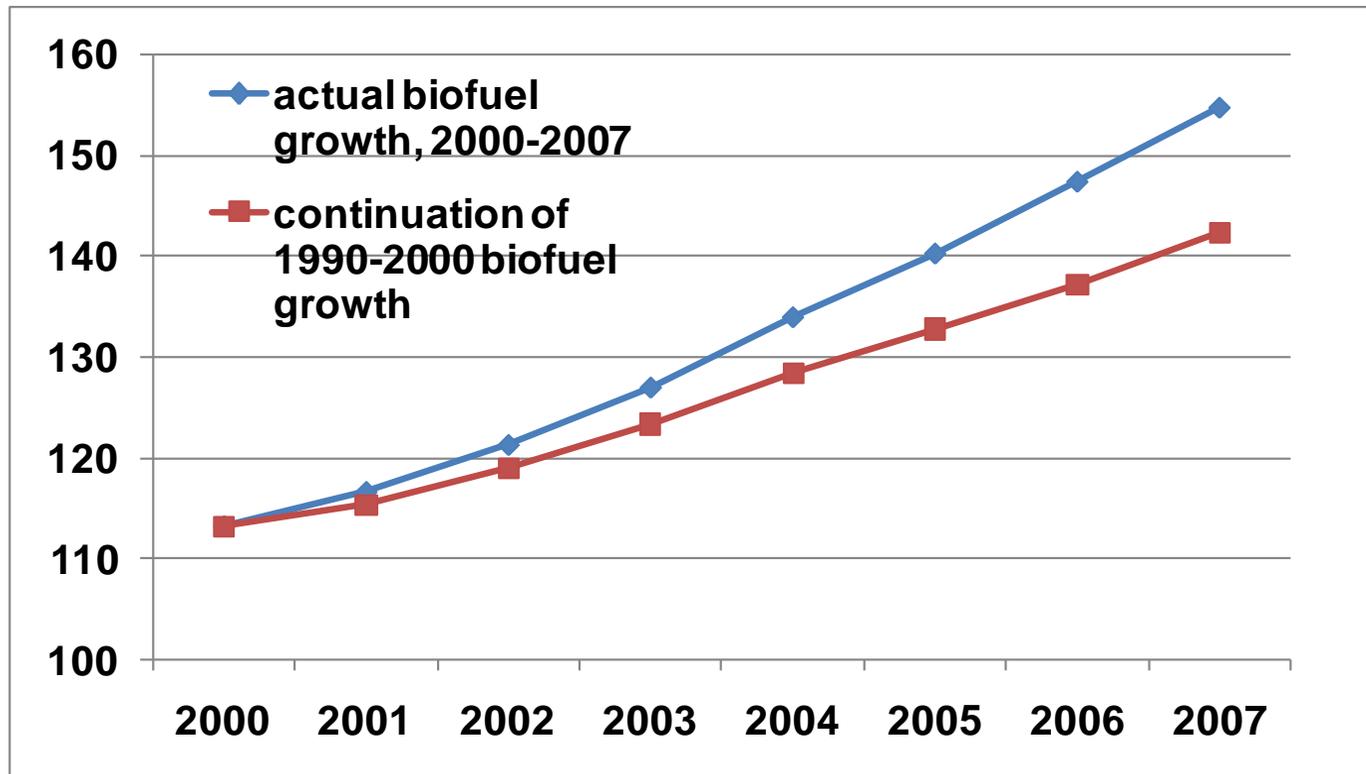


The Water Footprint differs significantly by commodity

- 1 kg of beef: 14-15,000 liters
- 1 liter of milk: 880 liters
- 1 liter of wine: 1000 liters
- 1 liter of coffee: 900 liters
- 1 liter of tea: 128 liters
- 1 kg of cereals: 1000-5000 liters

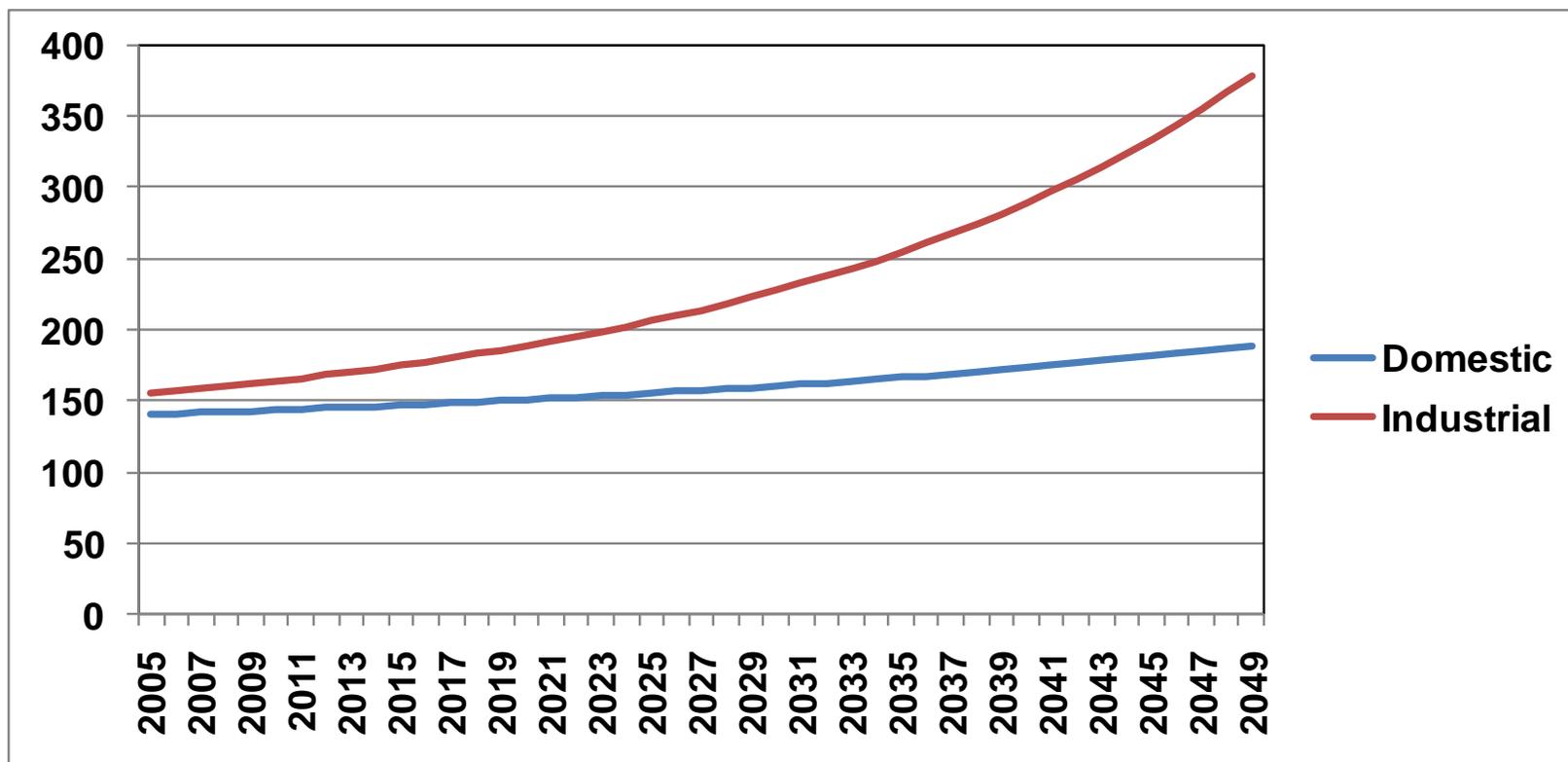
Source: Water Footprint Network

Biofuels—long-term increase in food prices of approx 30 percent



Source: IFPRI (2008).

Growing non-irrigation water demands

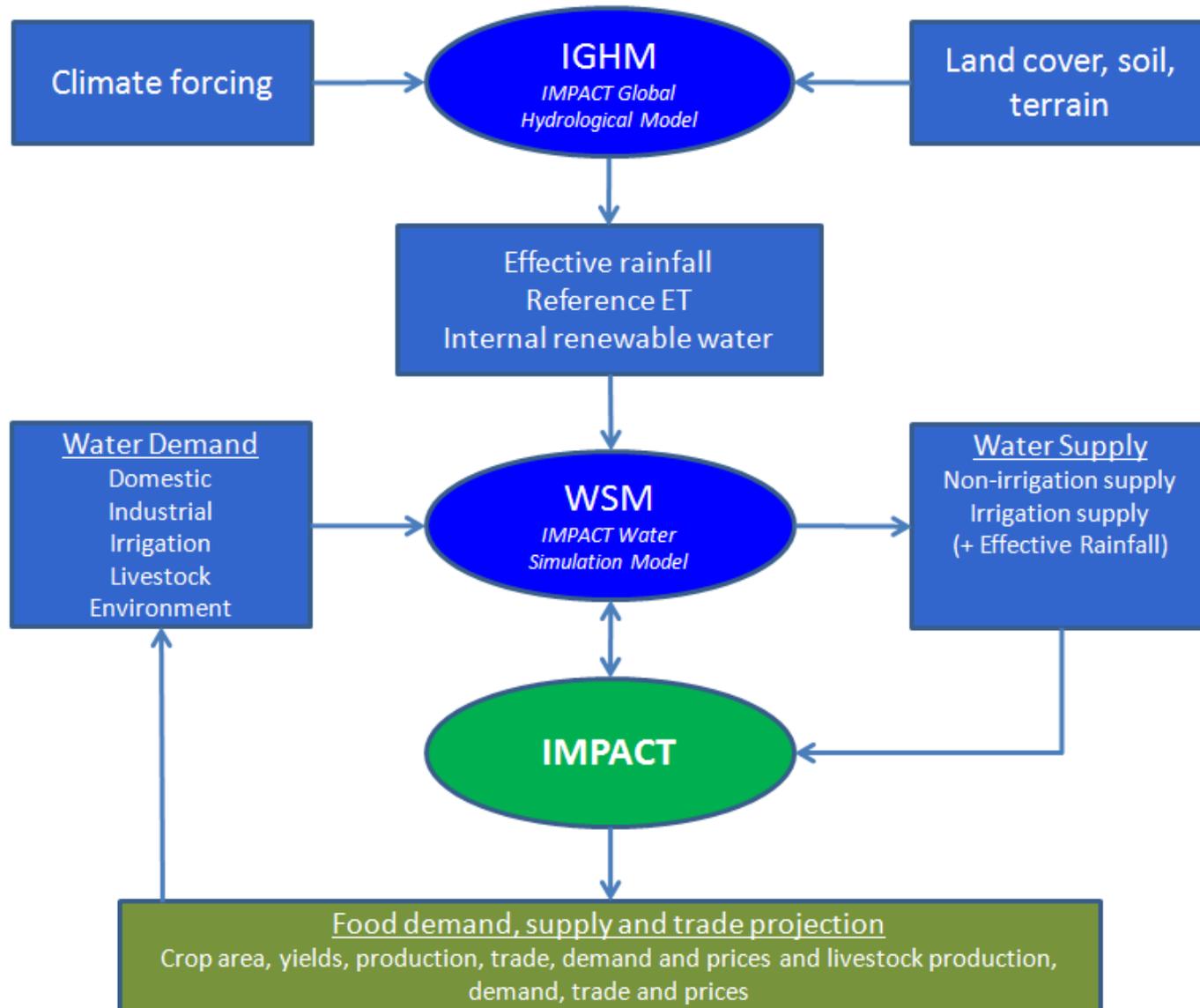


Source: IFPRI (2008).

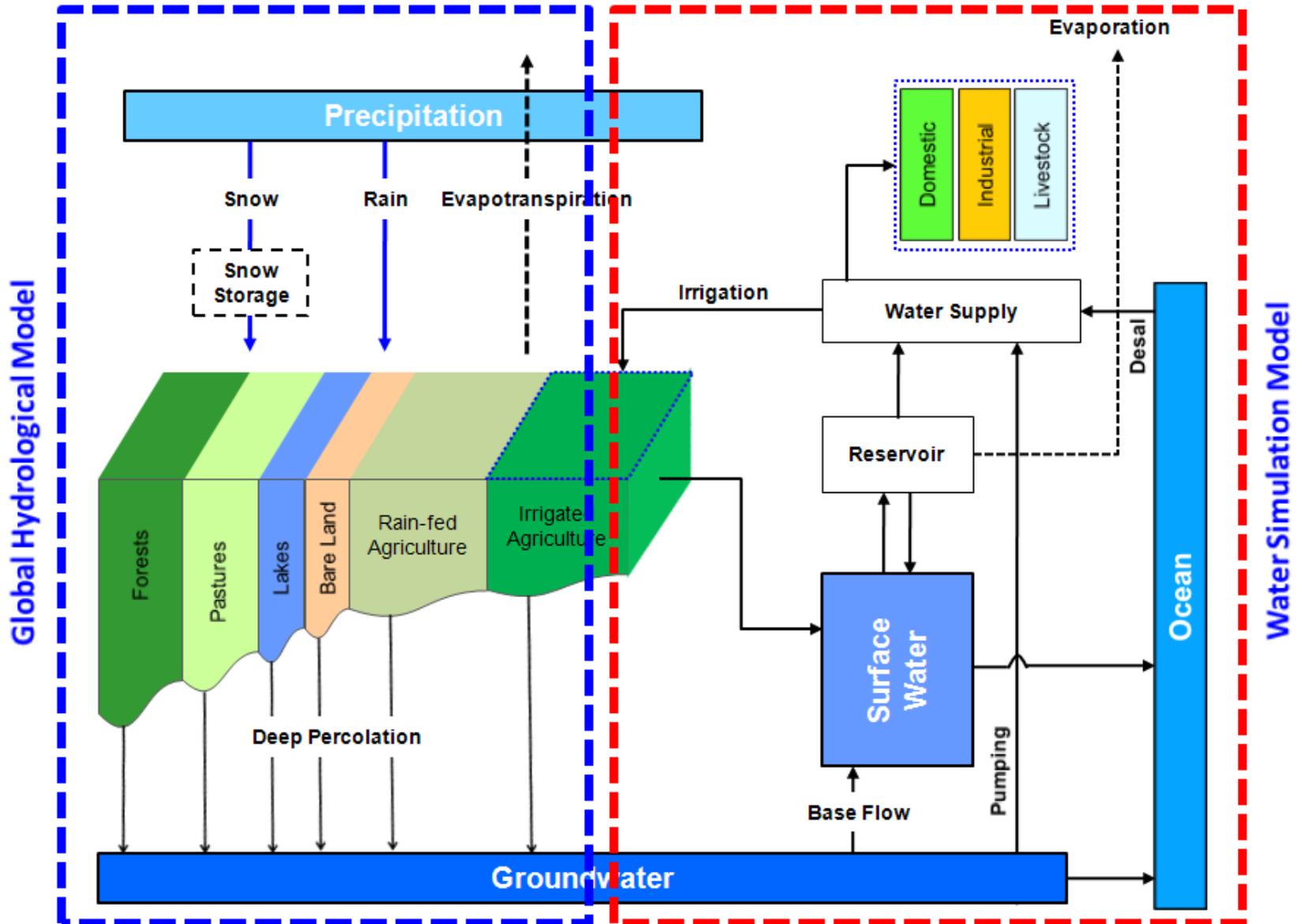
CLIMATE, WATER AND FOOD LINKAGES: *DECLINING SUPPLIES AND INCREASING DEMAND*



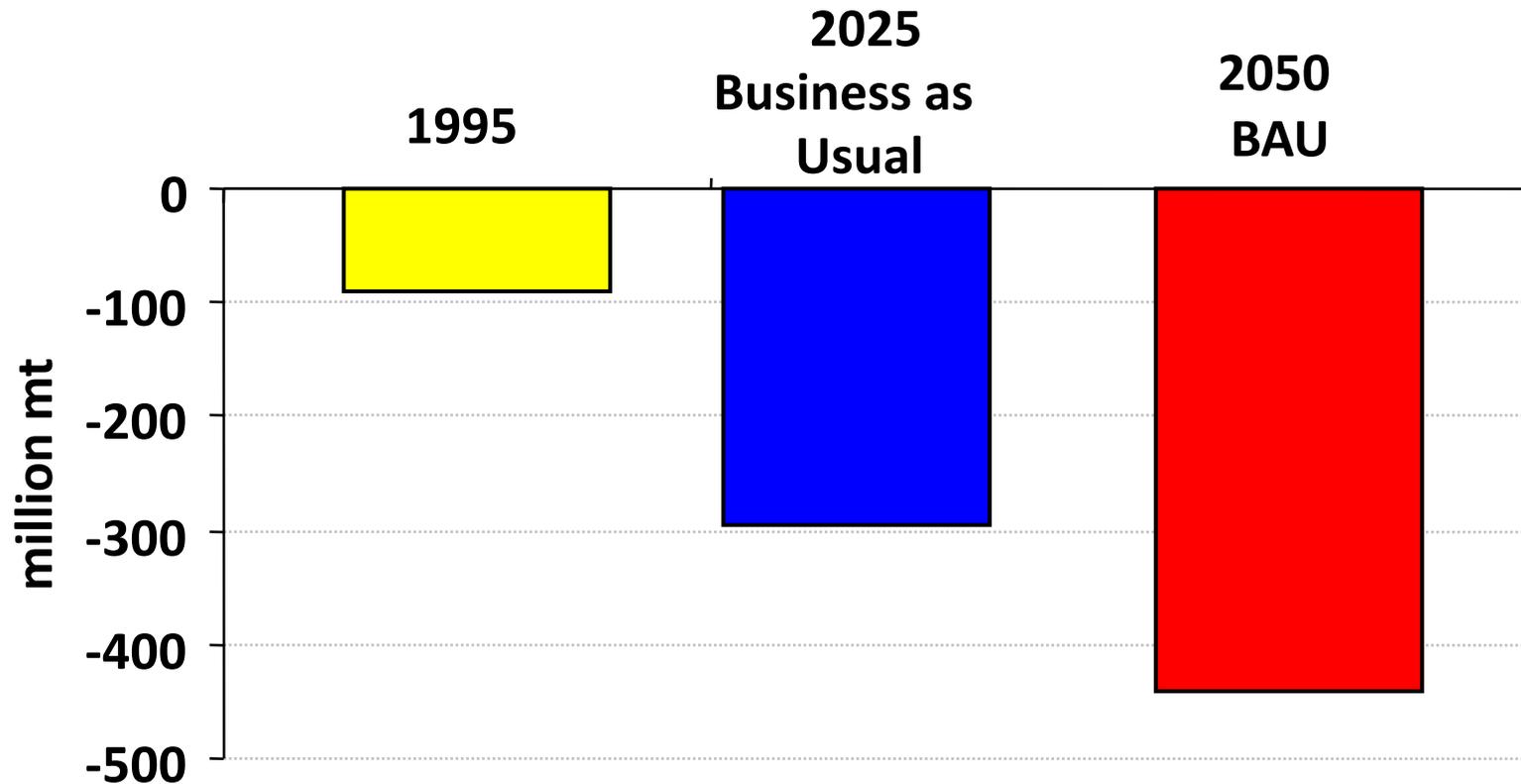
Data Flow and Basic Modeling Strategy



Modeled Natural & Artificial Processes



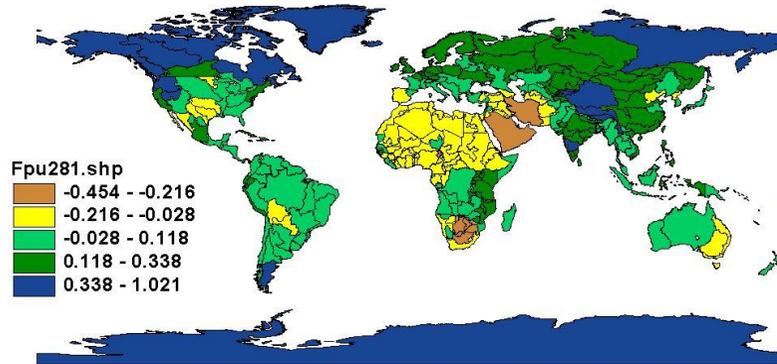
Loss of Grain Production Potential due to Water Scarcity, Developing Countries



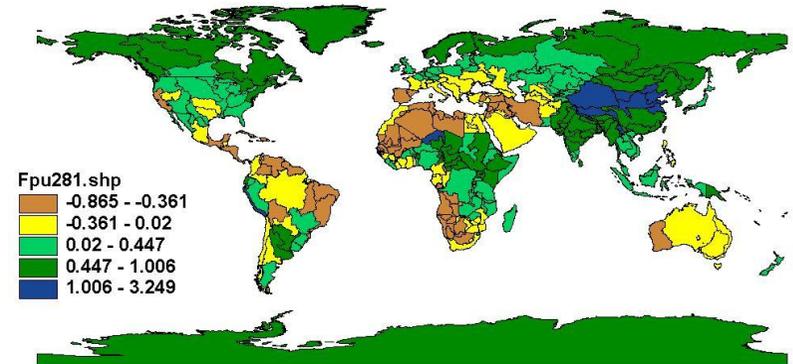
Source: IFPRI IMPACT Business as Usual Projections

Climate Change: Change in Annual Precipitation (1961-1990 to 2050)

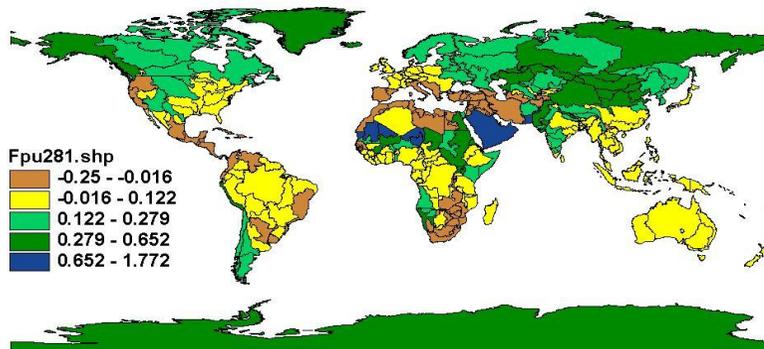
Precipitation Change under CSIRO2-B1



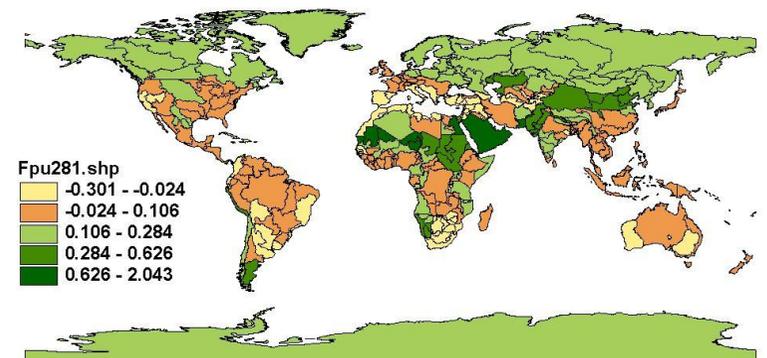
Precipitation Change under HadCM3-A1FI



Precipitation Change under PCM-A2

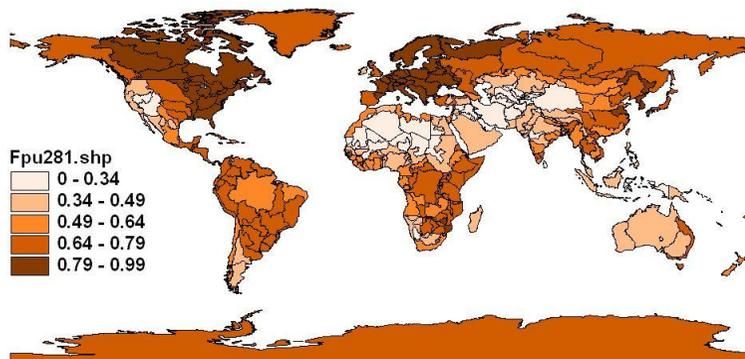


Precipitation Change under PCM-B2

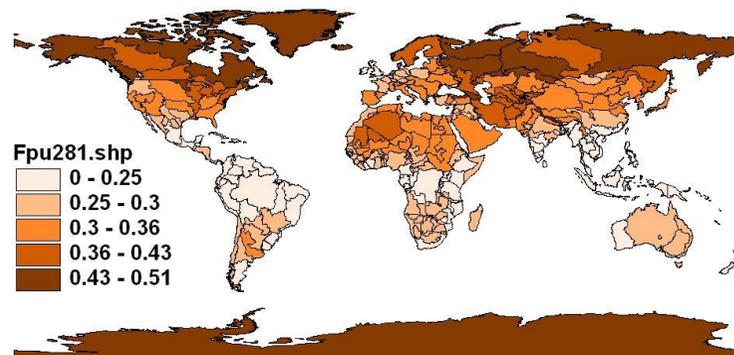


Climate Change: Change in Potential ET (1961-1990 to 2050)

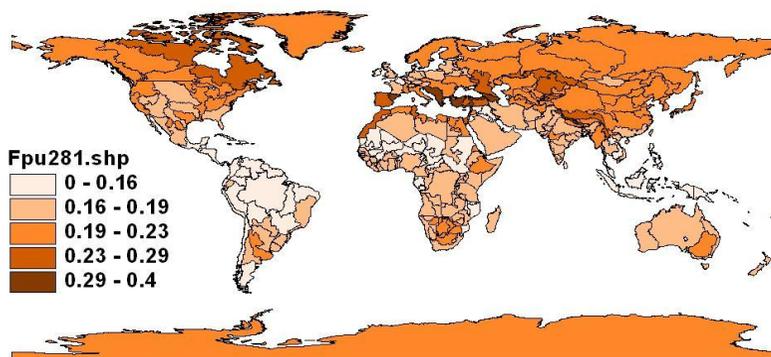
Potential ET Change under HadCM3-A1FI



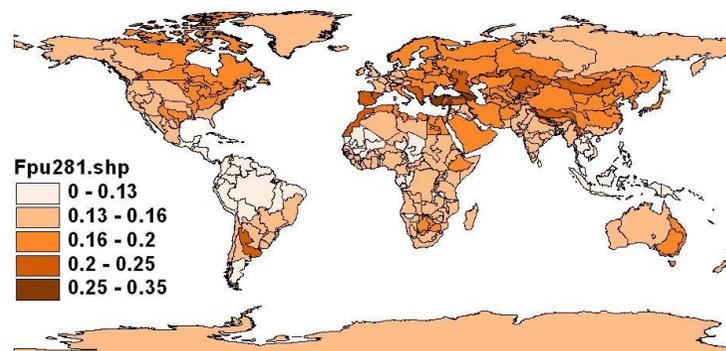
Potential ET Change under CSIRO2-B1



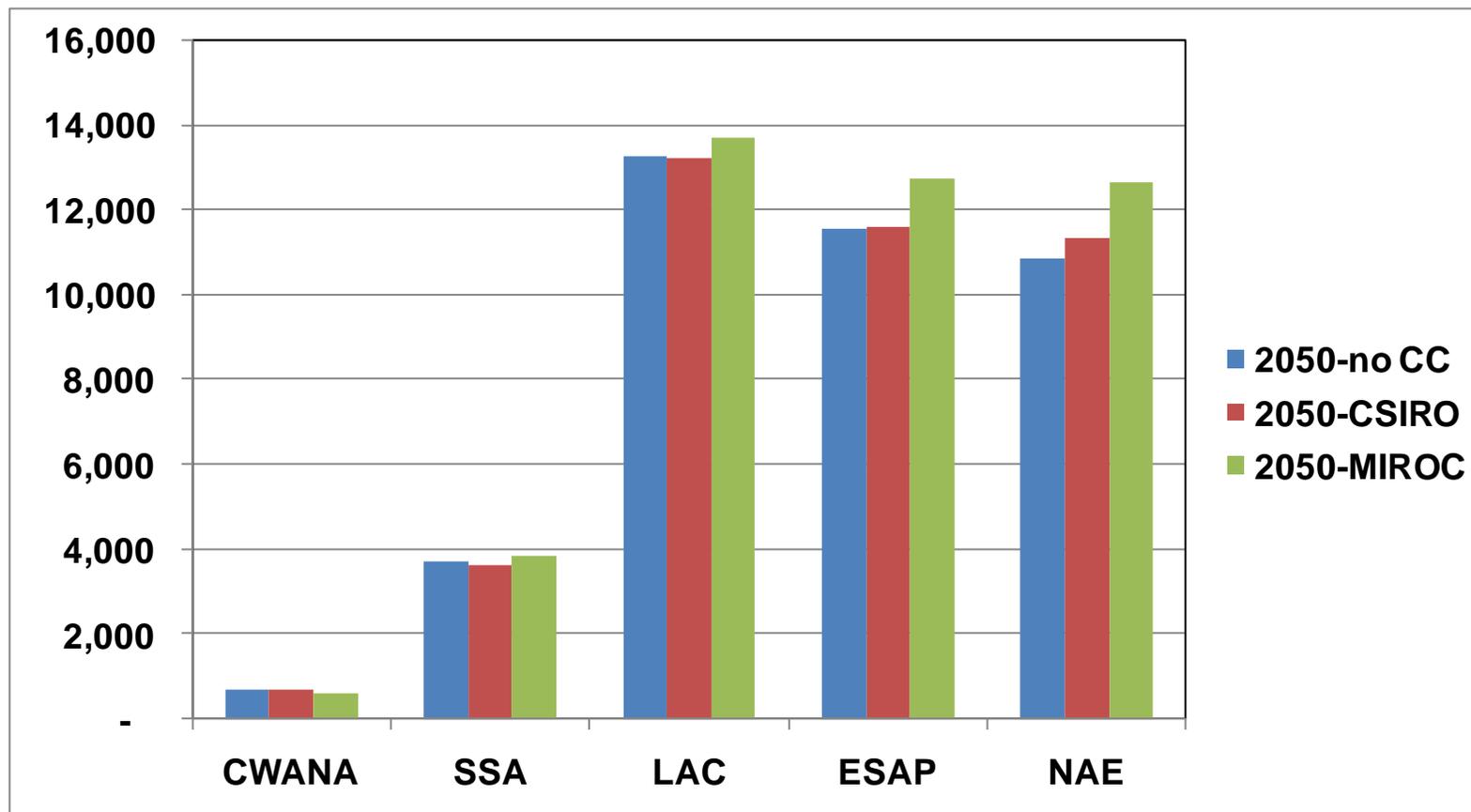
Potential ET Change under PCM-A2



Potential ET Change under PCM-B2

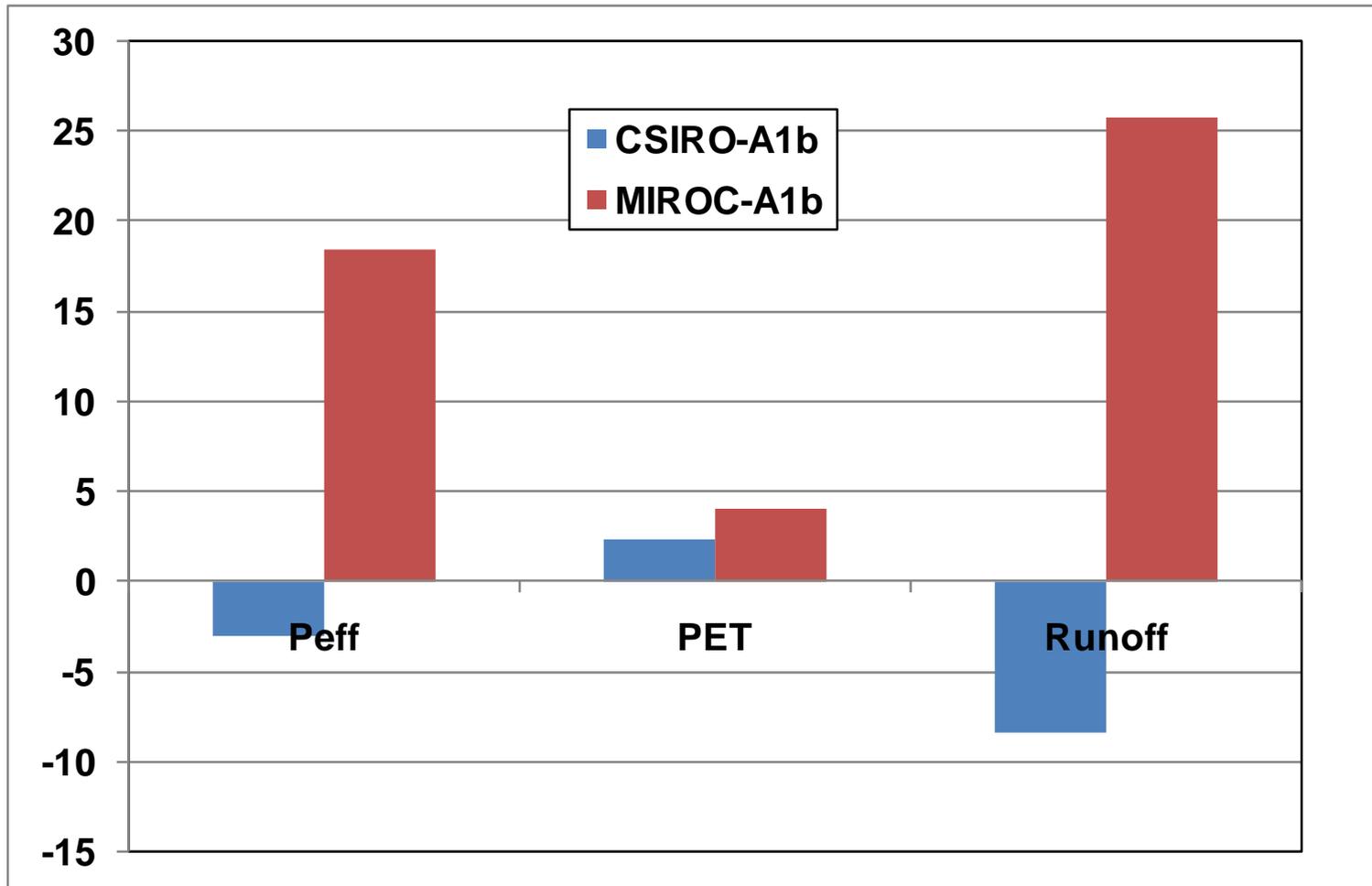


Change in Internal Renewable Water, by Region



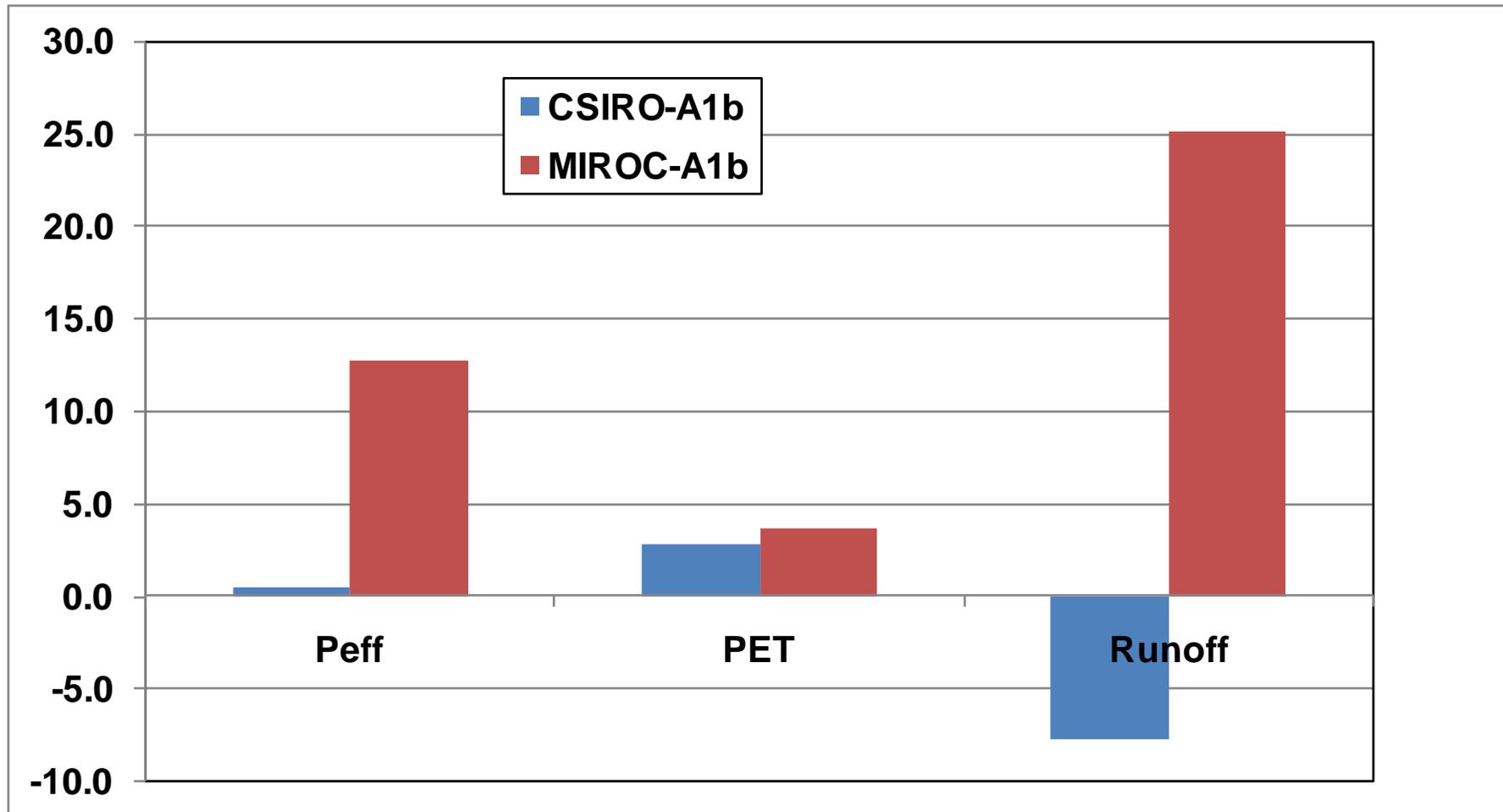
Source: IFPRI (2011).

Change in effective rainfall, PET, and Runoff, Example, Yellow River Basin



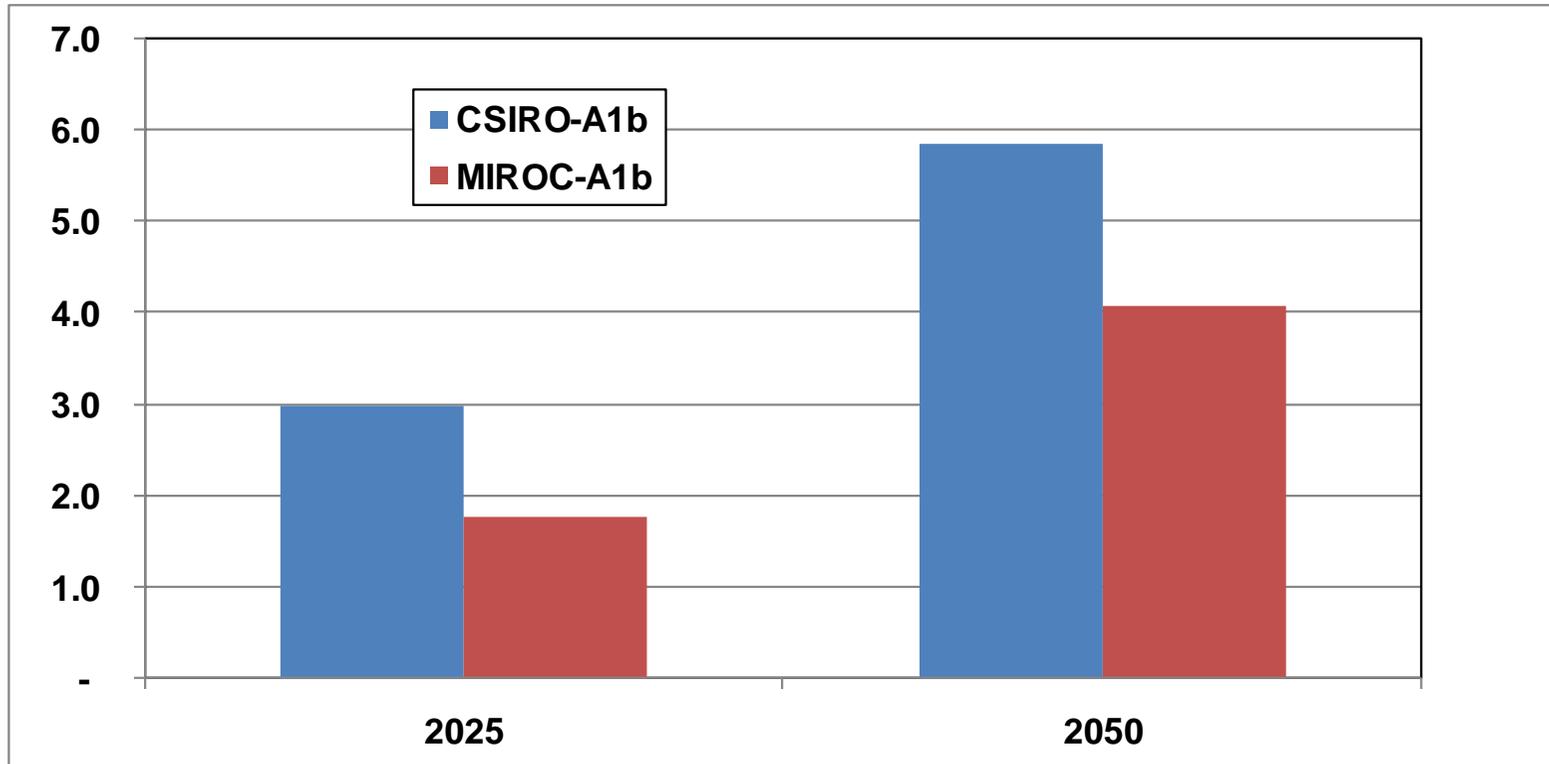
Source: IFPRI (2011).

Change in effective rainfall, PET, and Runoff, Example, Nile River Basin



Source: IFPRI (2011).

Change in irrigation water demand under climate change



Source: IFPRI (2011).

ECONOMIC GROWTH, WATER AND FOOD: *GROWTH INCREASES SCARCITY*



Core Research Questions on “Water and Growth”

... What are the economic growth levels that can be sustained given today’s water productivity?

... To what extent can gains in efficiency and water productivity enable higher levels of growth?

Growth scenarios to outline water requirement dynamics by sector and by country

High-level description

<p>High growth</p>	<ul style="list-style-type: none"> ▪ High growth estimates <ul style="list-style-type: none"> – Developed (+2.4)/ middle income (4.8%) and developing countries (+5.6%) – BRIC¹ countries estimated separately (5.2%/+3.9%/8.4%/9.1%)
<p>Medium growth (default)</p>	<ul style="list-style-type: none"> ▪ Consensus estimates for most likely future GDP performance <ul style="list-style-type: none"> – Developed economies (2.1%), middle income (4.0%) and developing countries (4.3%) – Brazil (4.4%), Russia (3.4%), India (5.9%) and China (6.8%)
<p>Low growth</p>	<ul style="list-style-type: none"> ▪ Minimum growth forecasts <ul style="list-style-type: none"> – Developed (1.6%) /middle income (3.9%) and developing countries (3.3%) – BRIC¹ countries estimated separately (2.9%/3.2%/5.9%/6.8%),

Overall assumptions and methods

- Use of per-country forecasts until 2040, linear extrapolation of trend from 2040-2050
- Differentiation between developing/middle income and developed countries
- Growth assumptions also reflected in food demand

Growth scenarios

Source: McKinsey (2010).

Productivity scenarios established by sector

Water Productivity scenarios

“Grey” productivity

- **No water productivity improvements achieved**, resulting reactive environmental behavior
- **Irrigation**, gradual erosion of irrigation efficiency
- Only **minor energy efficiency gains** reached **Energy demand growing** by ~20% in OECD and +100% in Non-OECD countries, with corresponding water use; **energy mix** shift to nuclear and thermo electrical power generation as assumed by IEA World Energy Outlook for “Current scenario”



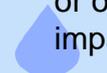
Business-as-usual

- **Domestic sector** shows moderate improvements in **leakage reduction** and water efficiency gains
- **Irrigation**, moderate improvements and small expansion
- **Industry**, 50% of maximum water productivity levels achieved
- **Energy demand increase** at ~19% in OECD and +110% in Non-OECD countries; **energy mix with slight shift towards renewable energy mix**, high share of conventional thermal electric generation



“Blue” Productivity

- **Domestic sector** shows high improvements in **leakage reduction** and water efficiency gains
- **Majority of water productivity potential** achieved in industry
- High efficiency in **irrigation**
- **Energy demand growing** at ~19% in OECD and +110% in Non-OECD ; **high share of renewable energy** increasing from ~19% (2008) to 29% (2030) with biomass produced from waste material or otherwise without water impacts



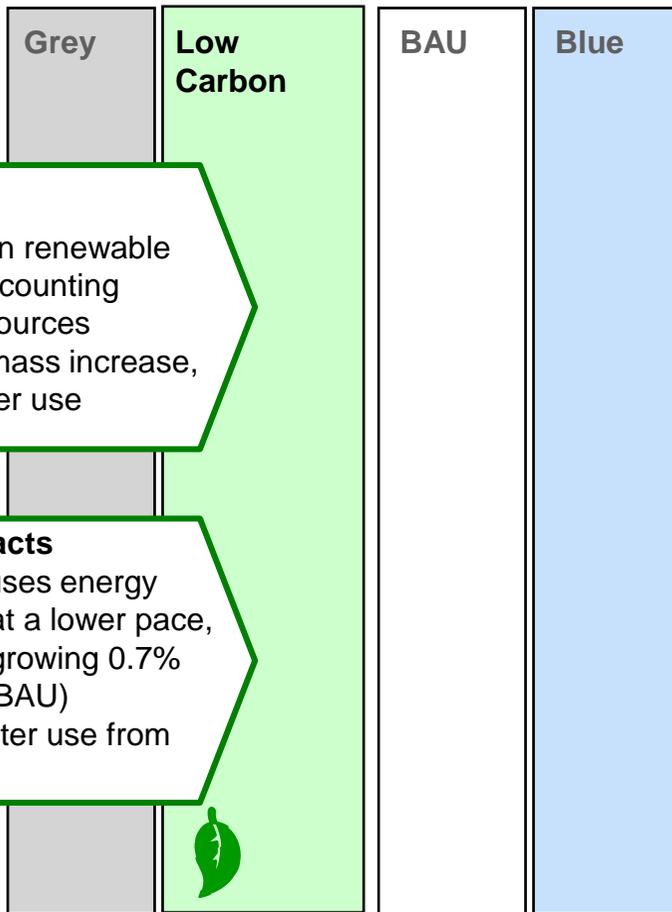
← *Low water productivity*

High water productivity →

A low-carbon energy mix impacts water productivity in terms of higher usage of biomass but also higher energy efficiency

Water productivity scenarios

Drivers of water productivity under low-carbon growth



Energy mix impacts

- Strong emphasis is on renewable energy generation accounting for >25% of energy sources
- Hydropower and biomass increase, with increases in water use

Energy efficiency impacts

- Energy efficiency causes energy demand to increase at a lower pace,
 - Energy demand growing 0.7% p.a. (vs. 2.1% in BAU)
- Lower increase of water use from conventional energy

Water impacts of optimizing for low-carbon energy

- On balance, a low-carbon energy scenario has slightly lower water productivity than BAU
- The water impacts of biomass (some irrigation) and hydropower (evaporation) from reservoirs outweigh water savings from efficiency gains

← Low water productivity → High water productivity →

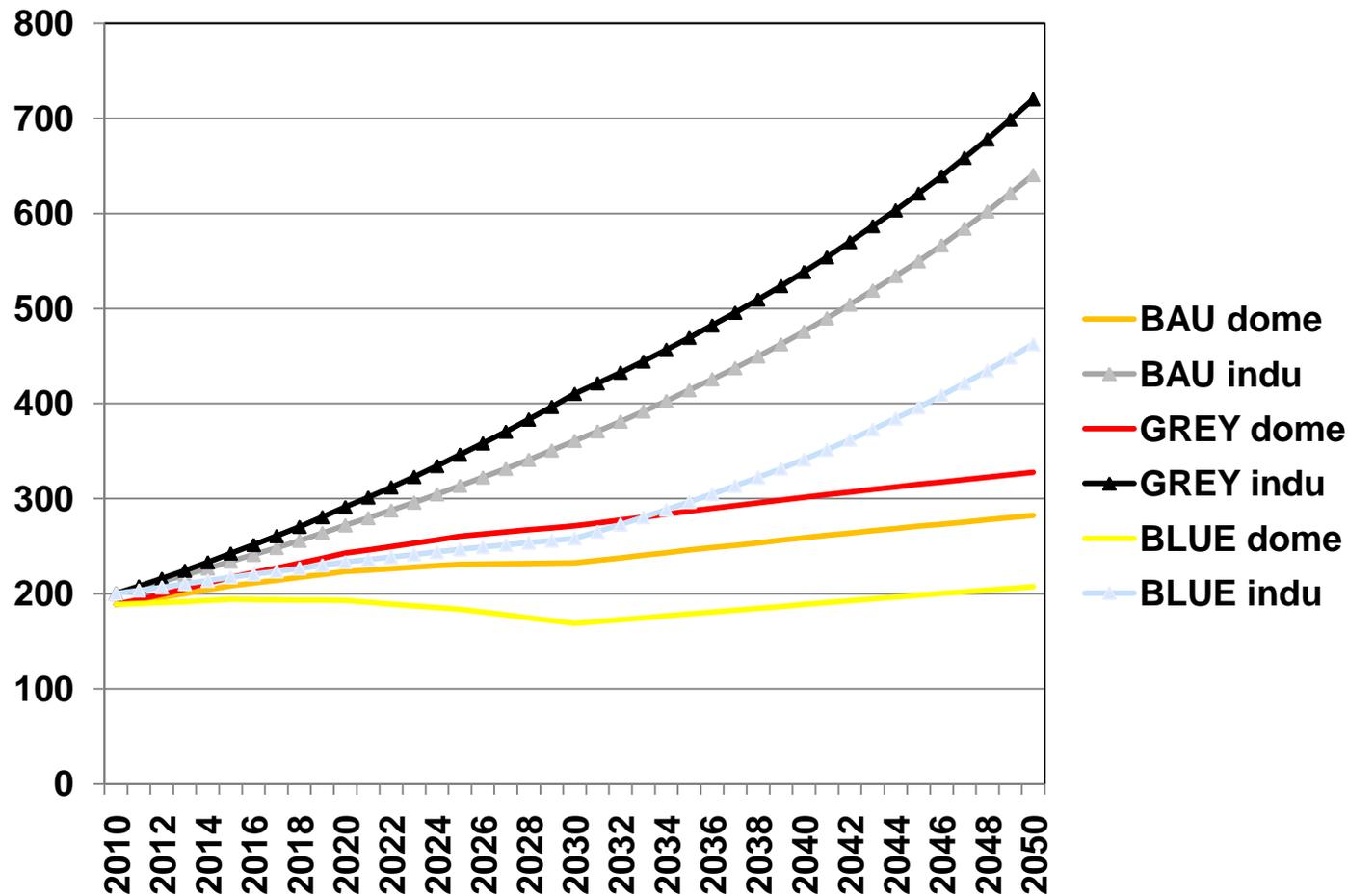
Megatrend scenarios – Parameter overview (1/2)

Driver		Grey 	BAU 	Low Carbon 	Smart blue 	SOURCE	
Climate change		CSIRO A1B	CSIRO A1B	CSIRO A1B	CSIRO A1B	IFPRI	
Environmental flow requirements		10%	10%	10%	10%	IFPRI	
Residential	Efficiency gain on consumption	Developed Middle Income Developing	0,5 % p.a. 0,3 % p.a. 0,0 % p.a.	1,0 % p.a. 0,5 % p.a. 0,0 % p.a.	1,0 % p.a. 0,5 % p.a. 0,0 % p.a.	2,0 % p.a. 1,5 % p.a. 1,0 % p.a.	Expert interviews
	Leakage reduction	Infrastructure: Good (<10% leakage) Medium (10-40% lkg) Poor (>40% lkg)	-0% + 5% - 10%	0% - 10% - 20%	0% - 10% - 20%	0% - 25% - 30%	Expert interviews
Industrial	Energy demand	IEA scenarios	"Current policy"	"New policy"	Green Energy "450"	"New policy" assuming biomass usage in low water stress regions or from waste	IEA World Energy Outlook 2010, World Economic Forum
	Energy mix						
	Energy water productivity improvement	High efficient Medium efficient Low efficient	0%	10%	10%	30%	McKinsey knowledge documents (China deepdive, South Africa deepdive, Industry factpack)
	Mining demand	IEA scenarios	"Current policy"	"New policy"	Green Energy "450"	"New policy" assuming biomass production in low water stress regions or from waste	IEA World Energy Outlook 2010, World Economic Forum
	Mining mix						
Mining water productivity improvement		0%	10%	10%	30%	McKinsey knowledge documents	
Water productivity improvement other industries ¹		0%	10%	10%	30%	McKinsey knowledge documents (China deepdive, South Africa deepdive, Industry factpack, Water impact on business)	

¹ Based on industry average (Beverage, Pulp&Paper, Chemicals, Food, Steel, Others) using China, South Africa, US & Australia

Changes in water use efficiency can significantly affect domestic and industrial consumption levels

Projected water depletion, cubic kilometers, global



Switching to low carbon energy production leads to significantly increased water consumption

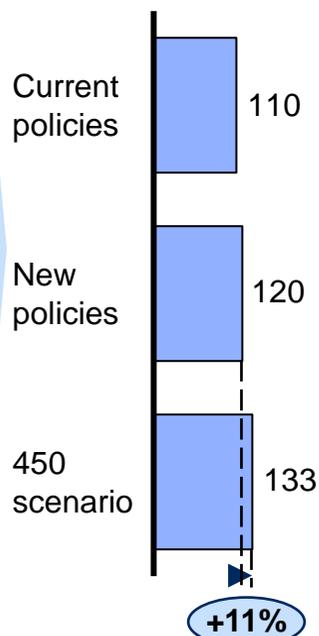
in 2050

■ Direct effect
■ Indirect effect

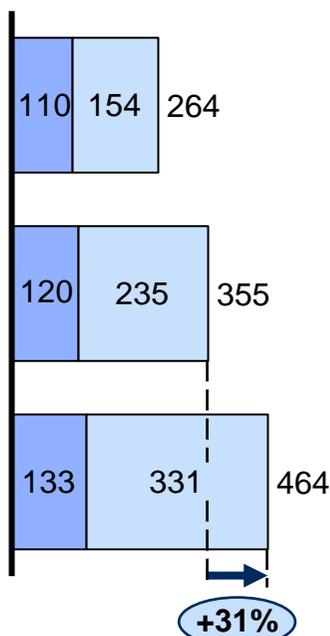
Methodology

- Using 2050 scenario energy mix estimate by IEA
- Average water productivity for various electricity generation technologies
- Water consumption figures adjusted by production levels of scenarios

Water consumption by electricity generation¹
in Tsd. km³ water



Water consumption by electricity generation including water consumption of biofuels
in Tsd. km³ water



Major scenario assumptions

- No change in government policy is assumed
- 23% of renewable energy generation
- Takes **current policies** and **declared intentions** into account
- Low carbon scenario** providing reasonable chance of **constraining average global temperature increase to 2° Celsius**
- 45% of renewable energy generation including hydropower

Low carbon energy mix can significantly increase water demand unless second generation biofuels are used

¹ Using the same energy demand across scenarios

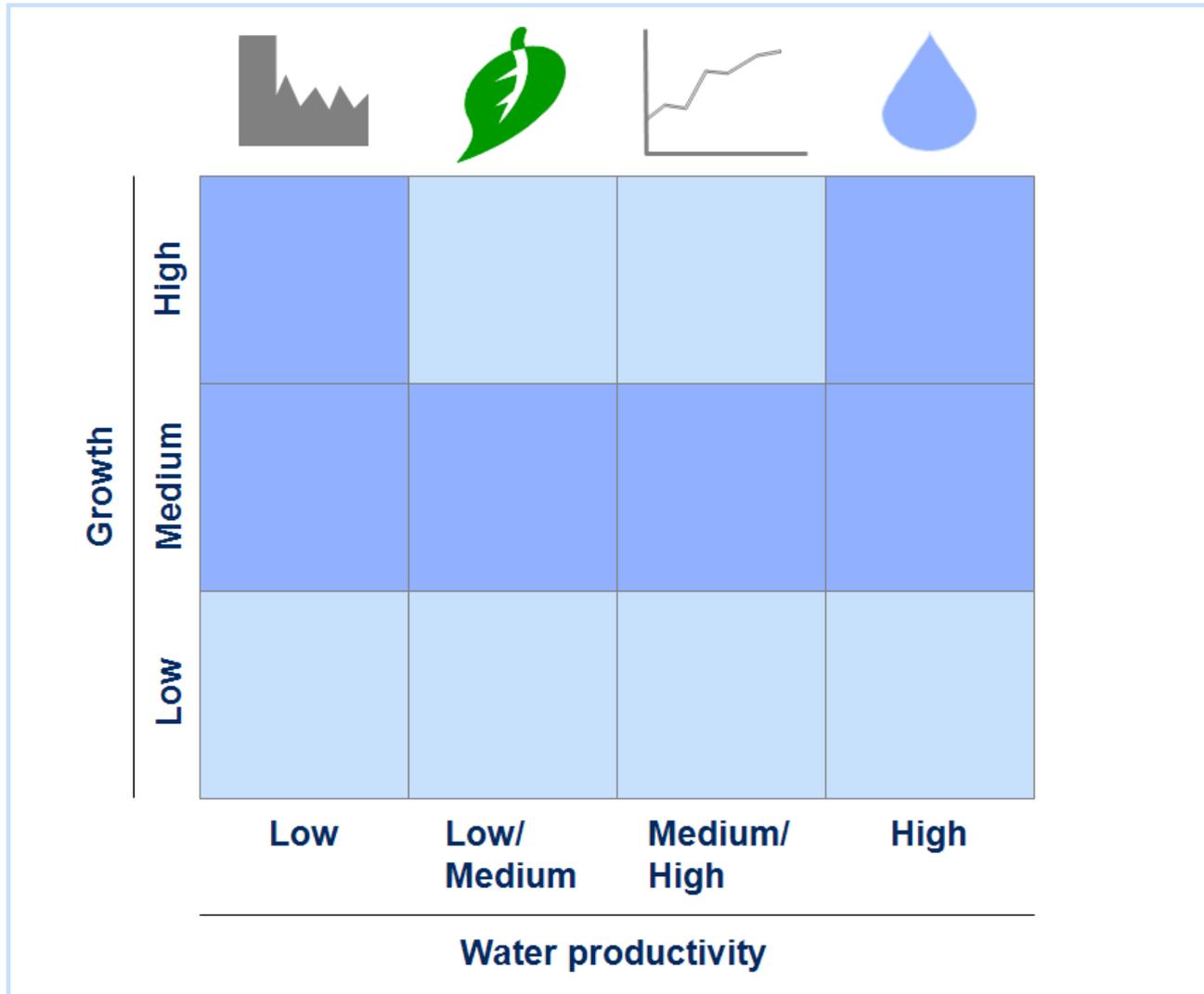
Megatrend scenarios – Parameter overview (2/2)

Results incl in doc

Agriculture

Driver 2010-2050		Grey 			BAU 			Low Carbon 			Smart blue 			SOURCE
GDP- growth		Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	
Change in agricultural GDP growth, implemented as change in crop yield growth	Developed	no change to BAU			- 2.5%	0%	2.5%	- 2.5%	0%	2.5%	- 2.5%	0%	2.5%	IFPRI
	MENA, Central Asia	medium growth scenario			- 5%	0%	5%	- 5%	0%	5%	- 5%	0%	5%	
	Eastern Europe				- 5%	0%	5%	- 5%	0%	5%	- 5%	0%	5%	
	SSA, SA and LAC				- 20%	0%	20%	- 20%	0%	20%	- 20%	0%	20%	
	India				- 15%	0%	15%	- 15%	0%	15%	- 15%	0%	15%	
China/Other East Asia				- 10%	0%	10%	- 10%	0%	10%	- 10%	0%	10%		
Change in agricultural GDP growth, implemented as change in crop area growth	Developed	-2.5%	0%	2.5%	no change to BAU			no change to BAU			no change to BAU			IFPRI
	MENA, Central Asia	-10%	0%	10%	medium growth scenario			medium growth scenario			medium growth scenario			
	Eastern Europe	-10%	0%	10%										
	SSA, SA and LAC	-20%	0%	20%										
	India	-15%	0%	15%										
China/Other East Asia	-10%	0%	10%											
Change in irrigated area expansion	Developed	no change to BAU			0%	0%	0%	0%	0%	0%	no change to BAU			IFPRI
	MENA, Central Asia	medium growth scenario			0%	0%	0%	0%	0%	0%	medium growth scenario			
	Eastern Europe				0%	0%	0%	0%	0%	0%				
	SSA, SA and LAC				- 10%	0%	20%	-10%	0%	20%				
	India				- 5%	0%	15%	-5%	0%	15%				
China/Other East Asia				- 2.5%	0%	10%	-2.5%	0%	10%					
Change in basin efficiency (gradual decline until 2030, constant between 2030-2050)	Developed	-0.15	-0.15	-0.15	no change to BAU			no change to BAU			Basin efficiency increase by 0.2			IFPRI
	MENA, Central Asia	-0.1	-0.1	-0.1	medium growth scenario			medium growth scenario						
	Eastern Europe	-0.1	-0.1	-0.1										
	SSA, SA and LAC	-0.12	-0.12	-0.12										
	India	-0.1	-0.1	-0.1										
China/Other East Asia	-0.1	-0.1	-0.1											
Other changes	-	n.a.			n.a.			<ul style="list-style-type: none"> 27% increased first-generation biofuel demand over BAU 			<ul style="list-style-type: none"> Increased crop transpiration efficiency leading to 10% increase in irrigated yields Increase soil water holding capacity by 20% over baseline) Increase in female sec edu & access to safe drinking water (MDG vision) 			IFPRI

Scenario matrix



Thresholds of water withdrawals represent degrees of sustainability within river basins

Water Stress Index – Total withdrawals as share of internal renewable water resources

Relying on commonly agreed thresholds for "total withdrawal over internal renewable water resource" within the scientific community



Description

Moderate stress (< 20%)

- "Safe" withdrawals less than 20% of internal renewable water resources
- Generally avoids local environmental impacts

Water stress (20 - 40%)

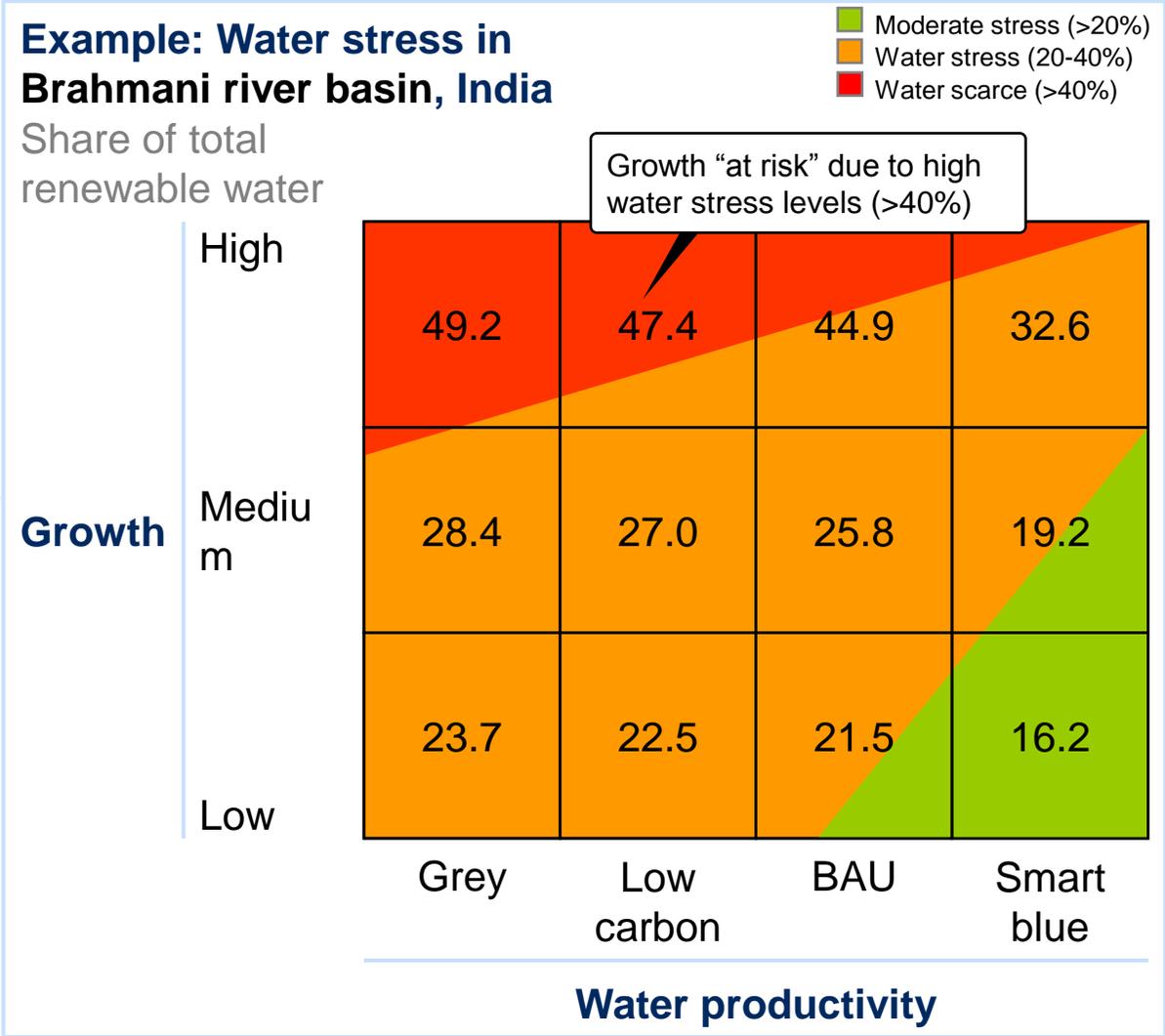
- Stress apparent during drought periods and with water quality impacts of water use
- Some transport of water within the region required to meet demand

Water-scarce (> 40%) - "at risk"

- Large spatial variability of demand results in "unsustainable" withdrawals within river basin
- Local impacts of over-extractions more common

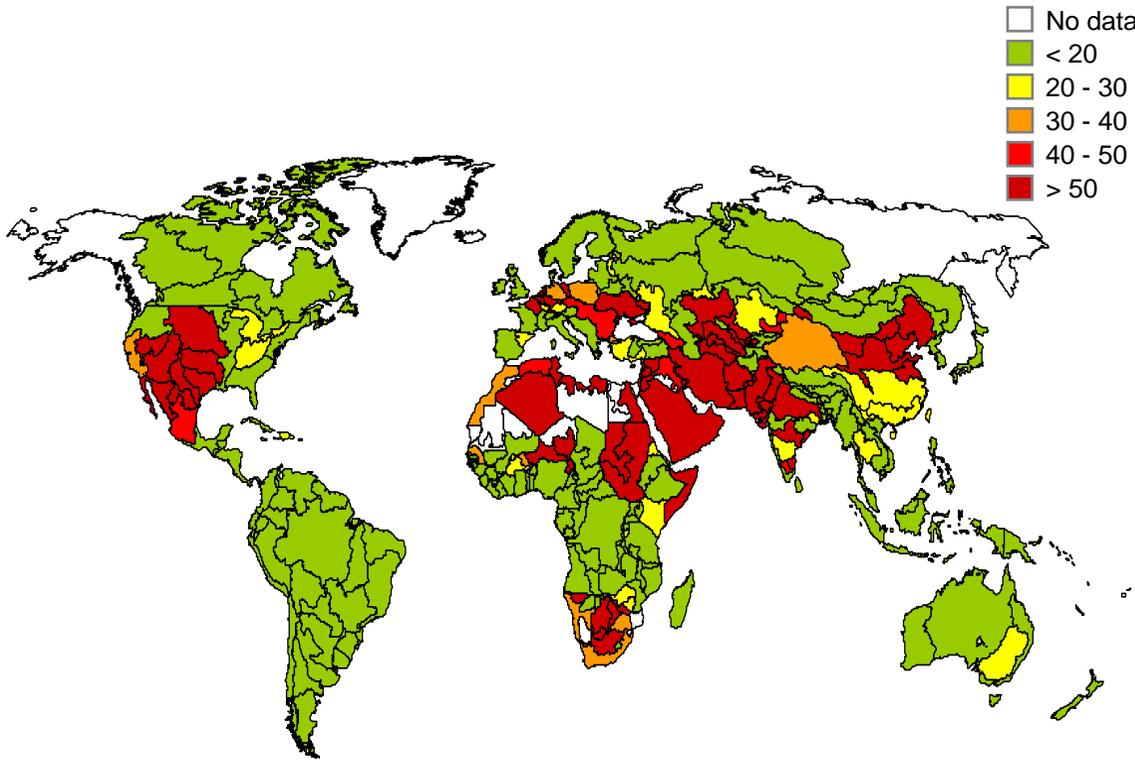
Example: Growth “at risk” when stress levels rise, while increasing water productivity can reduce risk

- **Sectoral growth in agriculture, energy and industry** drive increases in water requirements
- **Growth rates become “at risk”** when levels of water stress grow beyond thresholds
- **Higher-levels of productivity** can enable growth while maintaining sustainable withdrawals ratios

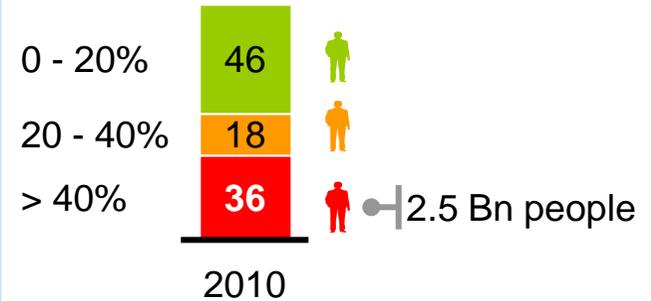


Today, 36% of the global population (2.5 Bn), 9.4 trillion USD (22%) of global GDP, and 39% of global grain production are at risk due to water stress

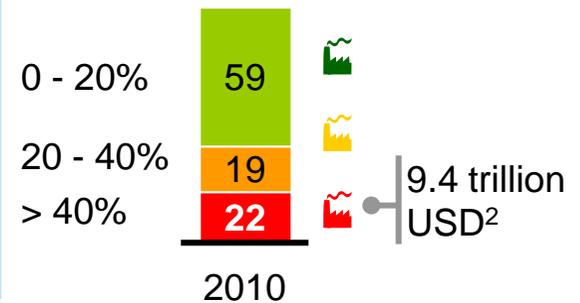
2010



How many people live in water short areas?



How much GDP is generated in water scarce regions?

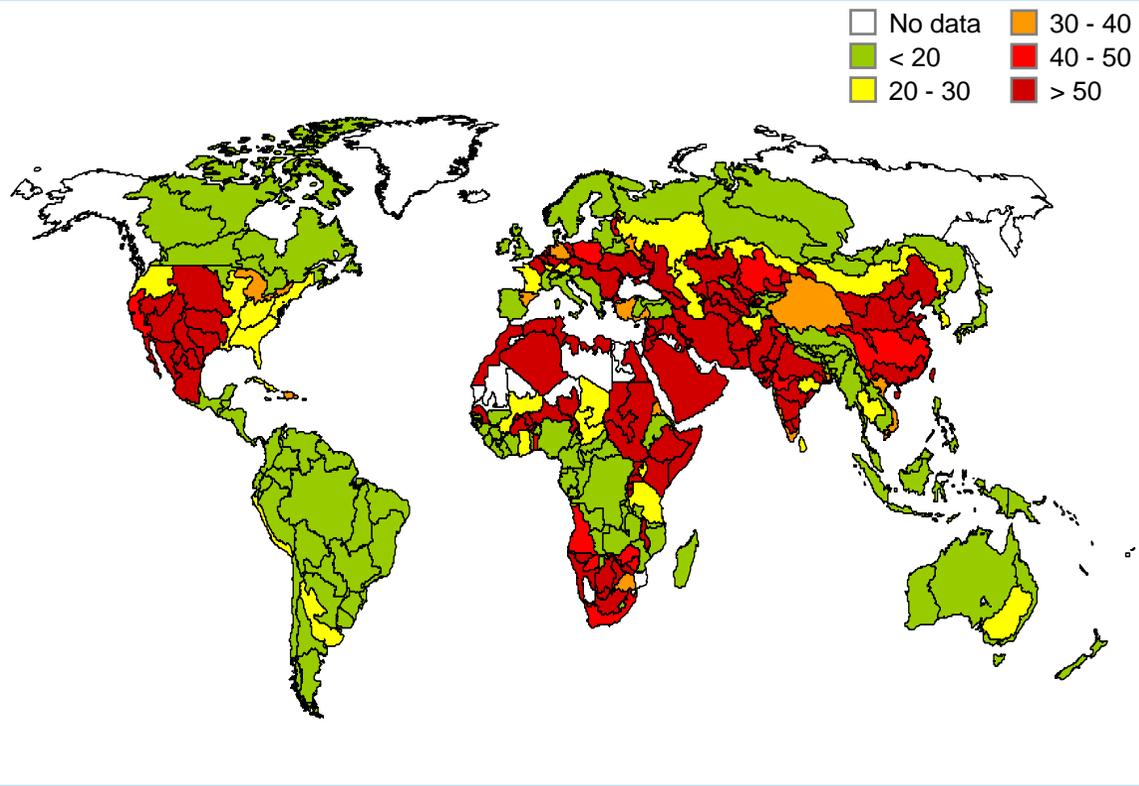


1 >40% water stress
2 Year 2000 prices

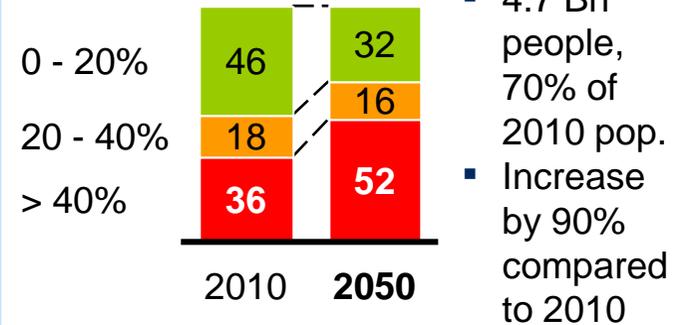
Source: IFPRI/Veolia (2010).

Under business-as-usual water productivity and medium growth, 52% of population, 45% of GDP and 49% of cereals will be produced in regions at risk due to water stress

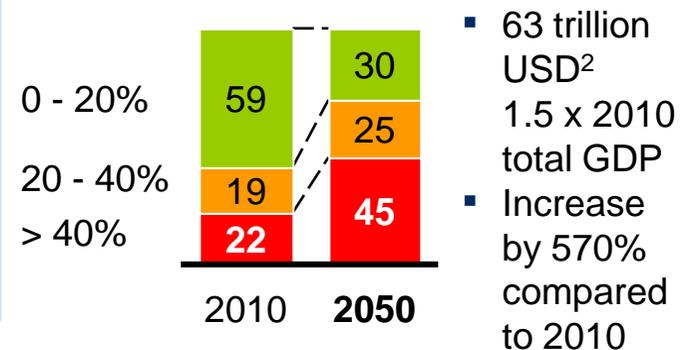
Business as usual (BAU) water productivity, medium growth, 2050



How many people live in water short areas?



How much GDP is generated in water scarce regions?



1 >40% water stress
2 Year 2000 prices

Source: IFPRI/Veolia (2010).

Change in international cereal prices under alternative economic growth and water productivity scenarios

Economic Growth	Water productivity			
	Grey	Low Carbon	BAU	Blue
Rice				
High	(1.0)	(4.1)	(4.1)	(6.9)
Medium	0.3	0.2	-	(6.2)
Low	3.1	3.8	3.6	(3.1)
Wheat				
High	13.5	8.8	7.3	3.5
Medium	2.2	1.6	-	(3.4)
Low	(0.8)	3.0	1.3	(2.2)
Maize				
High	12.6	8.5	4.6	3.1
Medium	0.3	3.9	-	(3.5)
Low	(2.1)	8.7	4.5	0.7

Notes: Base case is BAU medium growth

Source: IFPRI/Veolia (2010).

By growing blue 70% of economies, including China, US, Mexico, etc. can stay below the 40%-threshold

Medium growth

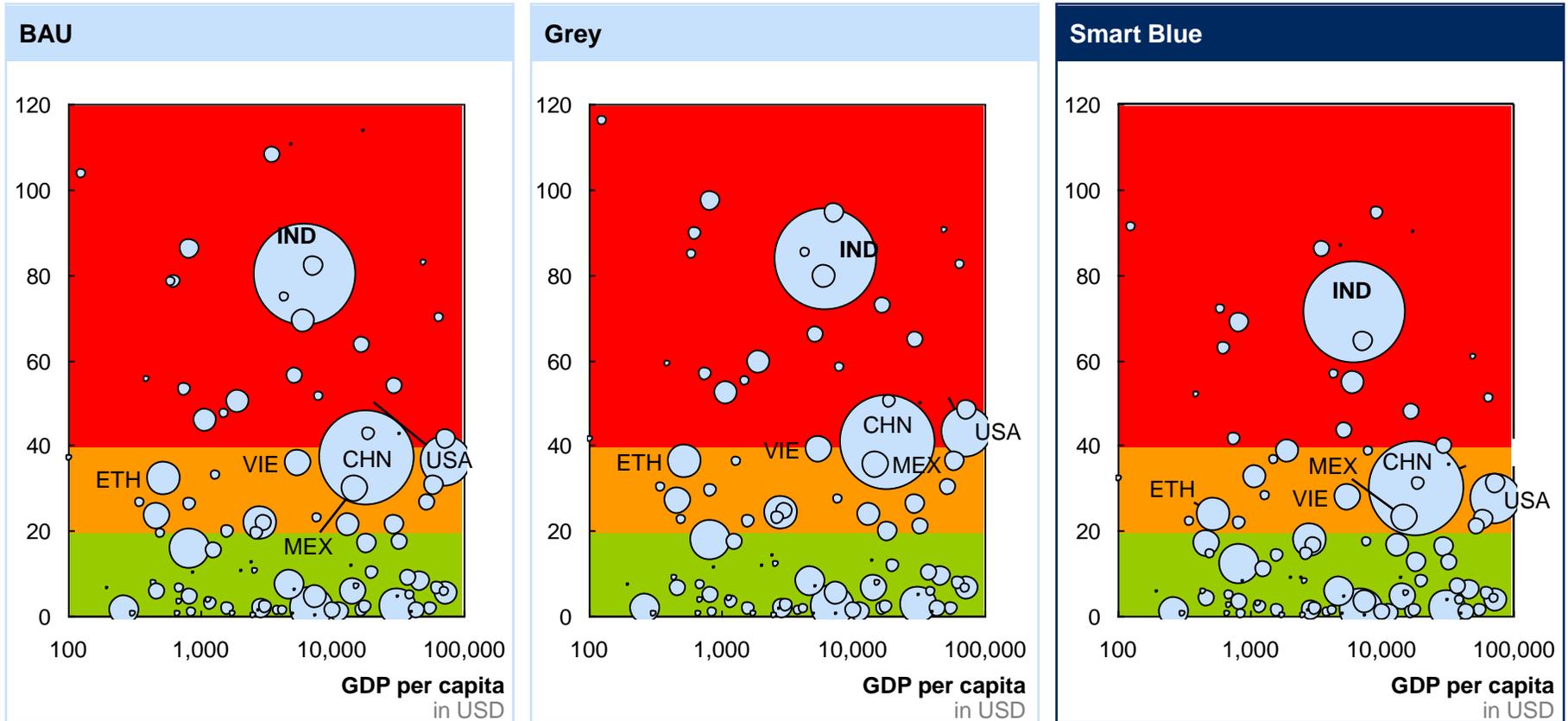
Size of bubble reflects size of population

- Low stress
- Medium stress
- High stress

Water stress over GDP per capita¹

Water stress by country

Percent



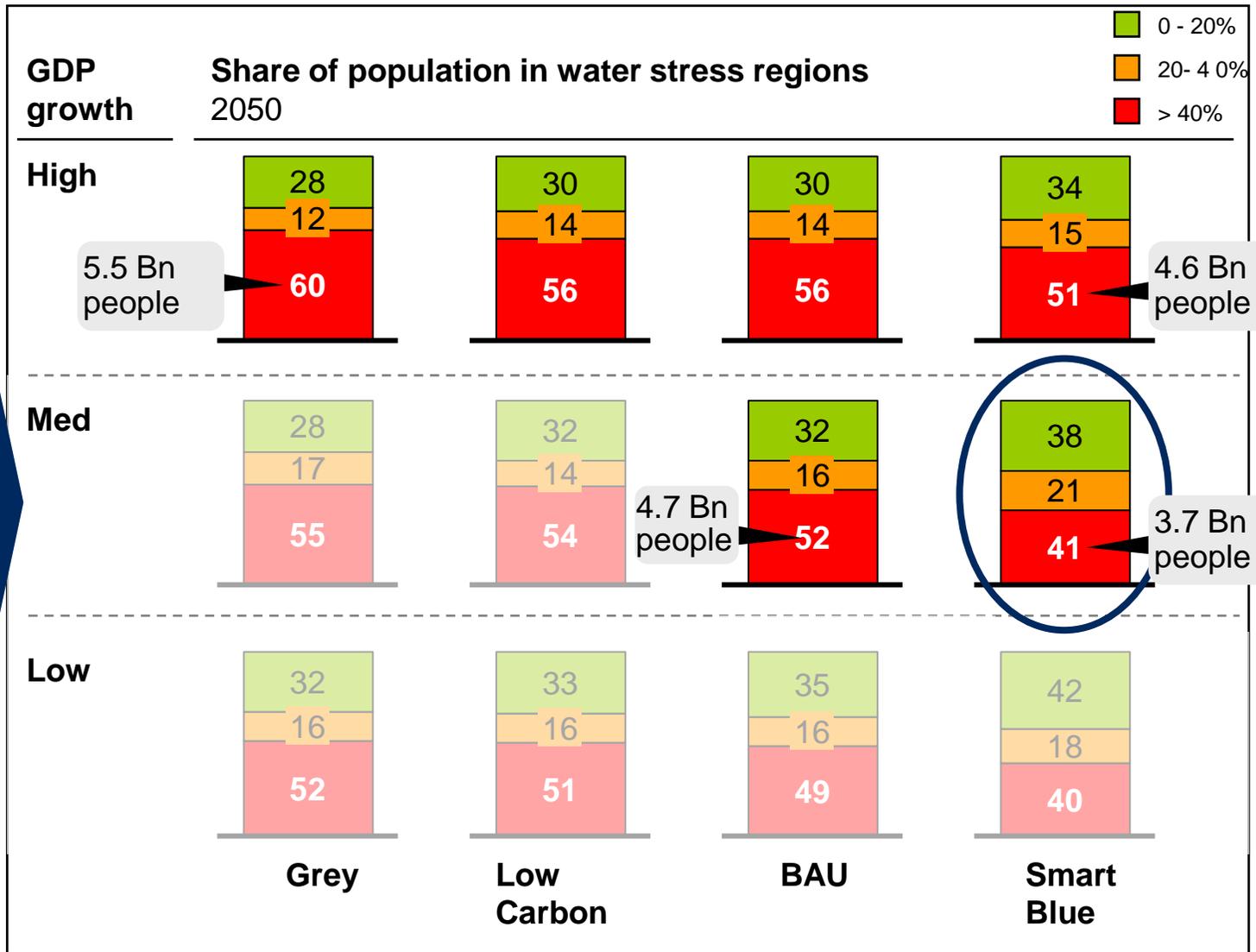
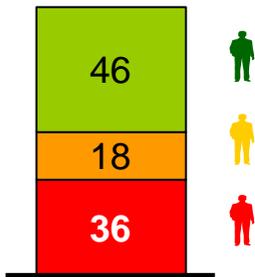
1 2000 prices

SOURCE: IFPRI; McKinsey

A smart blue scenario supports high growth at the level of BAU for medium growth. A medium growth Blue world represents the best compromise—balancing growth and sustainability

Percent

Share of population in water stress regions 2010



OTHER RELEVANT WATER WORK



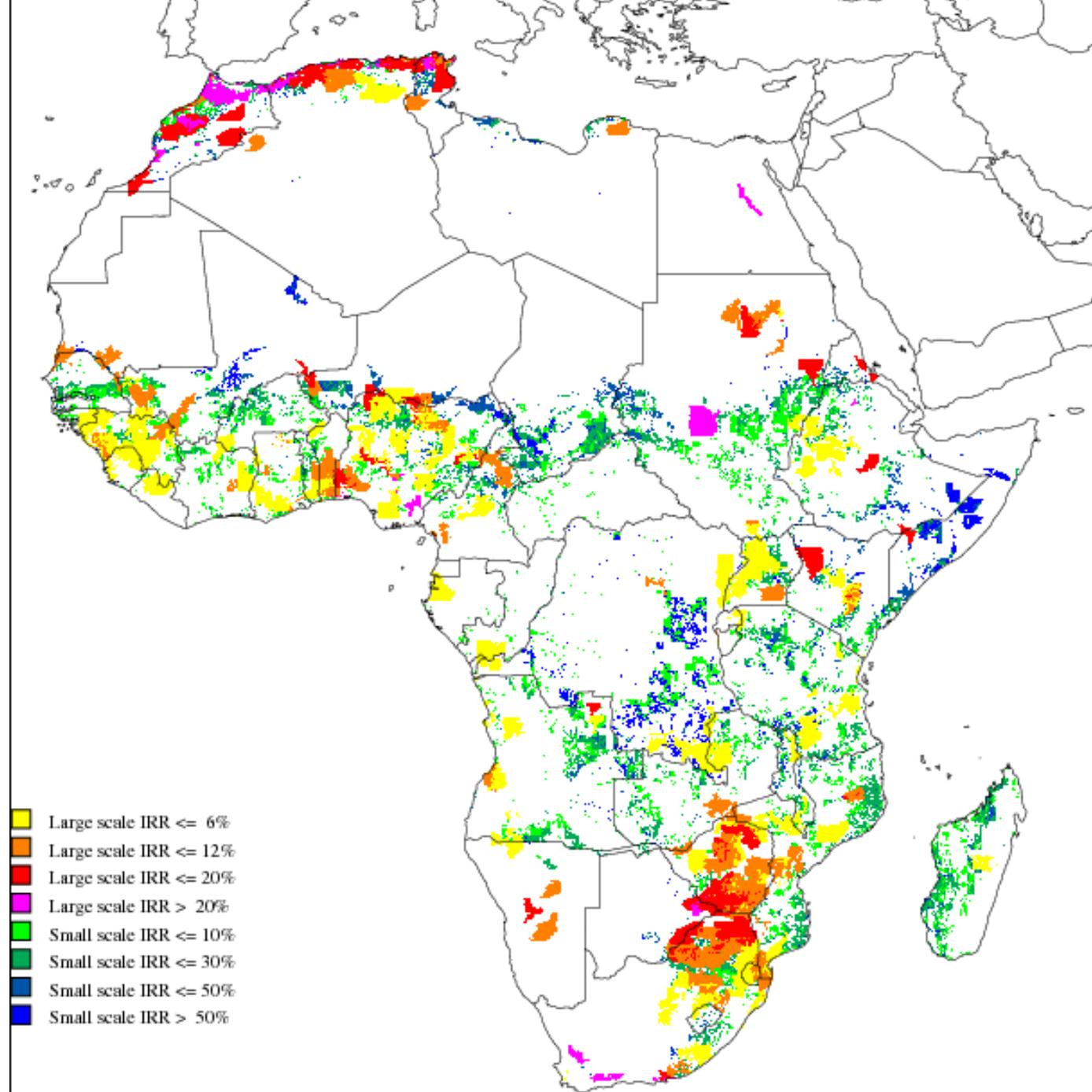
Africa Irrigation Investment Potential

--combining biophysical with socioeconomic data for all of Africa--

Selected Key Findings

- 16.3 m ha could be profitably irrigated w/ large-scale, dam-based irrigation (over 50 yrs)—area drops to 1.9 m ha at IRR of $\geq 12\%$
 - 7.3 m ha has potential for profitable small-scale irrigation; 5.8 m ha at IRR of $\geq 12\%$
- 100% increase over today's 13.4 m ha

Returns to investment, small- and large-scale irrigation, Africa



HOW TO MOVE FORWARD



On water and climate change...

- Re-incorporate climate variability
- Explore water-based adaptation options
- Include water quality parameters

On water and economic growth...

- How can efficiency potential simulated be achieved most cost-effectively/efficiently?
- Using water-CGE or econometric models to compare results