Water Scarcity and Food Security

Challenges in Water-Food-Energy Nexus

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AIT: 50 YEARS OF EMPOWERING ASIA 1959 - 2009

ASIAN INSTITUTE OF TECHNOLOGY 1959

AIT Asian Institute of Technology

The context

Is there enough **land**, **water** and **human capacity** to produce food for a growing population over the next 50 years?

The answer is **NO**, unless we act to improve water use in agriculture. Today's food production and environmental trends, if continued, will lead to crises in many parts of the world.

Food security

- Exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life

(World Food Summit, Rome, 1996; FAO, 2002)

- Food security issues:
  - Availability
  - Nutrition
  - Economic access
  - Social access
  - Physical access
  - Cultural access
  - Water access and
  - Legal framework

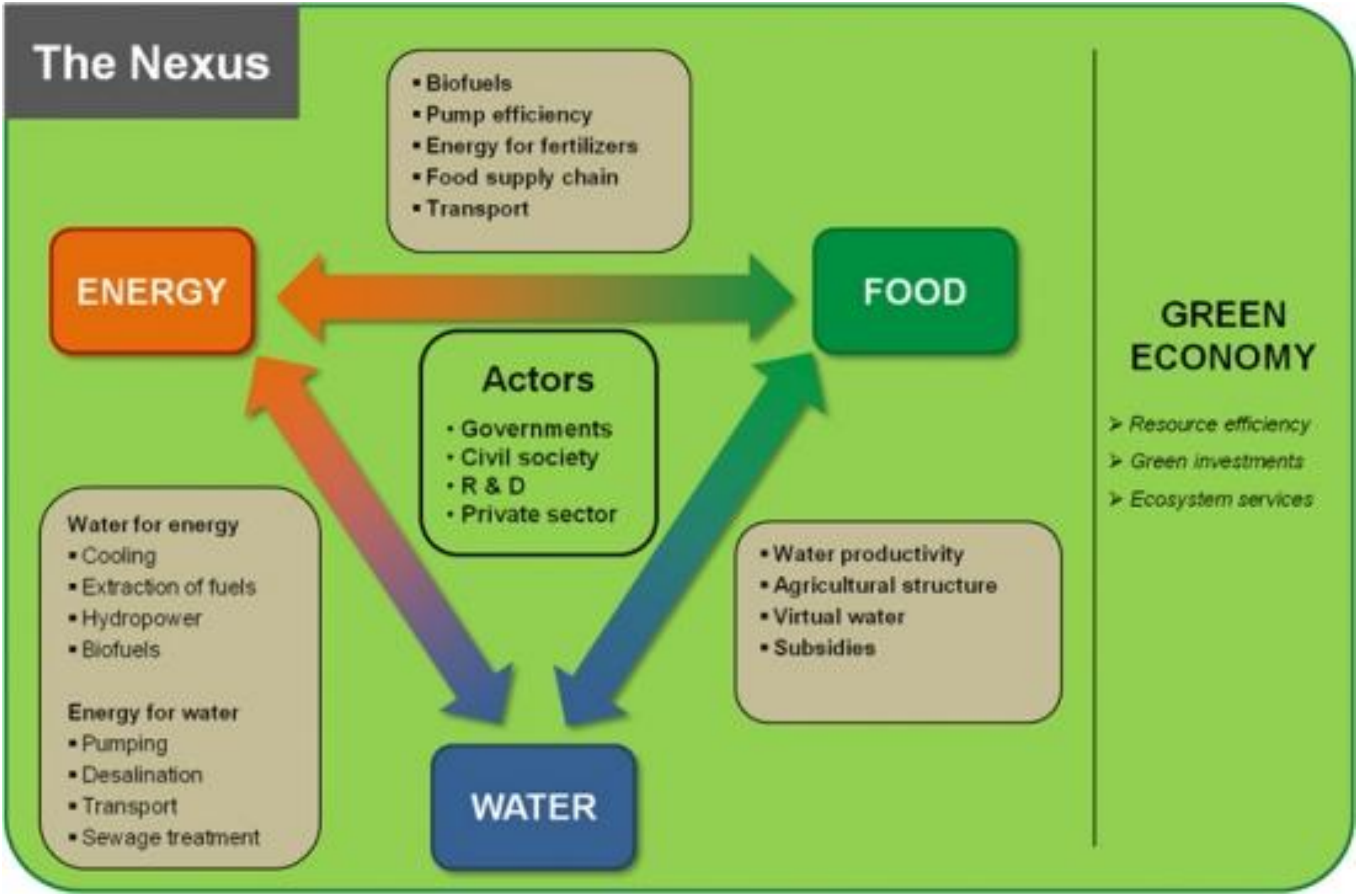
Imagine a canal 10 m deep, 100 m wide and 7.1 million km long (enough to go around the world 180 times). That is the amount of water it takes each year to produce food for today's 7 billion people….

Add 2-3 billion more people and accommodate their *changing diets* from cereals to more meat and vegetables and that could add another 5 million km to the channel of water needed to feed the world's people."

Outline

1. Water, food and energy issues
   - Facts and figures
   - Water and food issues
   - Water and energy issues
   - Energy and food issues
   - Exacerbation by climate change
2. Case studies
   - Climate change and rice production
   - Water-energy nexus: Bangkok water supply system
3. Final reflections

Water, food & energy are closely linked



Source: Bonn 2011 Secretariat

- Water security **underpins** and **connects** food, fiber, fuel, urbanization, migration, climate change, and economic growth challenges

Source: World Economic Forum 2011

"One of the many things I learned as president was the **centrality of water** in the social, political and economic affairs of the country, the continent and the world."
– Nelson Mandela, at the World Summit in Sustainable Development, 2002

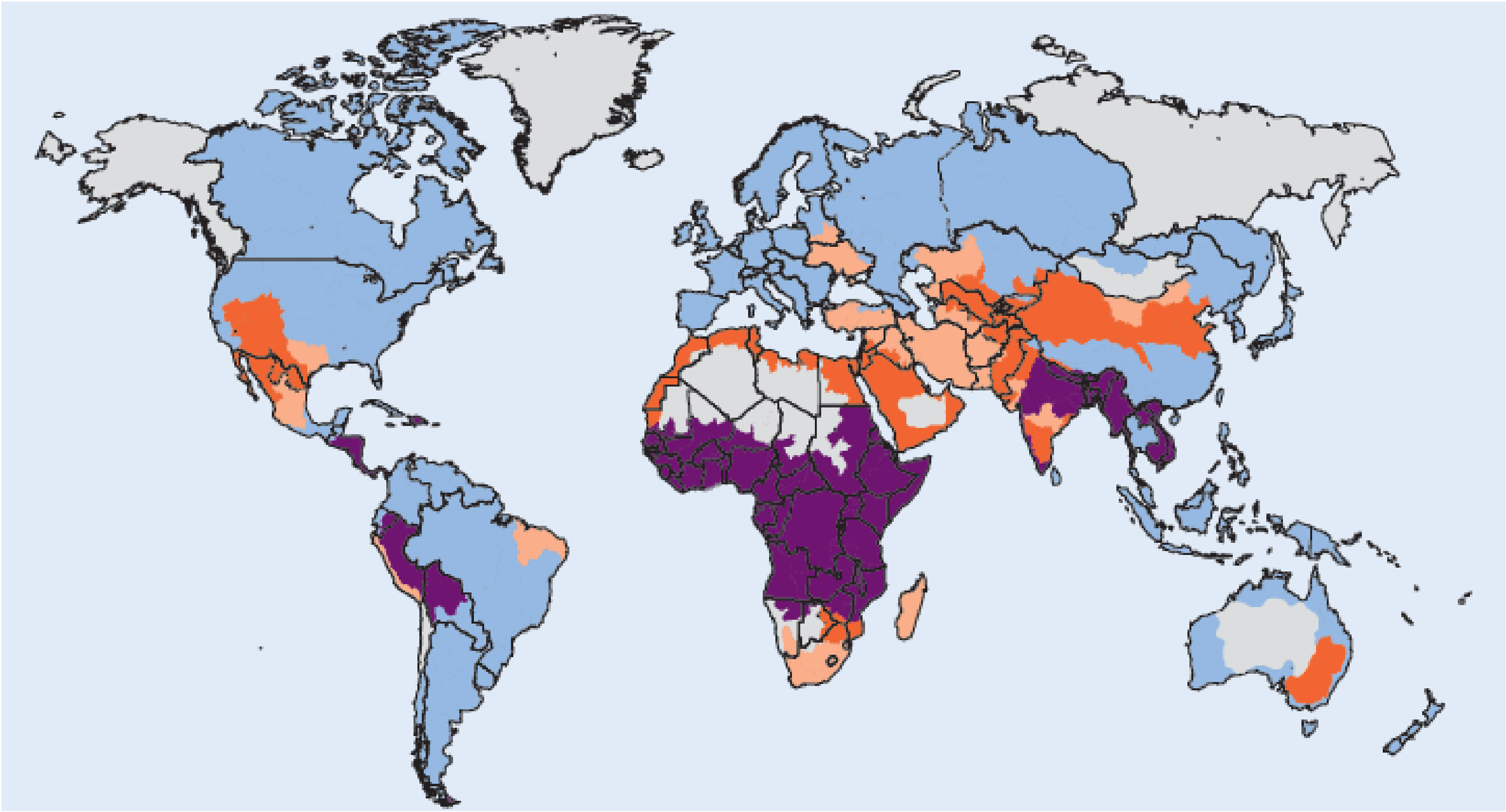
"There are **strong water connections** to **energy**, **climate** and **food security** policy issues… negative or positive… Policy decisions made on energy, climate and food policies have **determinate impacts** on water, and the reverse is also true."

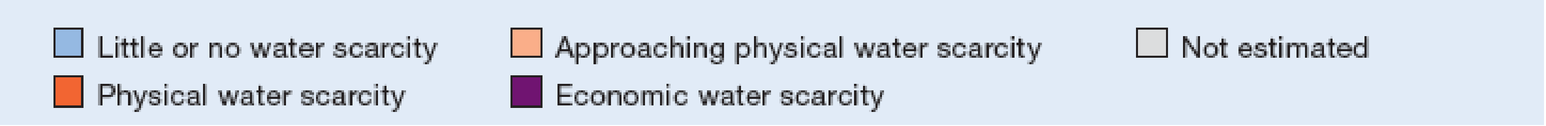
- World Economic Forum Global Agenda Council on Water Security, Dubai Statement 2008

IWRM highlights the interdependence of natural, economic, and social systems and provides a practical framework for such integration... – Global Water Partnership

1.1 Facts and figures

Physical and economic water scarcity





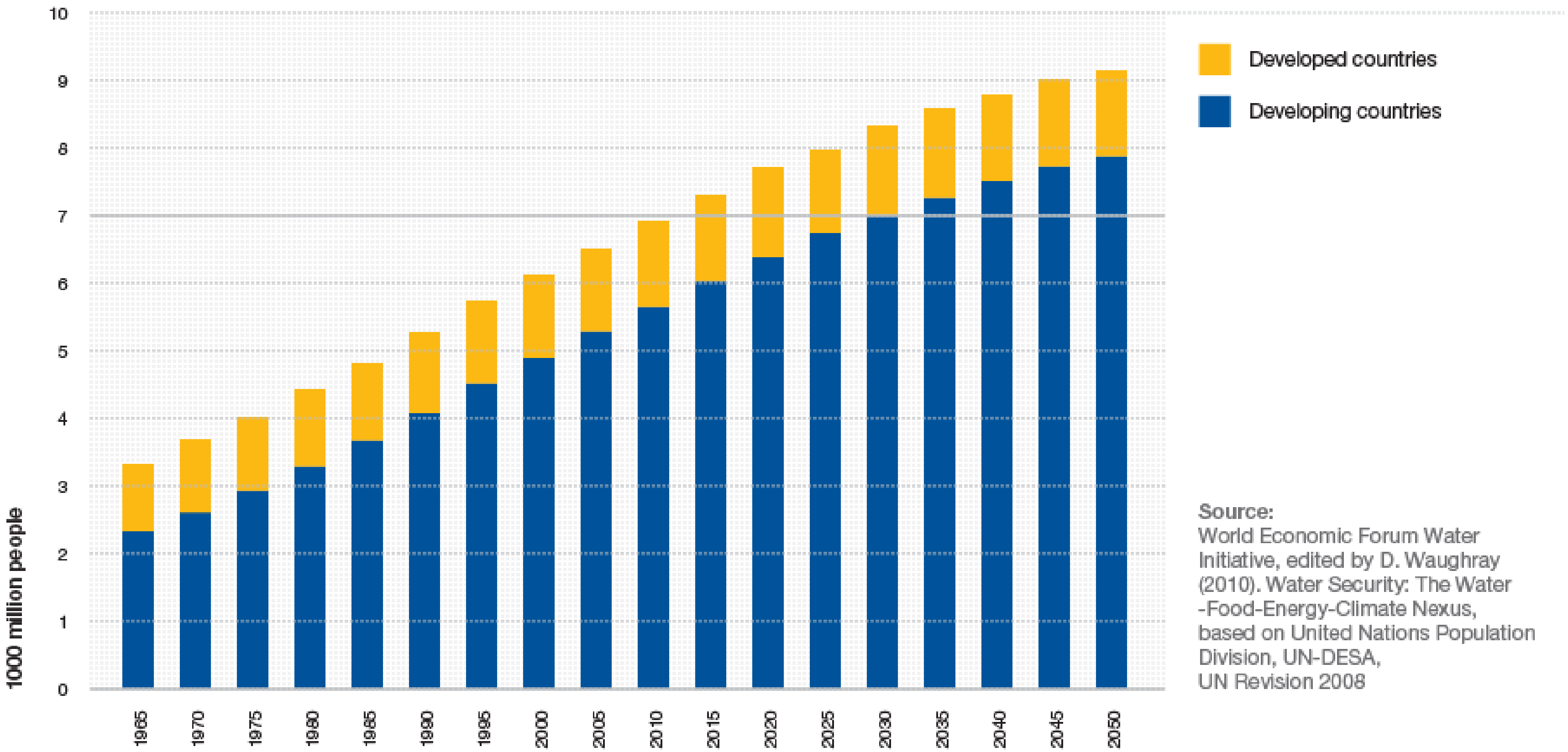
Source: IWMI 2007

Population growth

Between 1900 and 2000, the **population grew by a factor of four**, but **freshwater withdrawal grew by a factor of nine**

… if current trends continue, by 2030 two-thirds of the world's population will live in areas of high water stress

World Population 1960-2050



Source:
World Economic Forum Water Initiative, edited by D. Waughray (2010). Water Security: The Water -Food-Energy-Climate Nexus, based on United Nations Population Division, UN-DESA, UN Revision 2008

Economic growth

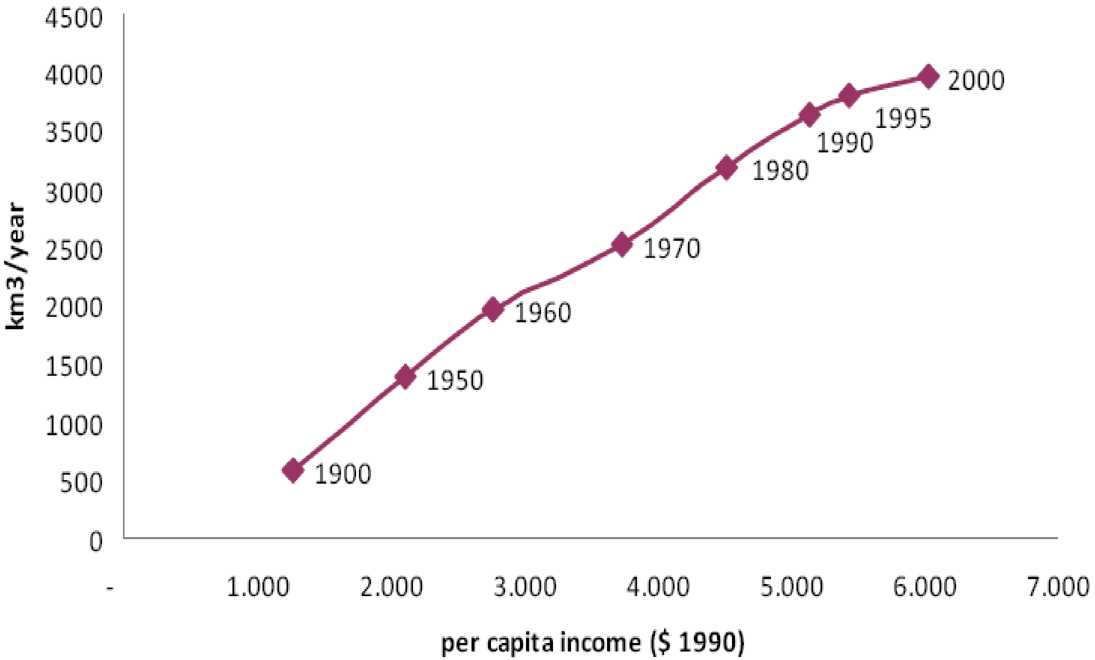
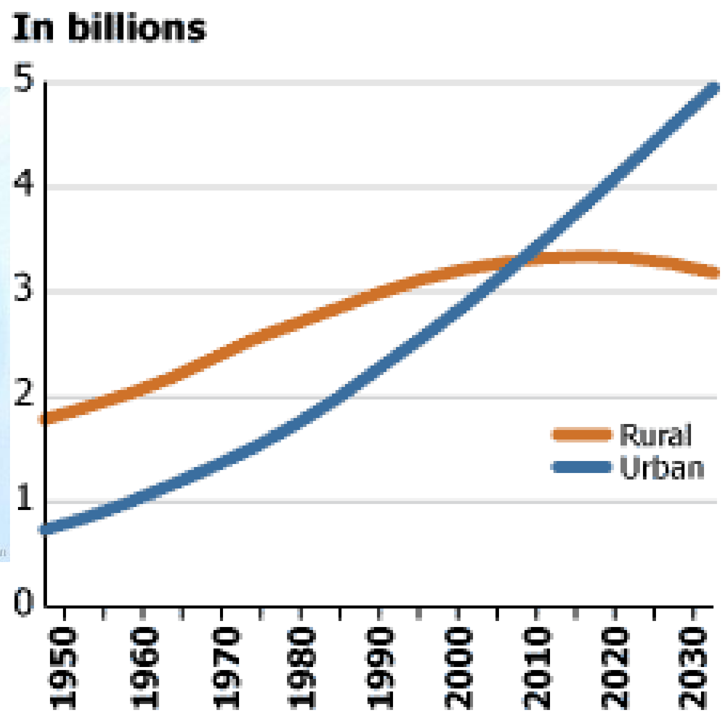
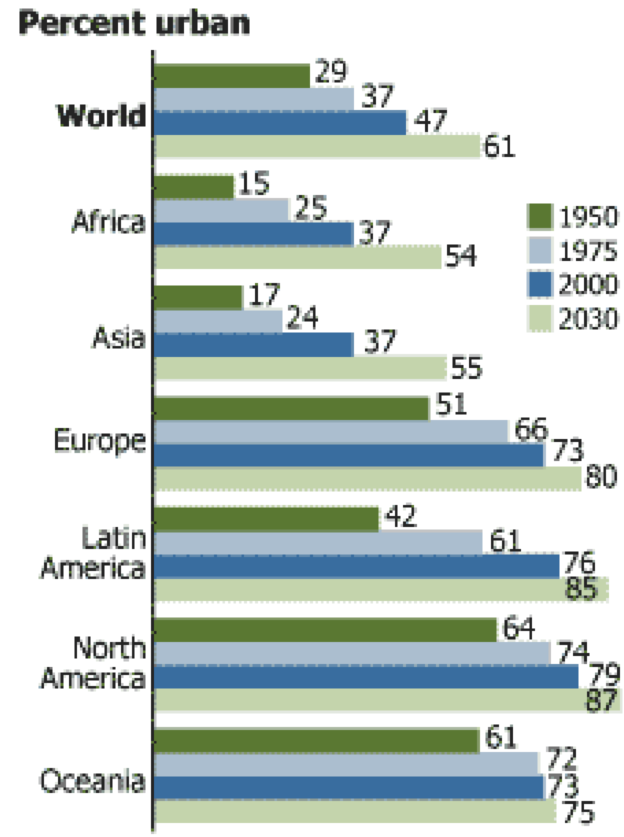


Figure 1: Worldwide water withdrawal, 1900-2000

Urbanization

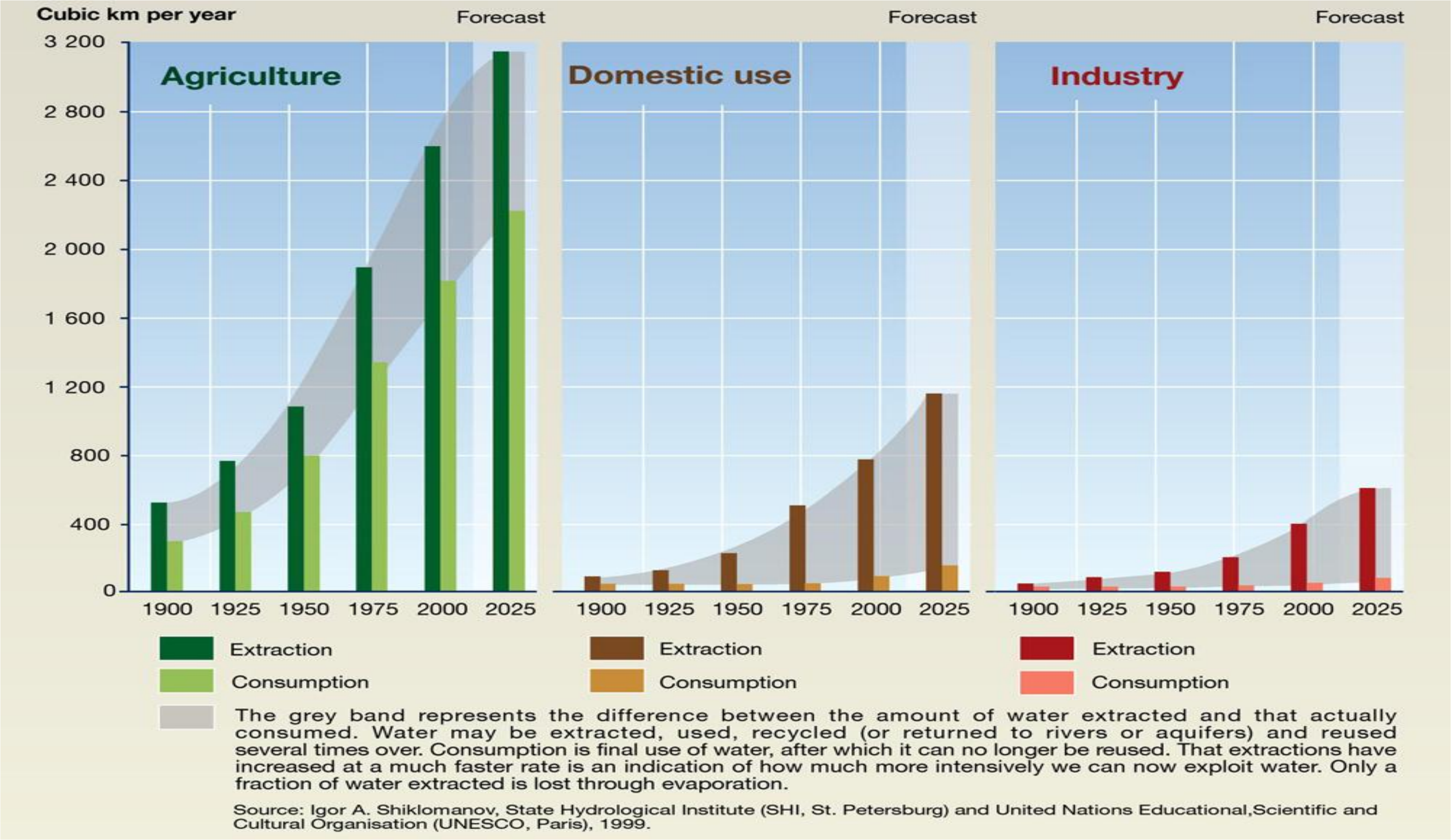
- More than half of the world's population now lives in an urban environment
- 17 out of 24 megacities with > 10 million people are in developing countries



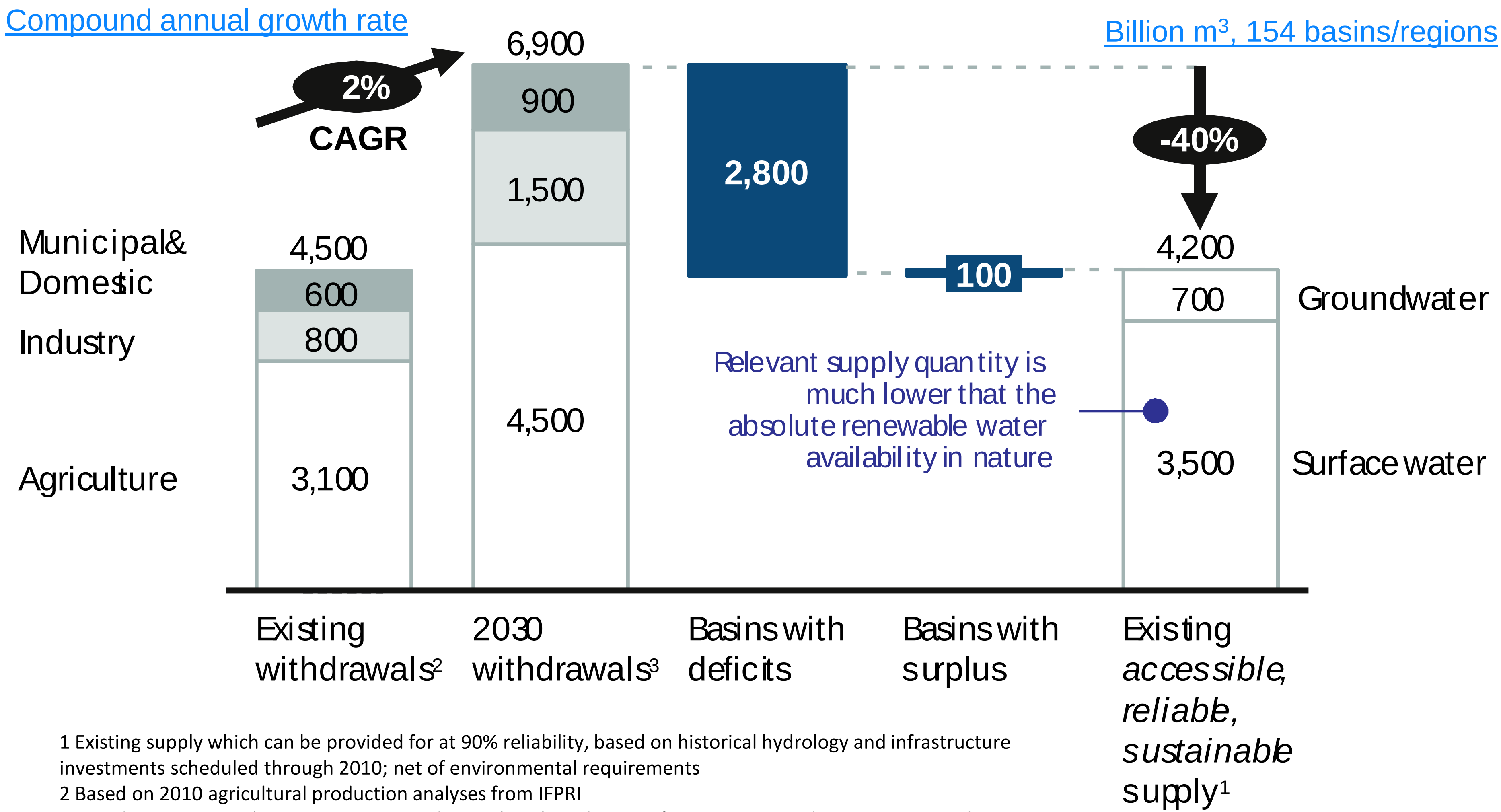


Source: World Economic Forum 2011

Trends in global water demand



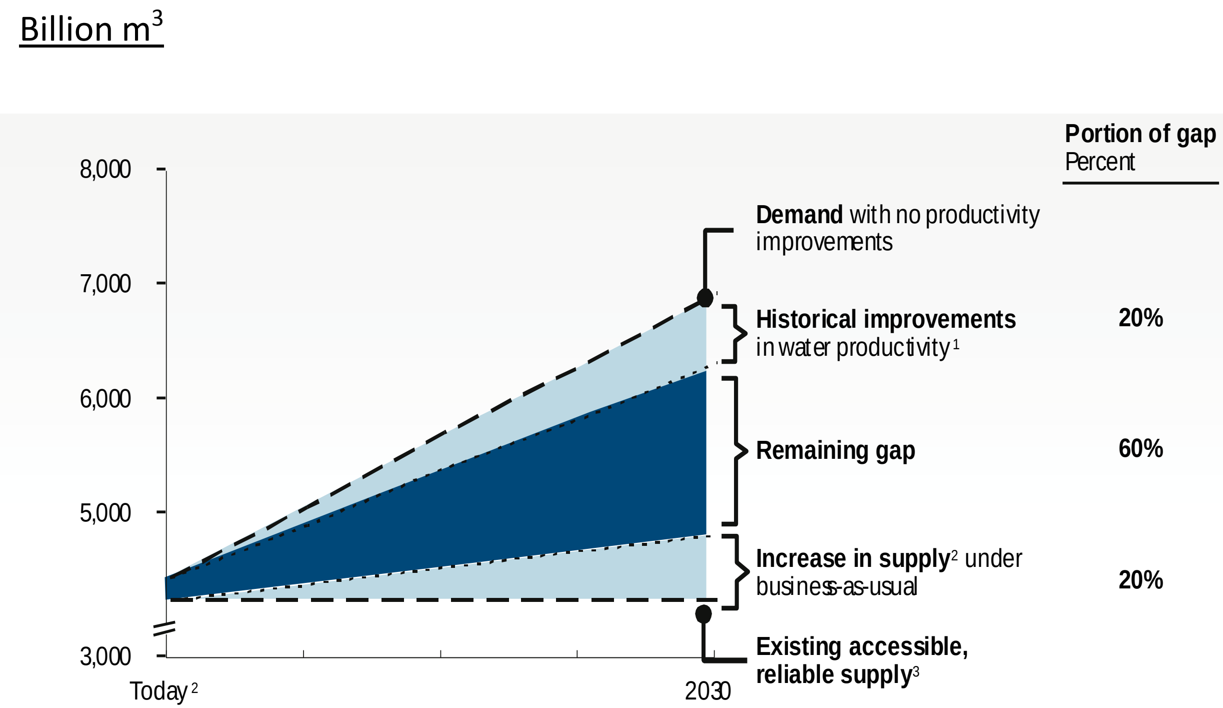
Aggregated global gap between existing accessible, reliable supply[1] and 2030 water withdrawals, assuming no efficiency gains



1 Existing supply which can be provided for at 90% reliability, based on historical hydrology and infrastructure investments scheduled through 2010; net of environmental requirements
2 Based on 2010 agricultural production analyses from IFPRI
3 Based on GDP, population projections and agricultural productions from IFPRI; considers no water productivity gaiins between 2005-2030

SOURCE: Water 2030 Global Water Supply and Demand model; agricultural production based on IFPRI IMPACT-WATER base case

Business-as-usual approaches will not meet demand for raw water

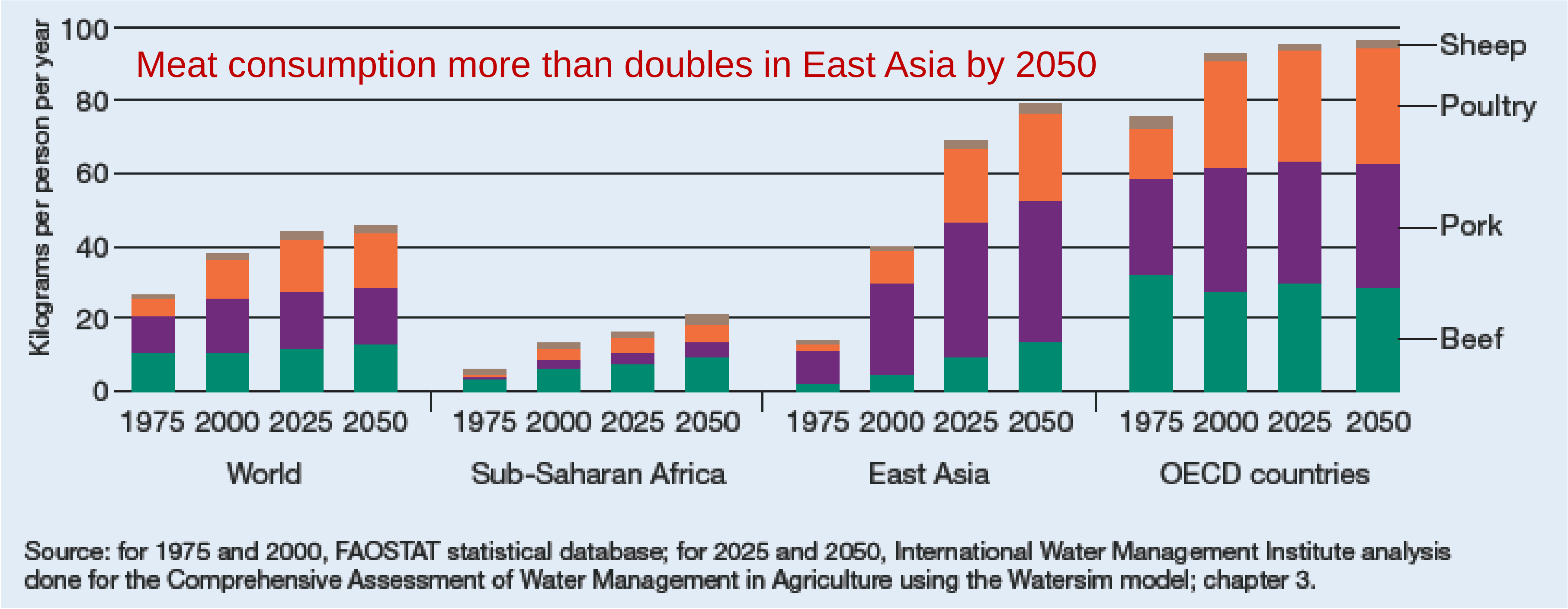


- If these trends are insufficient to close the gap:
  - Depletion of fossil reserves
  - Water for environment is drained
  - Demand will go unmet

Climate Change will exacerbate the problem

SOURCE: 2030 Water Resources Group - Global Supply and Demand model; IFPRI; FAOSTAT

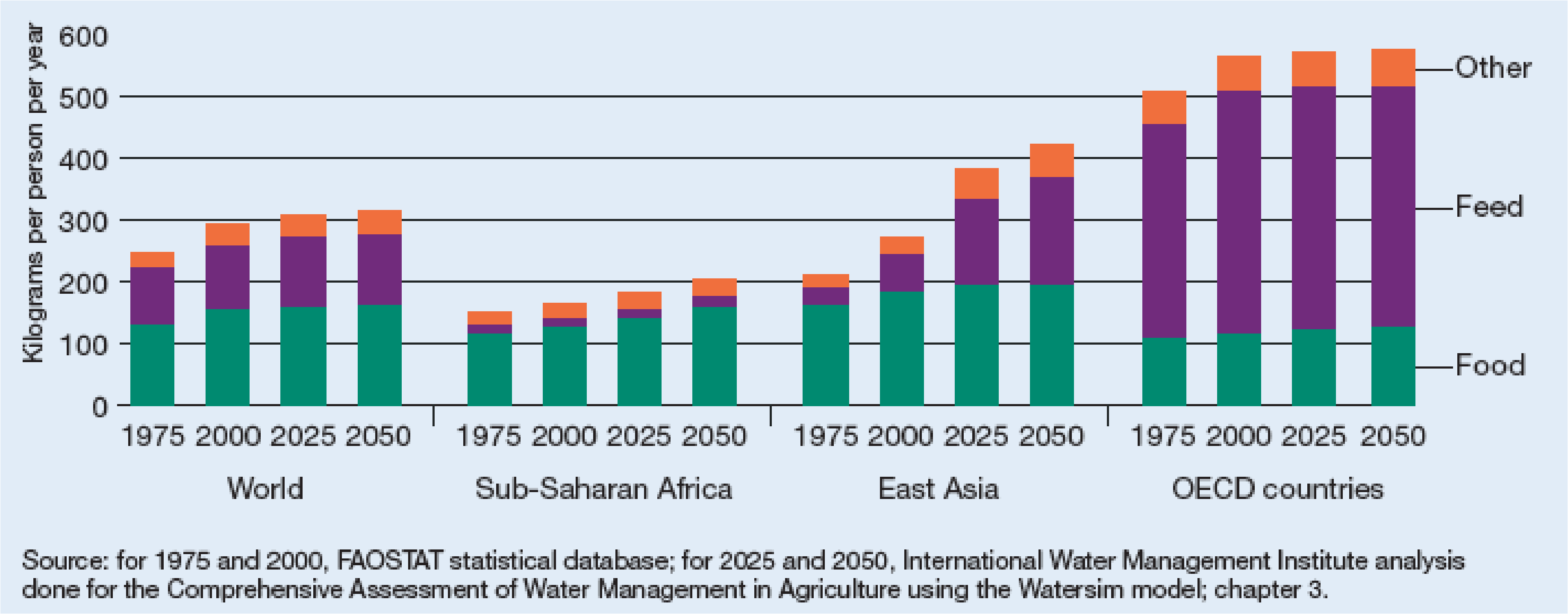
Increased food demand and **changing diets**: driven by rising incomes and other shifts, changing diets will increase demand for resource-intensive products such as meat



Global demand for meat will double from 229 million tonnes in 1999-2001 to 465 million tonnes in 2050.

Source: IWMI 2007

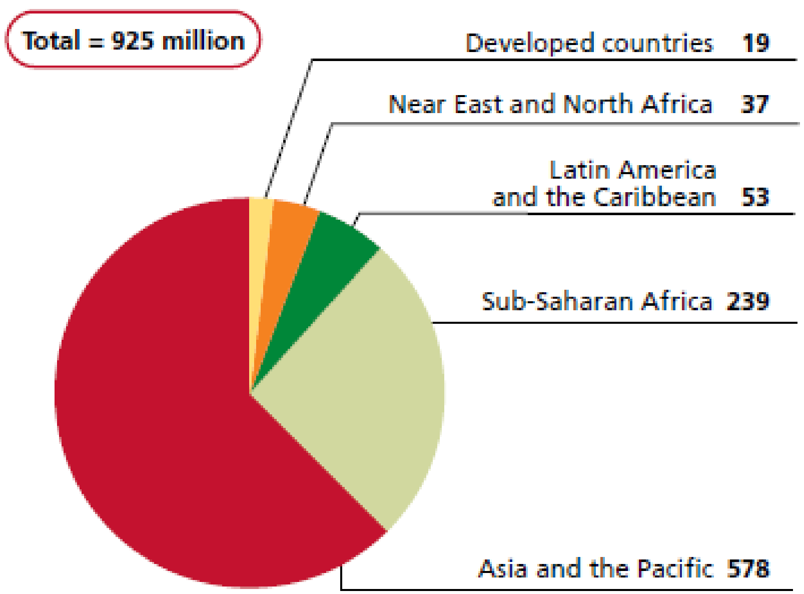
Expected trends



Feed demand drives future demand for grains

Source: IWMI 2007

Undernourishment in 2010, by region (millions)



Note: All figures are rounded. Source: FAO.

Nutrition is affected not only by food availability and access but also by disease, sanitation – including access to safe drinking water – and availability of preventive health services.

Among the poorest today, **over one billion people** − one-sixth of the world's population − do not have access to adequate food and nutrition

Undernourishment in Thailand

	1990-92	1995-97	2000-02	2005-07
Number of people undernourished (millions)	15.0	11.2	11.5	10.8
Proportion of undernourished in total population	26	18	18	16

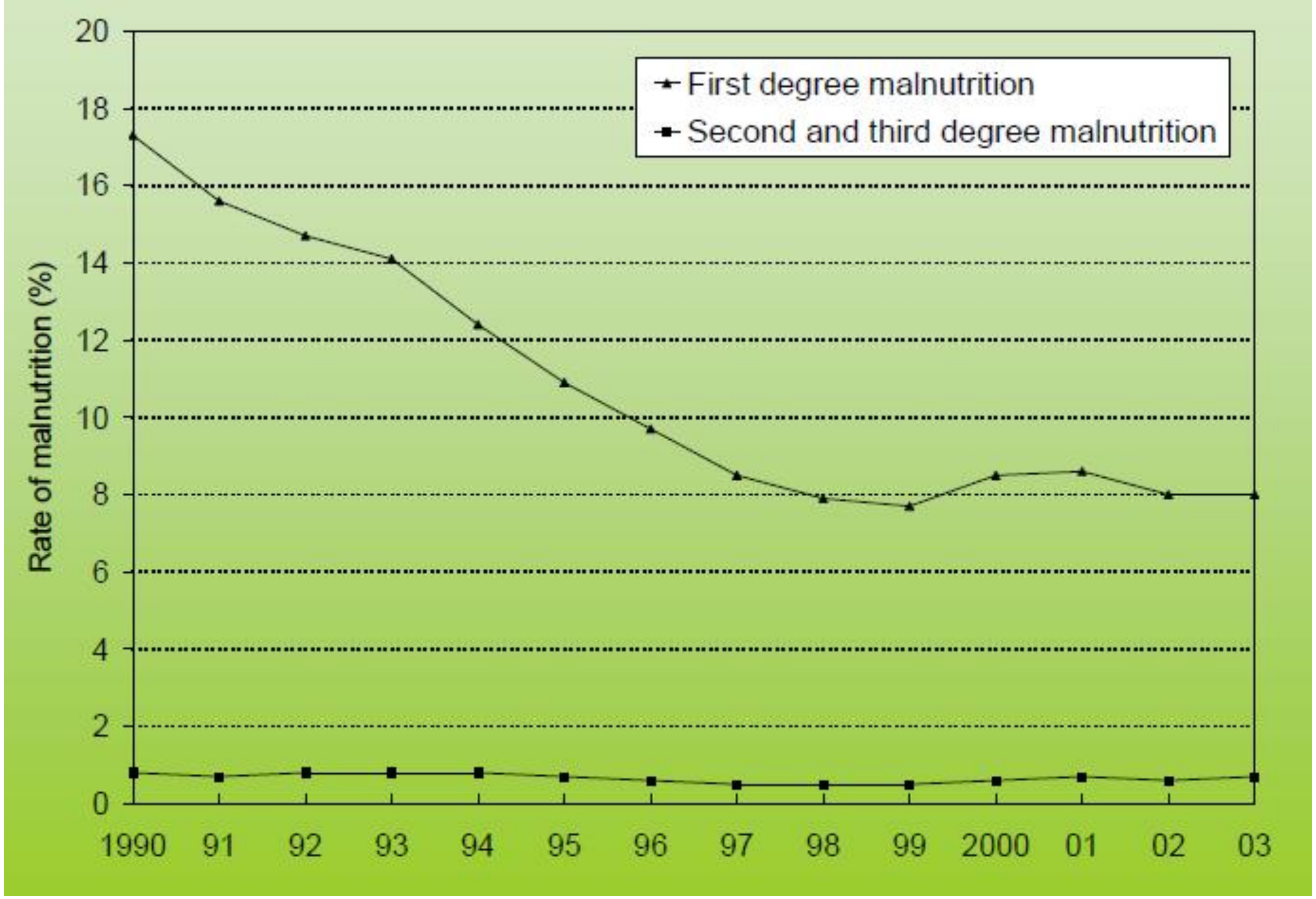
Total population: 2005-07: 66.5 million
Source: FAO, 2010

Despite the fact that Thailand is the TOP RICE EXPORTER* and one of the WORLD'S LARGEST EXPORTER of other food products!**

*Thailand exported an estimated 9.03 million tons of rice in 2010
**Canned pineapple, pineapple juice and concentrates, frozen shrimp

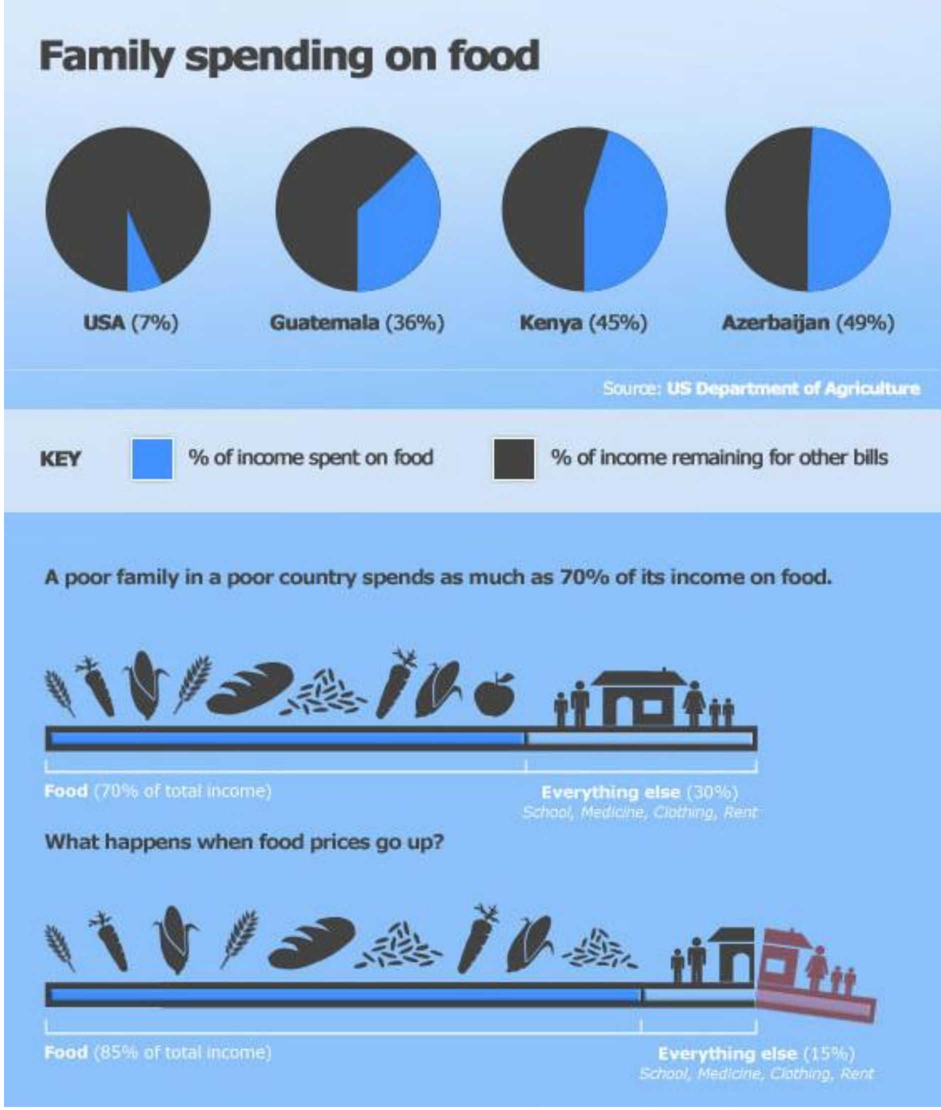
Thailand is also one of the world's leading producers of sugarcane, cassava, longan, durian, mangosteen and longkong

Malnourishment in Thailand



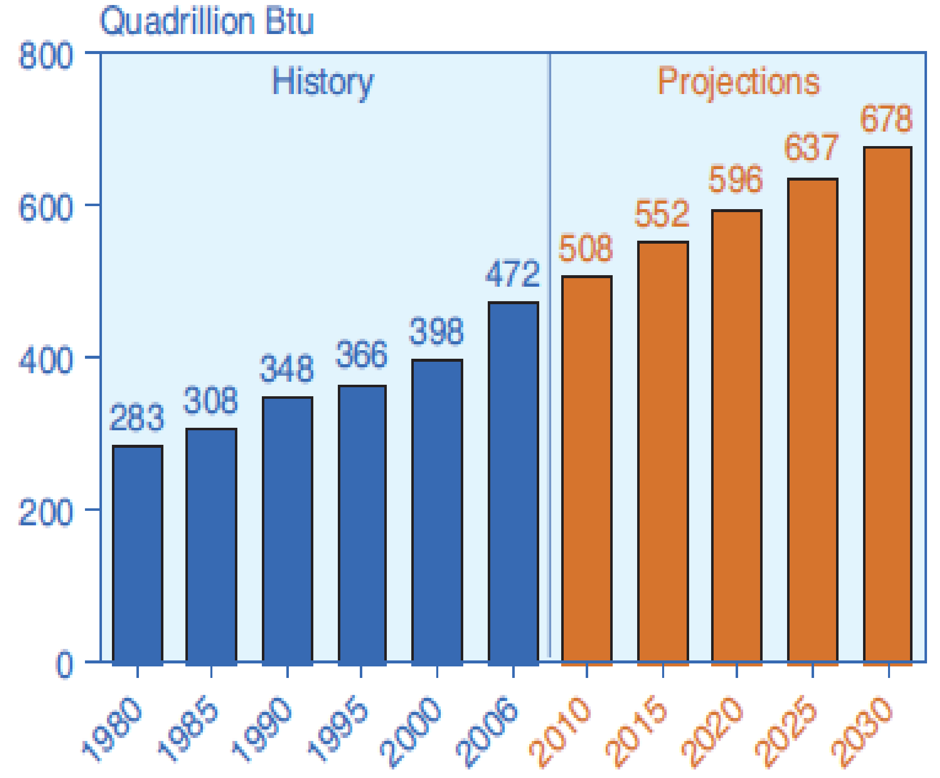
Source: Thailand Environment Institute

Rising food prices



Demand for more energy will drive demand for more water

- World energy demand to increase by 44% from 2006 to 2030
- The largest projected increase for the non-OECD economies
- 1.5 billion people in the developing world **lack access to electricity**
- More than 3 billion people rely on biomass for heating and cooking



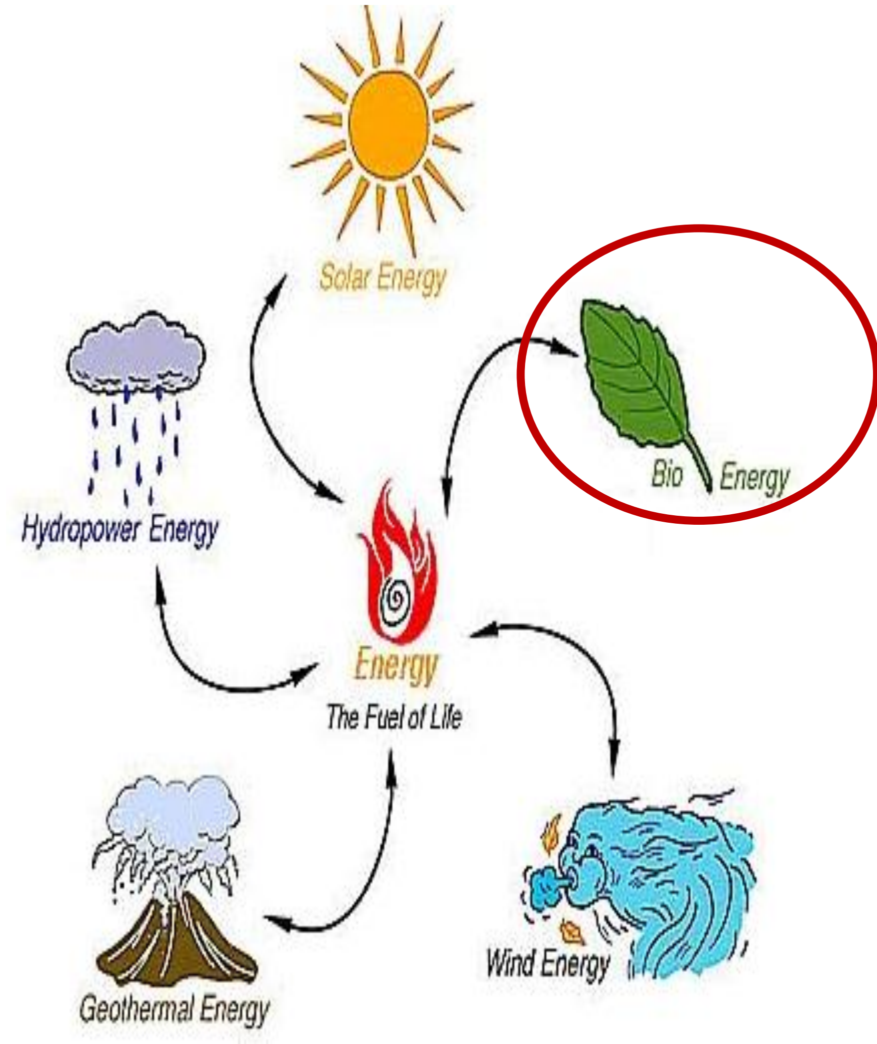
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

1 Btu (British Thermal Unit) = 1 055 Joules

OECD= Organization for Economic Co-operation and Development

Bio-fuel: attractive and alternative source of energy

- Bio-fuel as an opportunity
  - cut the fossil fuels consumption,
  - decrease oil import,
  - reduce the greenhouse gas emission and
  - reduce poverty of rural communities



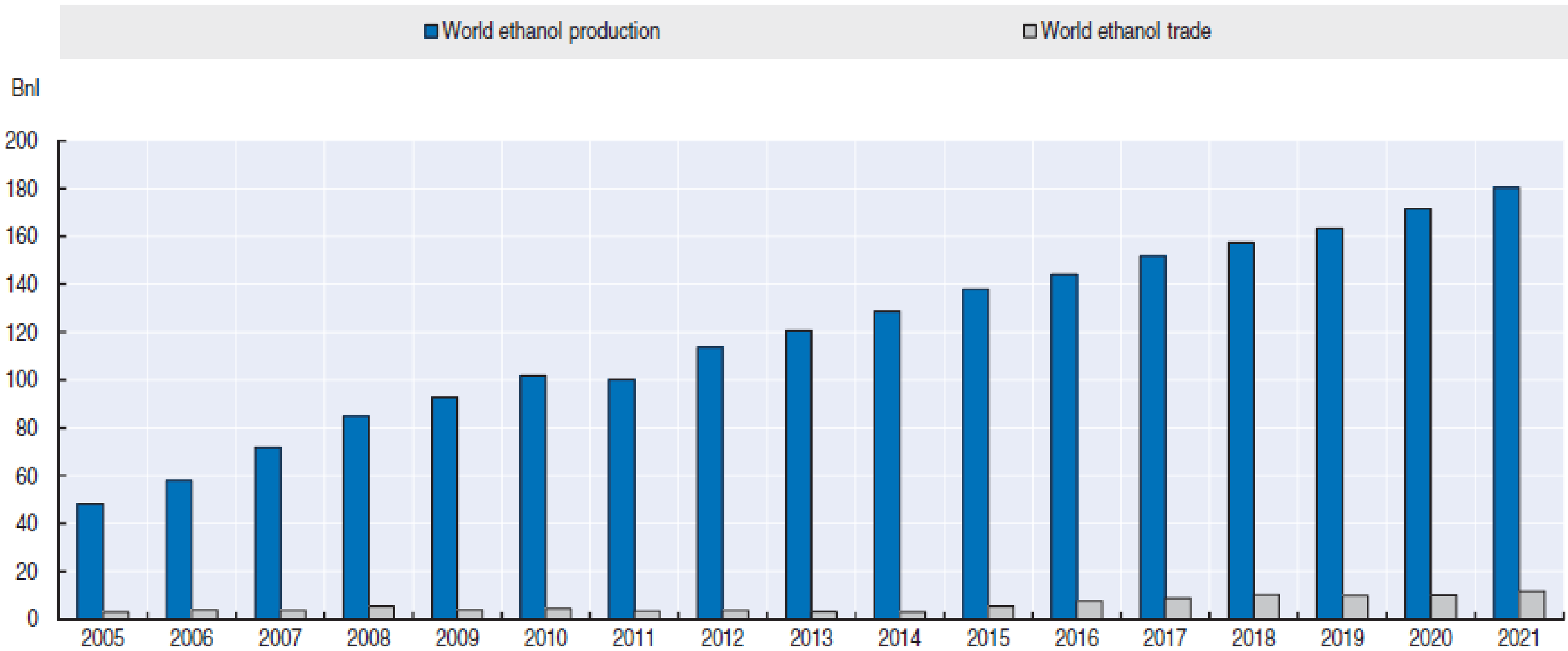
Bio-ethanol production statistics

Country	Bio-ethanol production (million litres)		Energy share in gasoline type fuel use (%)	
	2009-11 average[a]	2021	2009-2011 average[a]	2021
United States	47,617	82,610	5.4	10.9
Brazil	25,331	51,305	47.1	64.3
China	8,094	10,058	1.8	1.3
EU27	6,424	15,747	2.7	8.3
India	1,976	4,194		
Canada	1,565	1,992	2.6	3.4
Thailand	777	2,102		
Japan	102	104		
Rest of the world	6,333	12,290		
Total	98,219	180,402	5.9	10.8

Source: OECD/FAO (2012); [a] estimated value

Bio-ethanol production statistics

Figure 3.2. **Development of the world ethanol market**



Source: OECD/FAO (2012); Bnl means Billion Liters

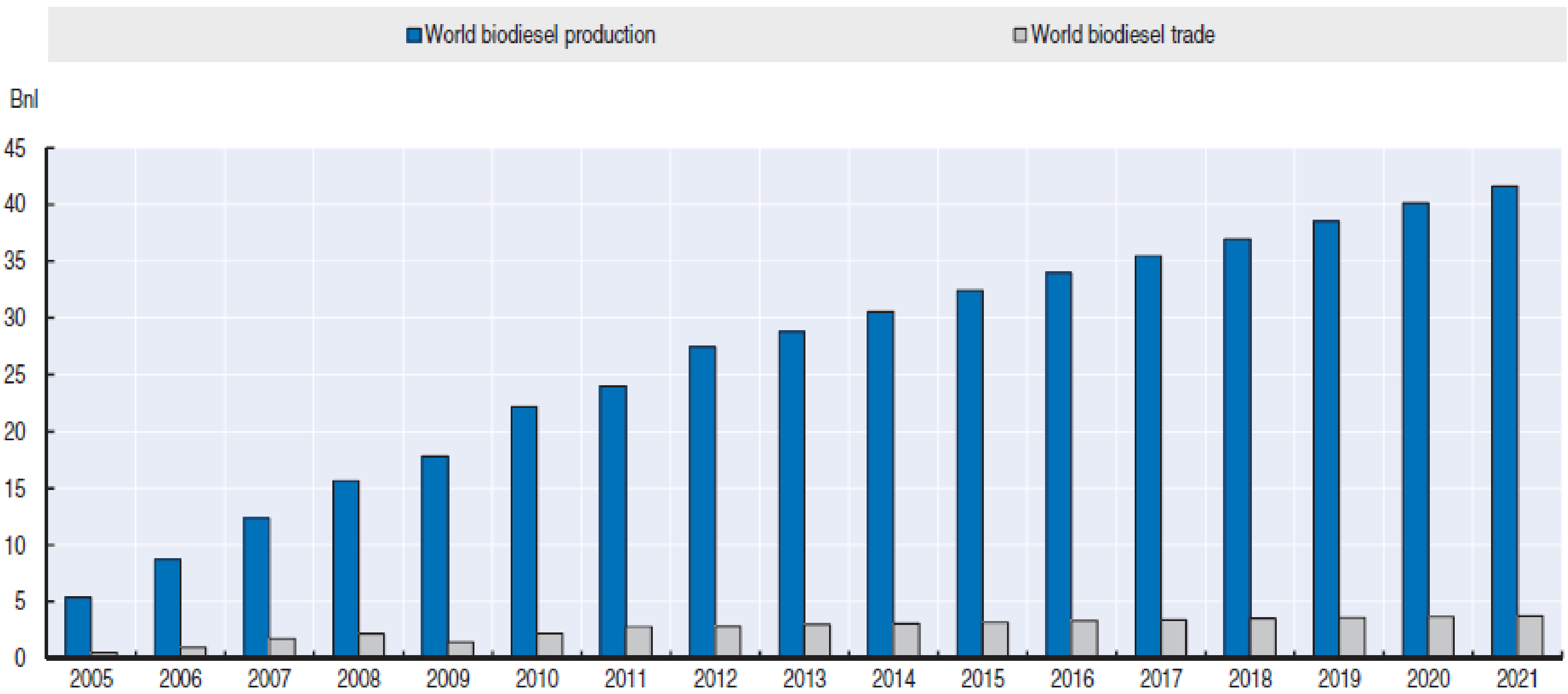
Main producers: USA, Brazil, EU & in developing countries: China and India

Bio-diesel production statistics

Country	Biodiesel production (million litres)		Energy share in diesel type fuel use (%)	
	2009-11 average[a]	2021	2009-11 average[a]	2021
EU27	10,436	19,864	5.1	8.5
United States	2,834	5,083	0.9	1.5
Australia	641	727	3.1	3.1
Argentina	2,231	4,204	3.2	4
Brazil	2,015	3,205	4	4.6
Thailand	664	1,339		
Malaysia	563	956		
India	330	1,297		
Columbia	431	917		
Canada	147	552	0.7	1.6
Rest of the world	1,030	3,451		
Total	21,322	41,595	2.5	3.8

Source: OECD/FAO (2012); [a] estimated value

Figure 3.3. **Development of the world biodiesel market**



Source: OECD and FAO Secretariats

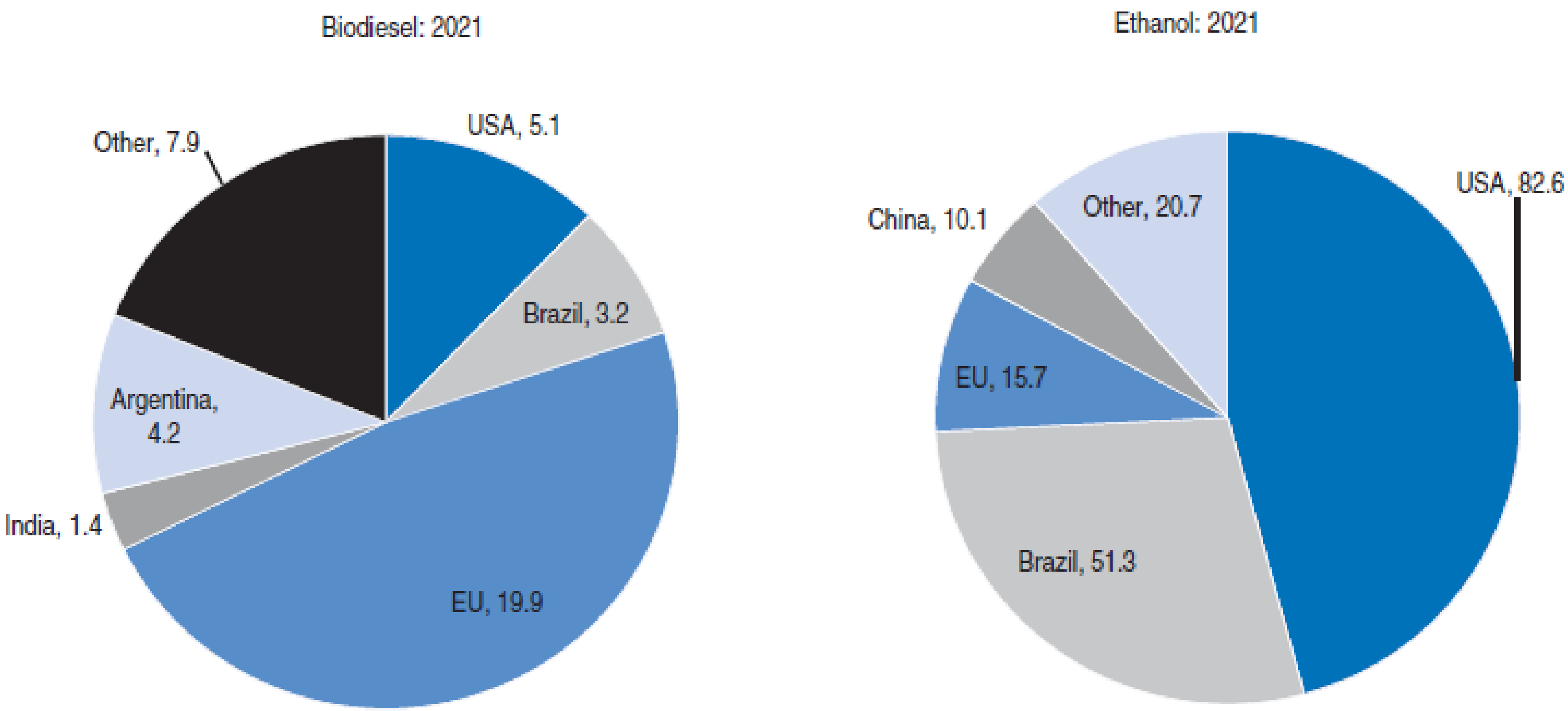
Source: OECD/FAO (2012); Bnl means Billion Liters

Main producer: EU & other players: Argentina, USA, Brazil, Thailand and Indonesia

Bio-fuel production by 2012

Figure 1.9. **Larger country shares of biofuels production by 2021**

Biodiesel and ethanol production in 2021, main countries, billion litres

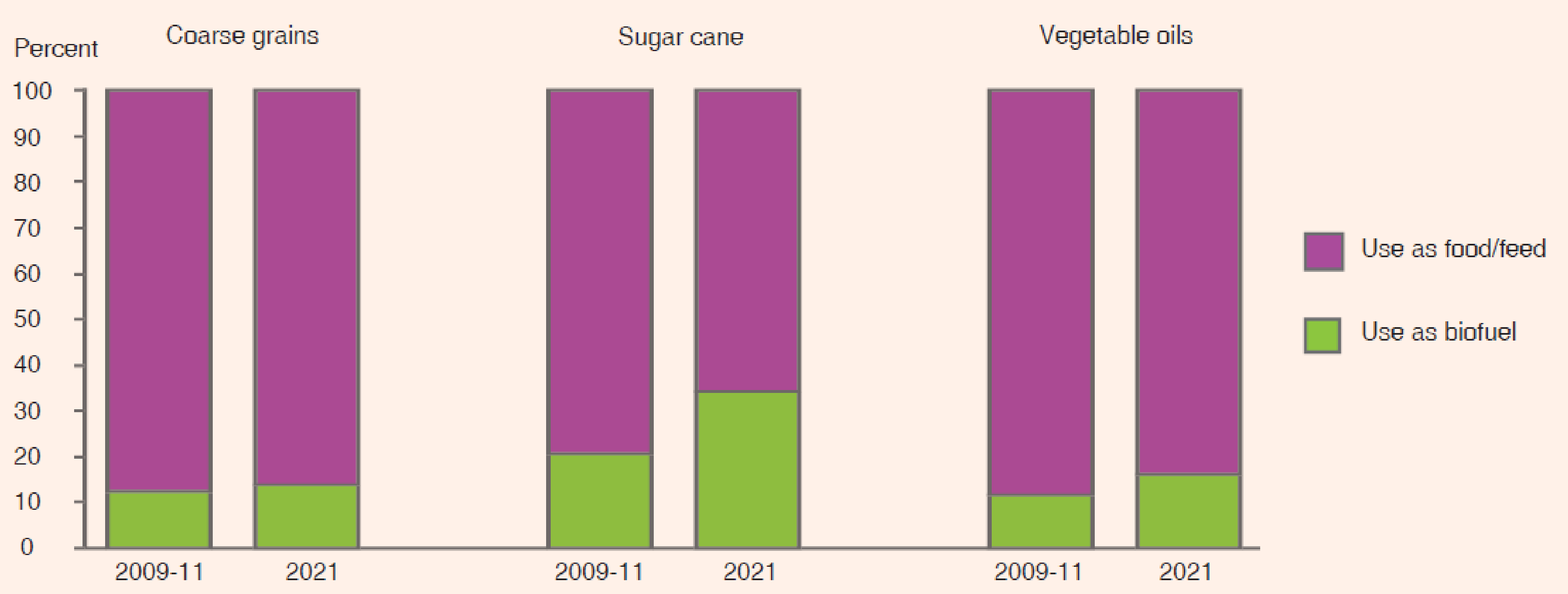


Source: OECD/FAO (2012)

Ethanol: Apart from USA, Brazil & EU, China, India and Thailand are expected to contribute to world production by 2-3% each by 2021

Food/feed and bio-diesel use

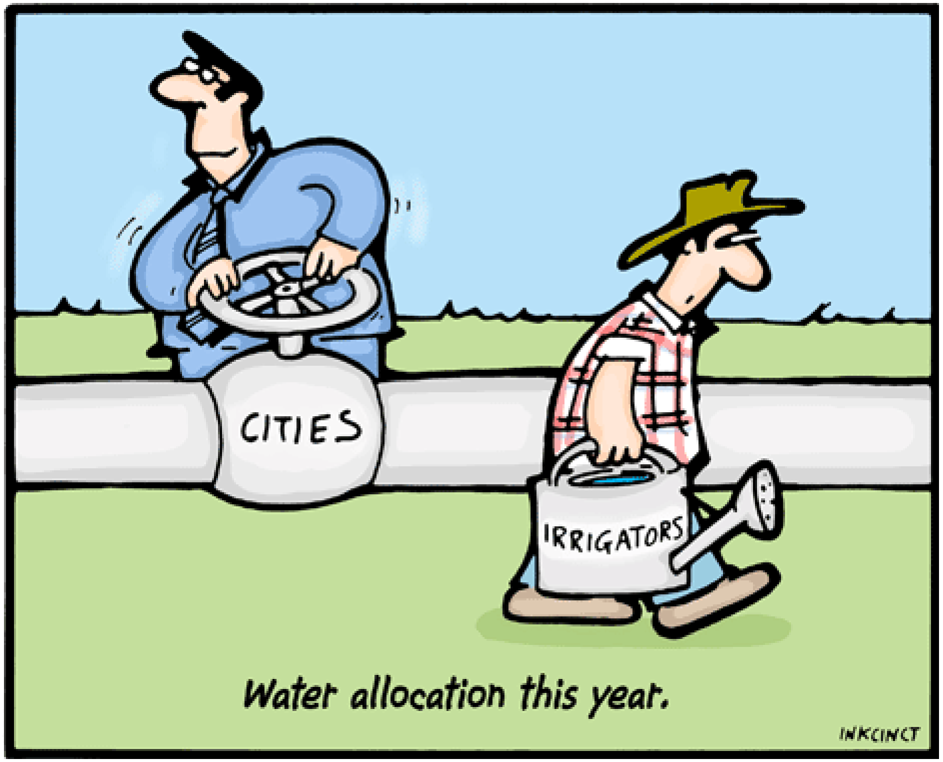
Figure 4. Share of global food/feed and biofuel use

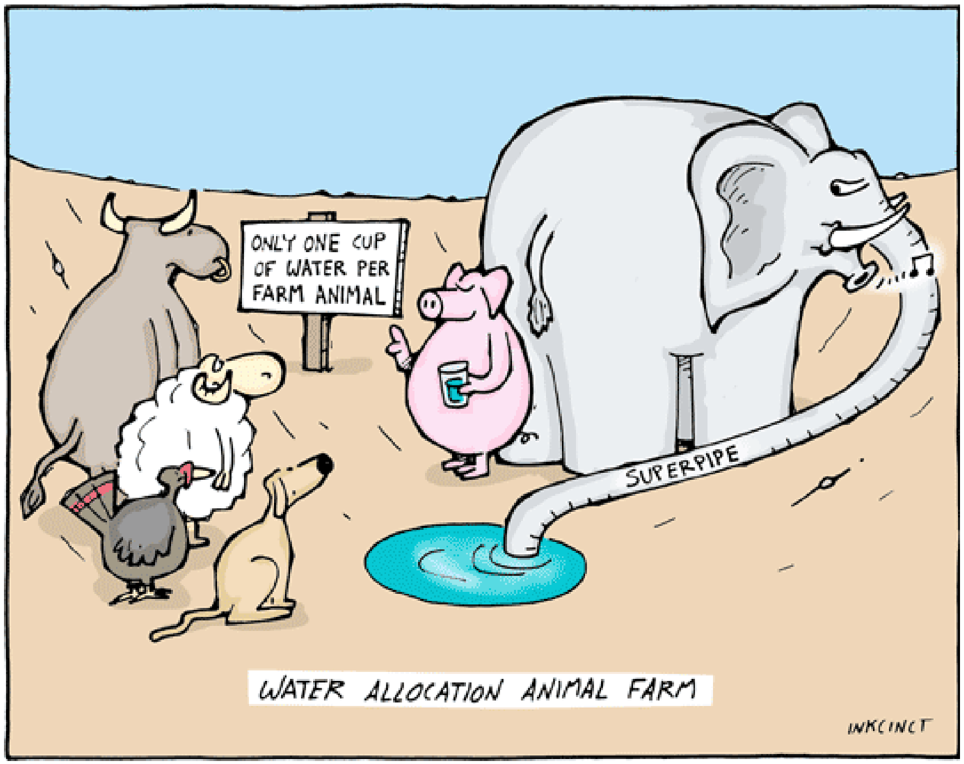


Source: OECD/FAO (2012)

- **Agricultural production needs to increase by 60% by 2050 to meet the rising demand for food which means an additional 1 Billion Tons of cereals and 200 Metric Tons of meat a year**
- **Expanding biofuel sector absorbs larger share of crop production**

A growing population is a **major factor** behind today's water scarcity; but the **main reasons** for water problems are lack of commitment and targeted investment, insufficient human capacity, ineffective institutions, and poor governance

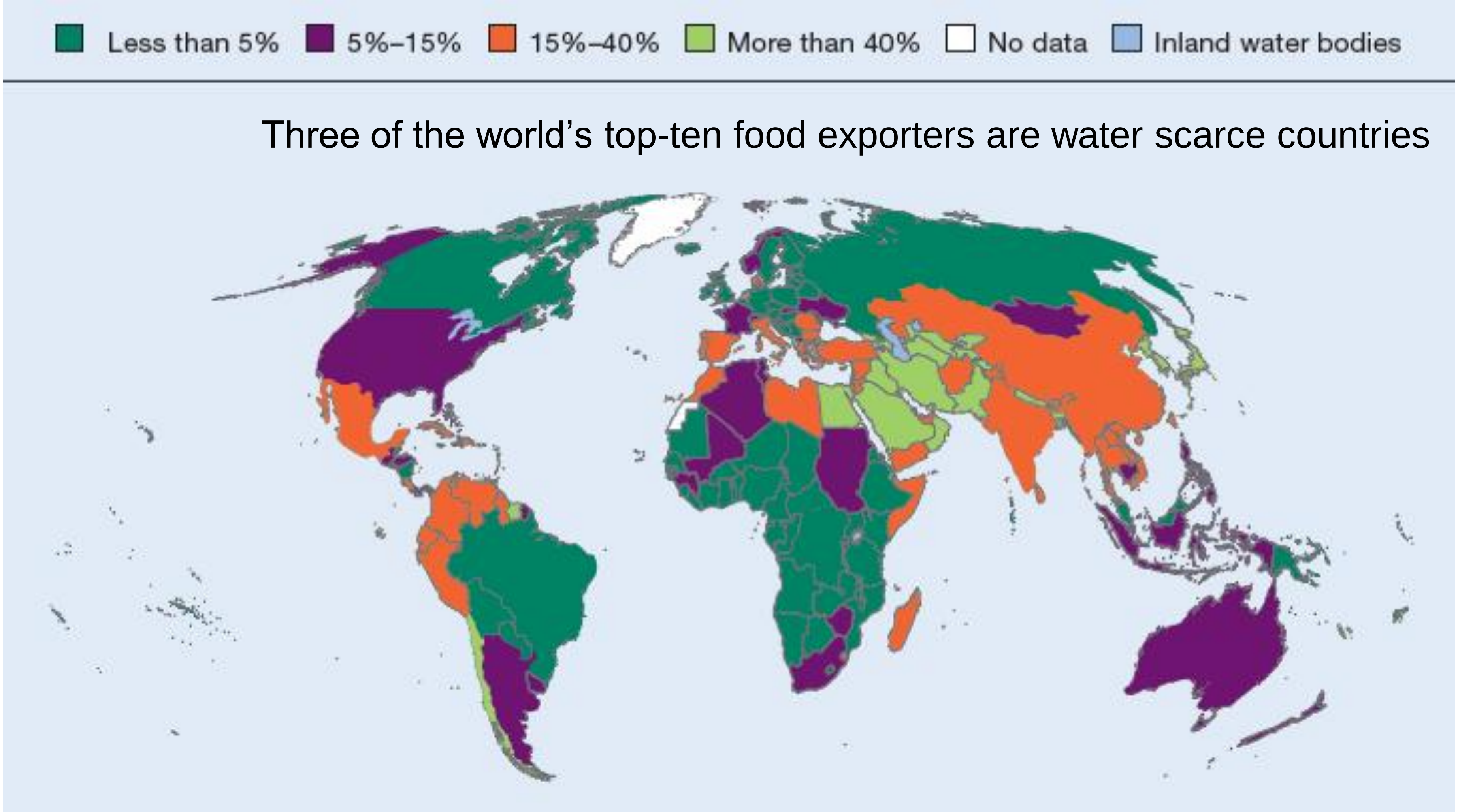




The challenge for global agriculture is to **grow more food** with **declining allocations of land and water**

1.2 Water and food issues

Area under irrigation as a share of cultivated land

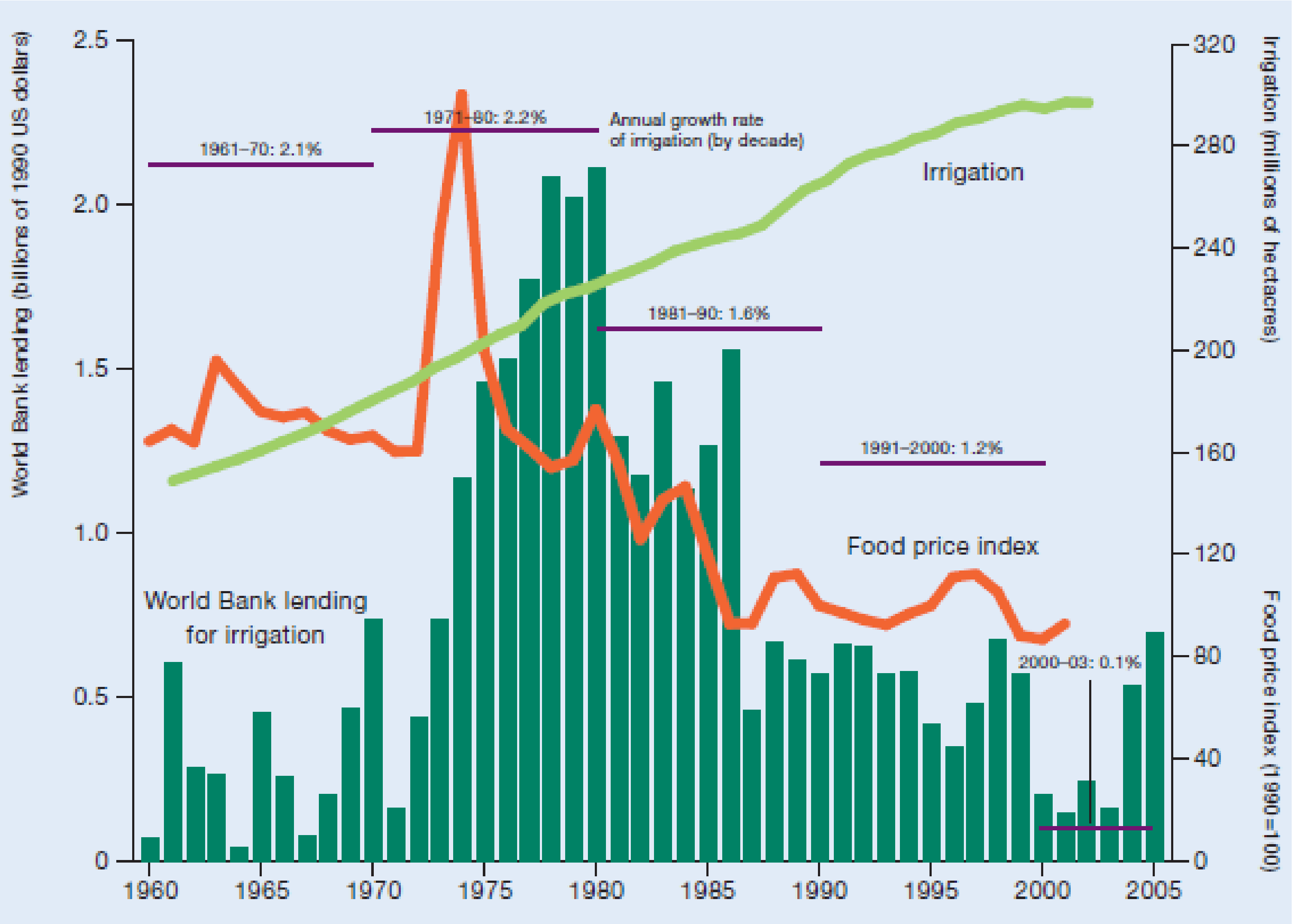


Three of the world's top-ten food exporters are water scarce countries

Three of the top-ten food importers are water rich

Source: IWMI 2007

Irrigation and food prices



Food price index

http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/

Virtual water content of selected products

Plant-based product	Water requirement	Animal-based product	Water requirement
Wheat	1,150	Beef	15,977
Rice	2,656	Pork	5,906
Maize	450	Poultry	2,828
Potato	160	Eggs	4,657
Soybean	2,300	Milk	865

Figures in global averages, liter of water per kg of product, Hoekstra 2003

Takes **1 liter** of water to grow **one calorie**

Meat, on average, requires about 10 times the water required per calorie from plants

On average human beings need to drink between 2 and 4 liters of fluids a day but consume 2,000 to 5,000 through the water used in producing their food

- Challenges
  - The growing population to be supplied with **sufficient food and water** as a basic need to alleviate poverty and improve livelihood of the poor. *(increasing crop per drop)*
  - Irrigated agriculture received large financial investments and subsidies not likely to be repeated in forthcoming decades. *(new irrigation financial model)*
  - Water diversion to **irrigated agriculture** will be under increasing stress and face competition with demanded shares claimed by other powerful water users. *(increasing water productivity)*
  - The necessity to **reserve water** to sustain the environment is recognized and will a priority factor for basin water management. *(integrated water resources management)*

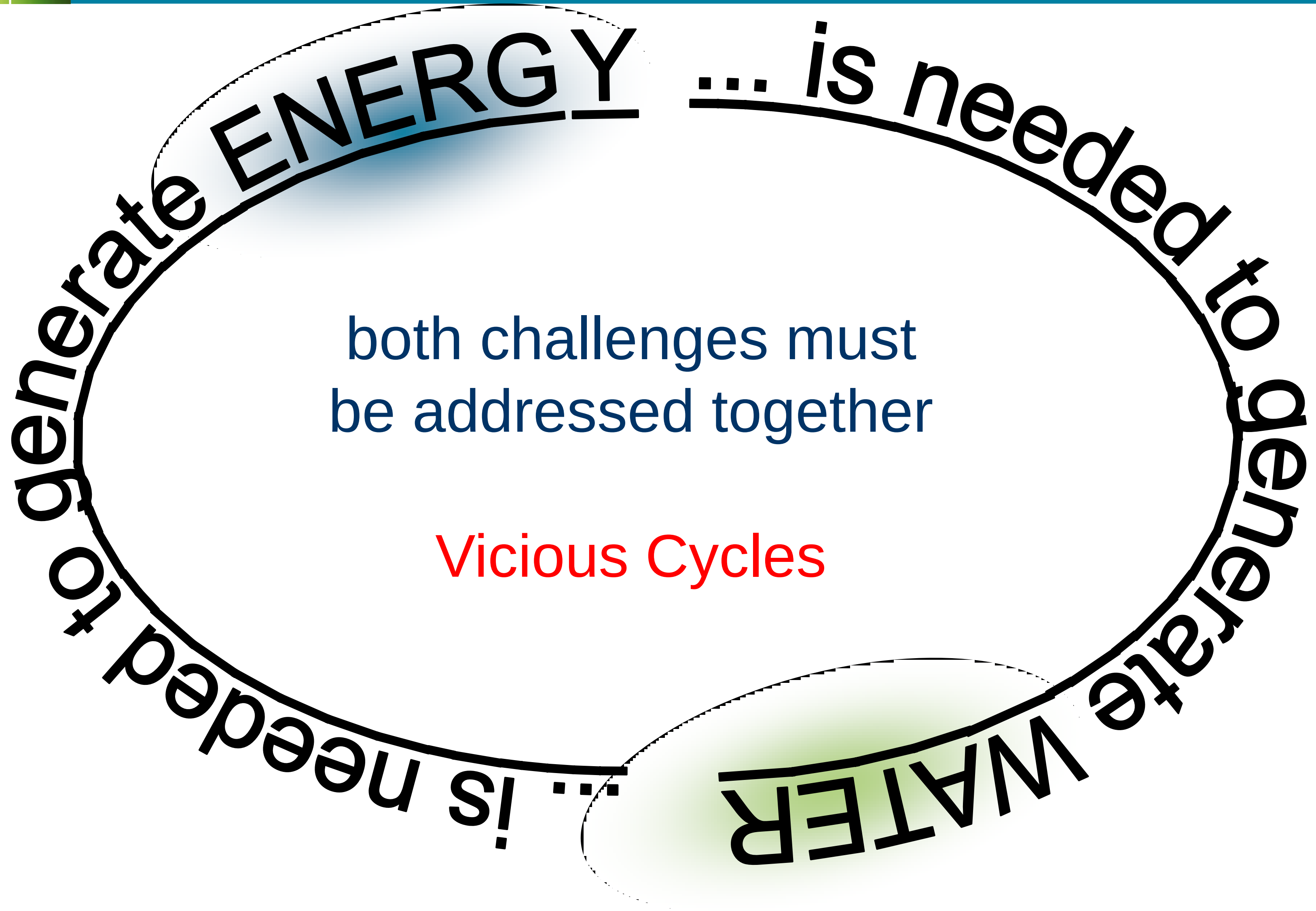
4 reasons to invest in irrigation:

- To reduce poverty in rural areas
- To keep up with global demand for agricultural products and adapt to changing food preferences and societal demands
- To adapt to urbanization, industrialization, and increasing allocations to the environment
- To respond to climate change

Challenges for irrigated agriculture:

- improve equity
- reduce environmental damage
- increase ecosystem services
- enhance water and land productivity in existing and new irrigated systems

1.3 Water and energy issues



Water required for energy production by different processes

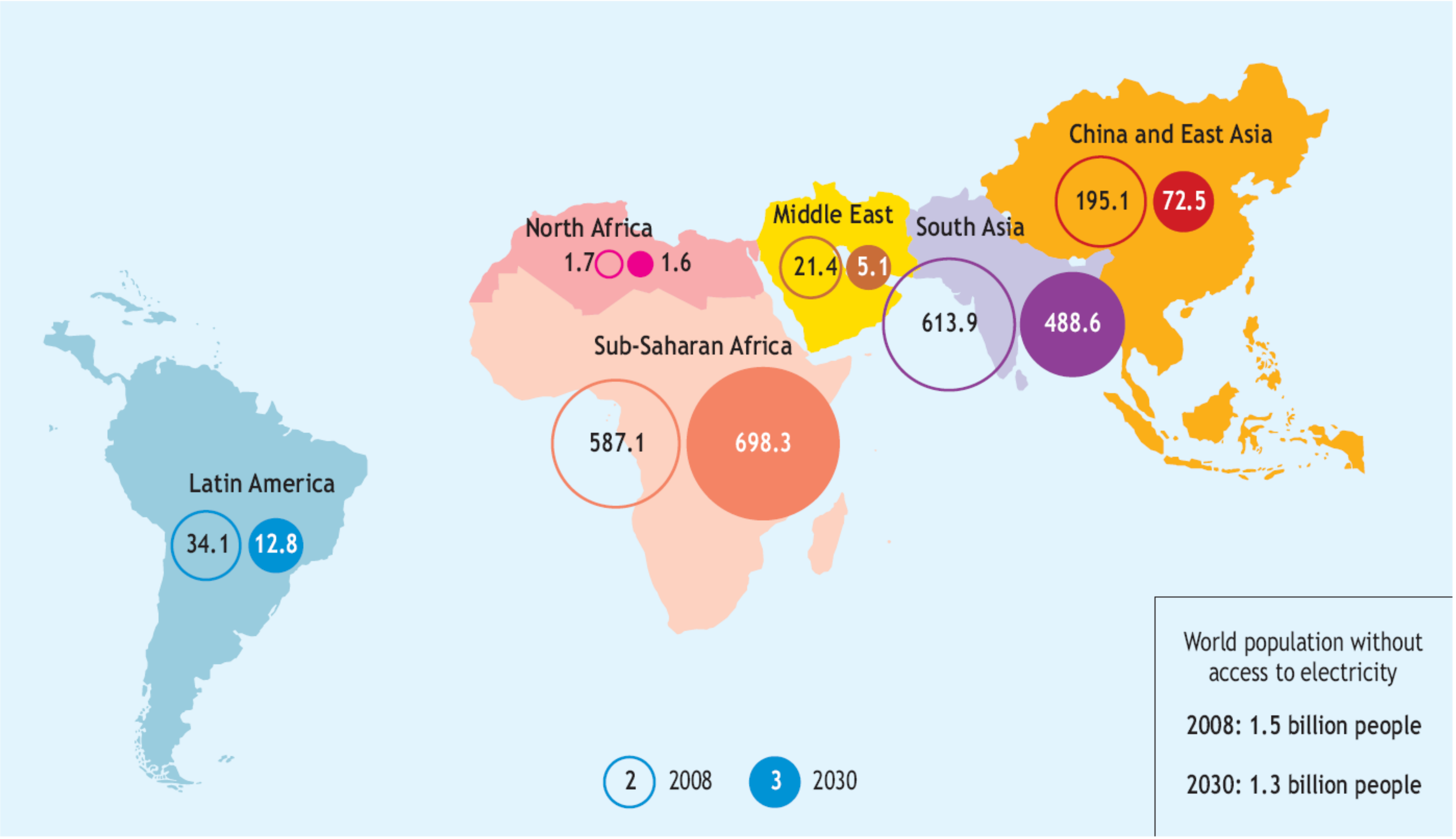
Water consumed to produce 1 MWh of electricity:[16]

Wind turbines	0 m^3/MWh
Solar	0 m^3/MWh
Natural gas	0.2 m^3/MWh
Coal	0.7-3.0 m^3/MWh
Nuclear	0.9-3.3 m^3/MWh
Oil/petroleum	0.1-6.5 m^3/MWh
Hydropower (from evaporation)	17.0 m^3/MWh
First generation biofuels*	32.3-360.0 m^3/MWh

** The amount of water consumed does not indicate whether the crop is irrigated or rainfed. The water intensity of biofuel feedstocks depends on the feedstock used and where and how it is grown. Irrigated crops are much more water intensive than non-irrigated ones. The higher numbers shown represent crops that are irrigated, while the lower numbers represent non-irrigated crops.*

Source: WEF Water Initiative 2009

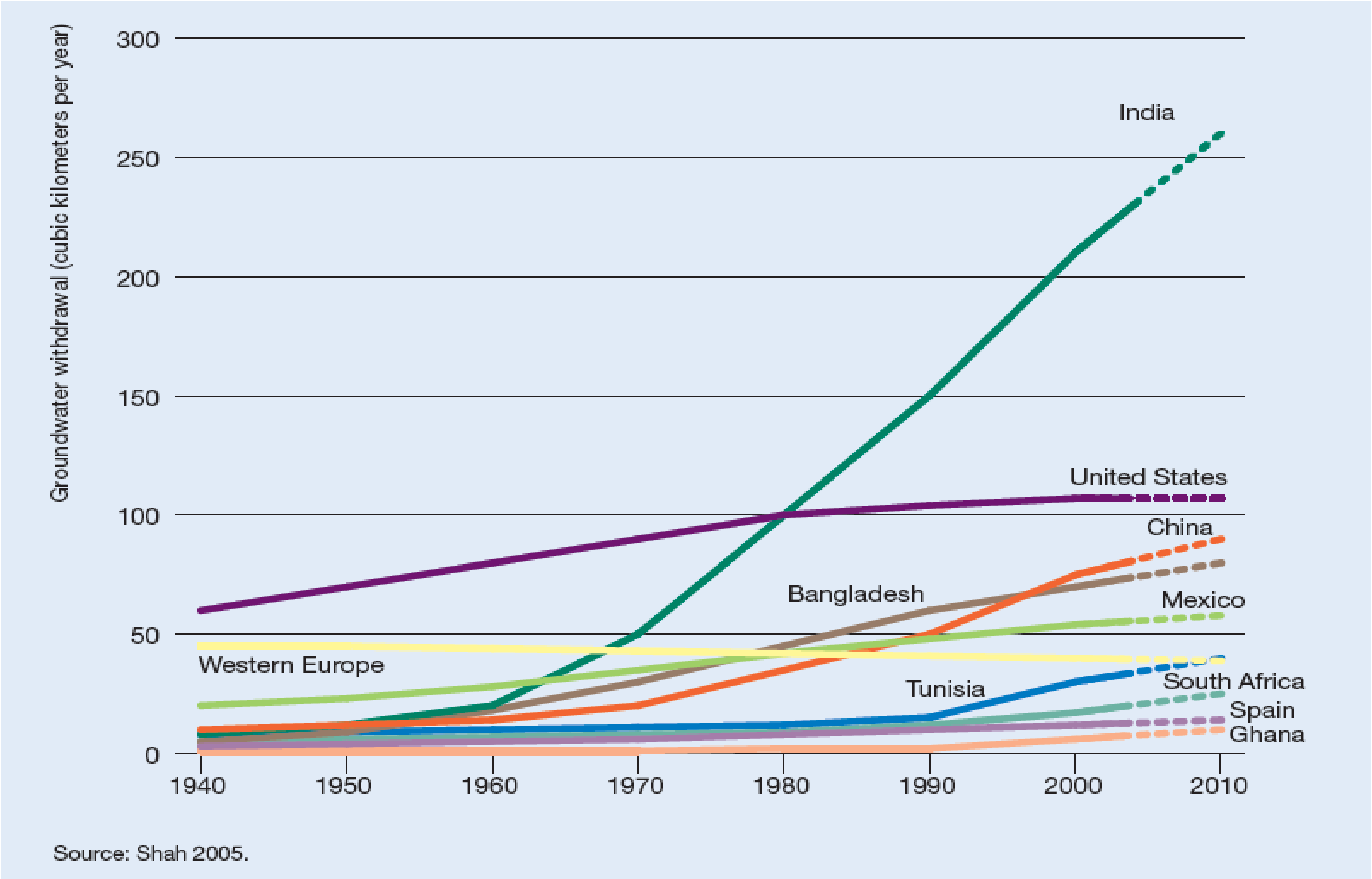
People without access to electricity (million)



The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Source: Organization for Economic Co-operation and Development (OECD) and International Energy Agency (IEA), 2009

Development in groundwater withdrawal



Source: IWMI 2007

Electricity consumption in Indian Agriculture

Electricity consumption	1980-81	1999-2000	Percentage change
Total electricty consumption (MkWh)	81 400	332 474	308
Electricity consumption in the agricultural sector			
Total (MkWh)	14 489	98 800	582
	(17.8)	(29.7)	
Per tube well (kWh)	3 346	8 100	142
Per 1000 ha of GCA(kWh)	80	520	550
Per Rs 1000 of agricultural output	31	116[a]	274

[a] Provisional

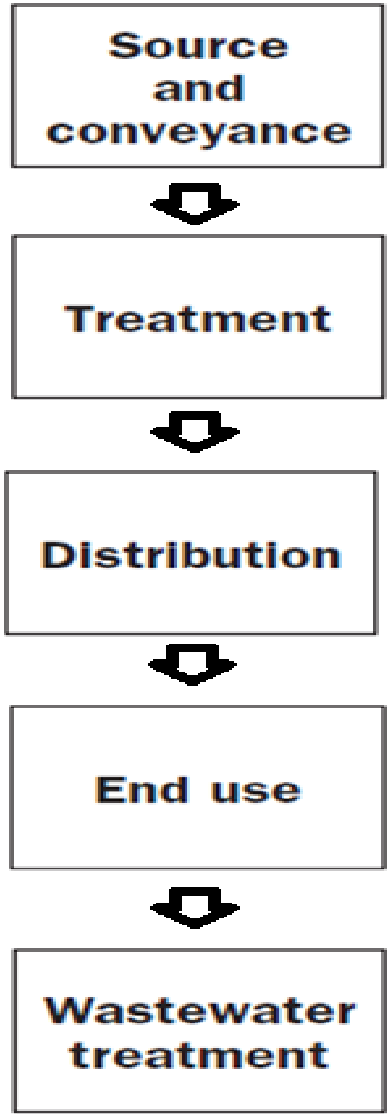
Note: Figures in parentheses denote percentage of total consumption.

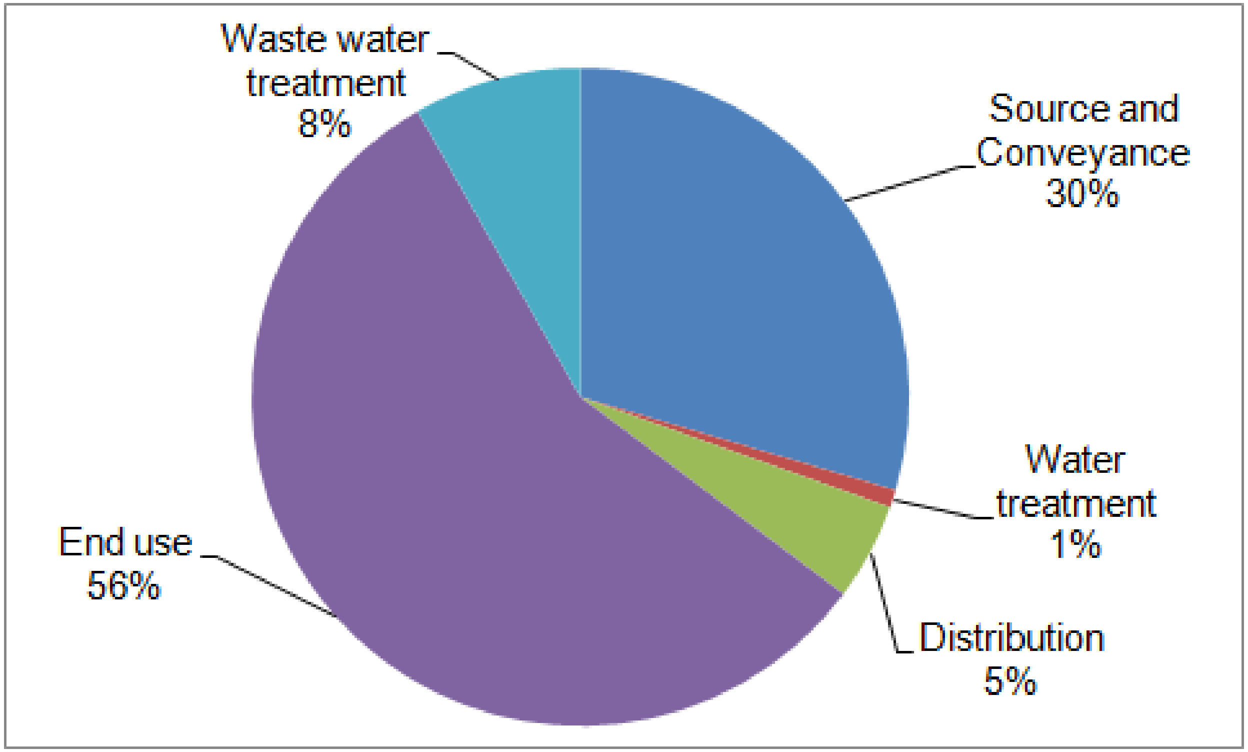
Source: Center for Monitoring Indian Economy (2001) and Malik (2002)

MkWh = Million kilowatts-hour

Energy use in industrial and domestic water

Components of the supply-use-disposal chain



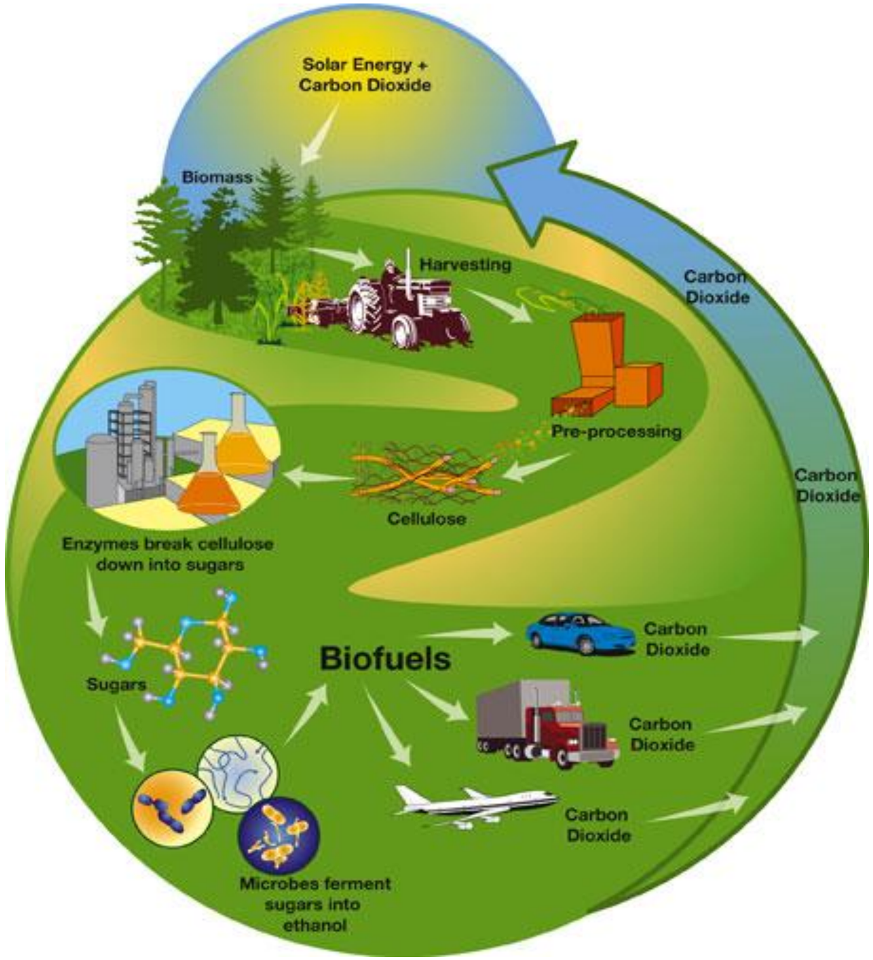


Estimated Energy Intensity Components of Water in San Diego

Source: Natural Resources Defense Council (NRDC), 2004

- Future energy production will be dependent on water access (Department of Energy Officials, USA)
- By 2030, **hydropower** will become the world's **dominant renewable energy source** (providing more than twice the amount of its nearest rival, onshore wind power)
- About **170 GW of hydropower** is currently under construction, 76% of this across Asia

- At present largely based on sugar (e.g. sugarcane), starchy (e.g. cassava) and oil crops (e.g. oil palm)
- A large scale expansion of energy crops would alter water balance in the river basin and may lead to a large increase in evapo-transpiration (Berndes, 2002)
  - Increase irrigation requirements
- **Consumptive use !!!**



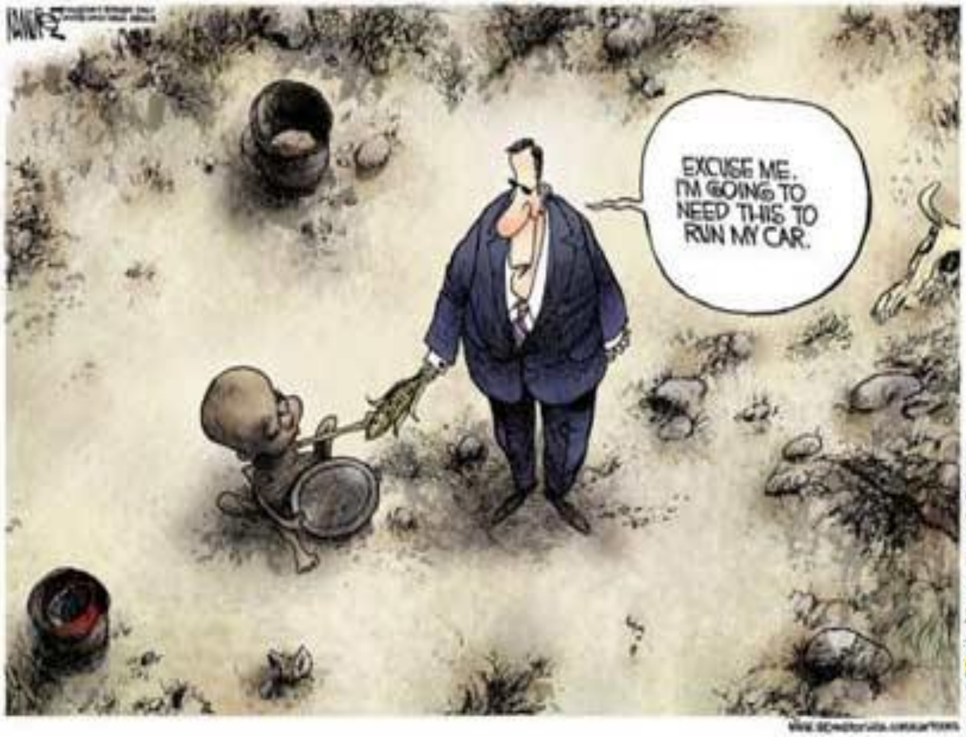
- Increased demand for irrigation water
- **Increased water demand** in ethanol processing factories
- **Water pollution** through increased use of fertilizer and pesticides
- Second generation bio-fuels (forest products; wood and waste) >> **exploitation of marginal lands**
- Water withdrawal for bio-fuel production may **worsen water scarcity problems** in some areas

1.4 Energy and food issues

Bio-fuel production and food prices

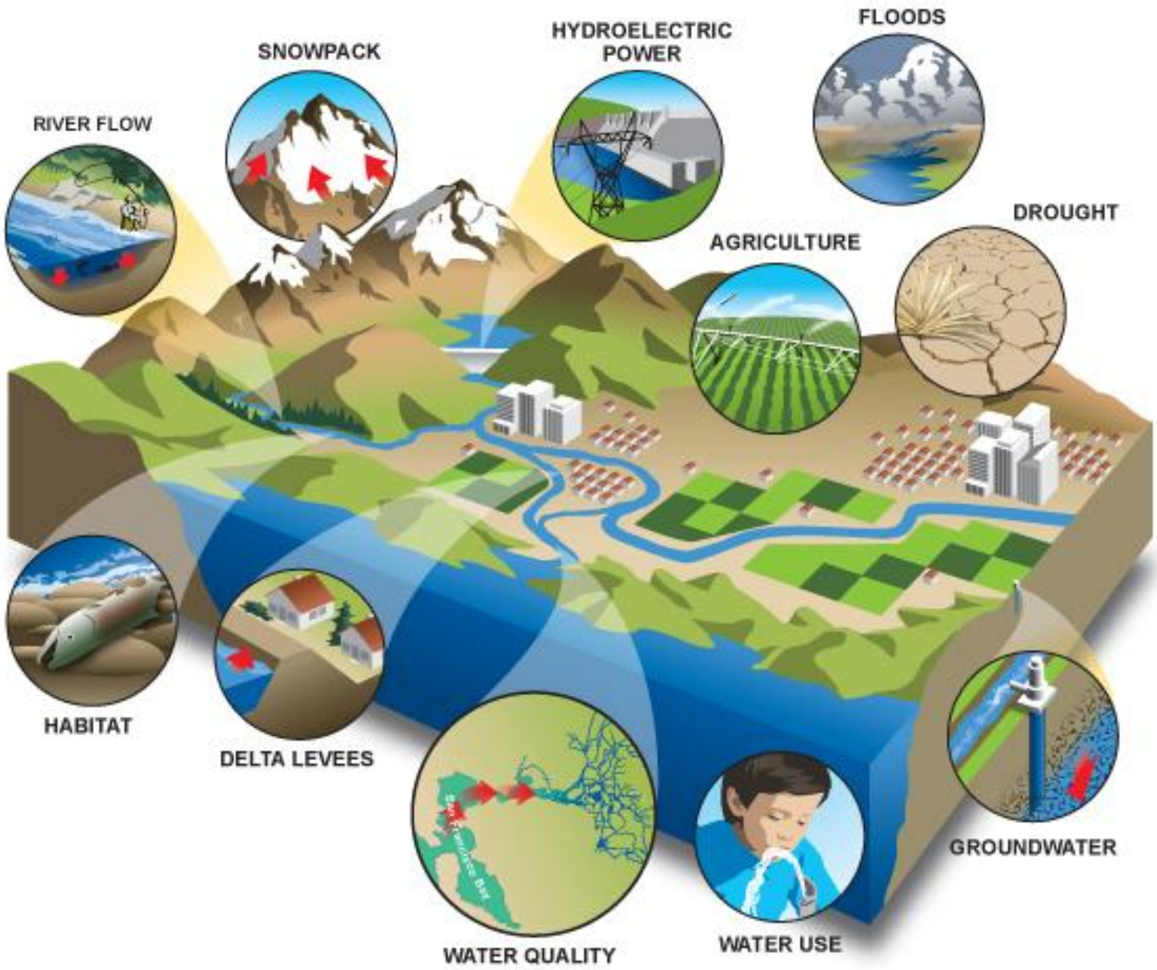
- **Increase in bio-fuel demand** could lead to **higher food prices** and adversely affect food availability and access
  - In 2006, a **rise in domestic food price** was observed when food grain was used for bio-fuel production in China
  - Substantial **increases in food prices** are foreseen in an aggressive bio-fuel scenario by 15-30%

- Use of staple food crops (e.g. maize) for energy contributed to higher food prices and civil unrest in poor countries
- No. of **food-insecure people** in the world will rise by over 16 million for every percentage increase in the real prices of staple foods
- Substitution of food farming by energy farming leads to increased competition for land and water
- The issue is not whether the production of food, fuel or feed compete with each other but to **what extent and how**


EXCUSE ME. I'M GOING TO NEED THIS TO RUN MY CAR.


NO, BUT I CAN OFFER YOU A GALLON OF ETHANOL!
CARLSON

1.4 Exacerbation by climate change



Climate change will affect all facets of society and the environment, with strong implications for water and agriculture now and in the future

Climate change affects four dimensions of food security

- Food production and availability
- Stability of food supplies
- Access to food
- Food utilization

Climate change impacts on irrigation

- Reduction in crop yield and agricultural productivity where **temperature constrains crop development**;
- Reduced availability of water in regions affected by **reduction in total precipitation**;
- **Increased climate variability** in places where it is already highest;
- **Reduced storage of precipitation** as snow and earlier melting of winter snow, leading to shifts in peak runoff away from the summer season when demand is high*;*
- **Inundation** and increased damage in low-lying coastal areas affected by sea-level rise, with storm surges and increased saline intrusion into vulnerable freshwater aquifers;
- **Increased overall evaporative demand** from crops as a result of higher temperatures;
- Further **depletion of non-renewable groundwater resources**

Source: FAO 2008

Case Studies

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Climate Change Impacts and Adaptation Measures for Rice Cultivation in Northeast Thailand

AIT: 50 YEARS OF EMPOWERING ASIA
1959 - 2009

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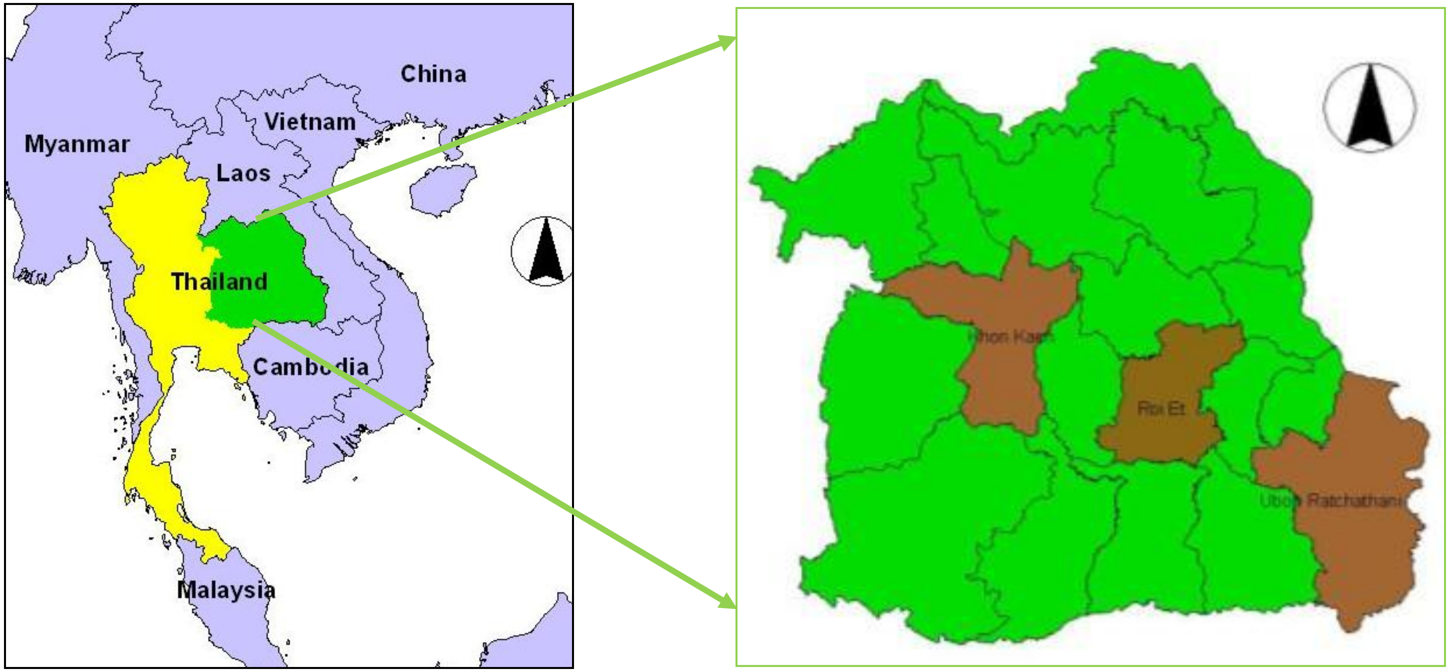
Objectives

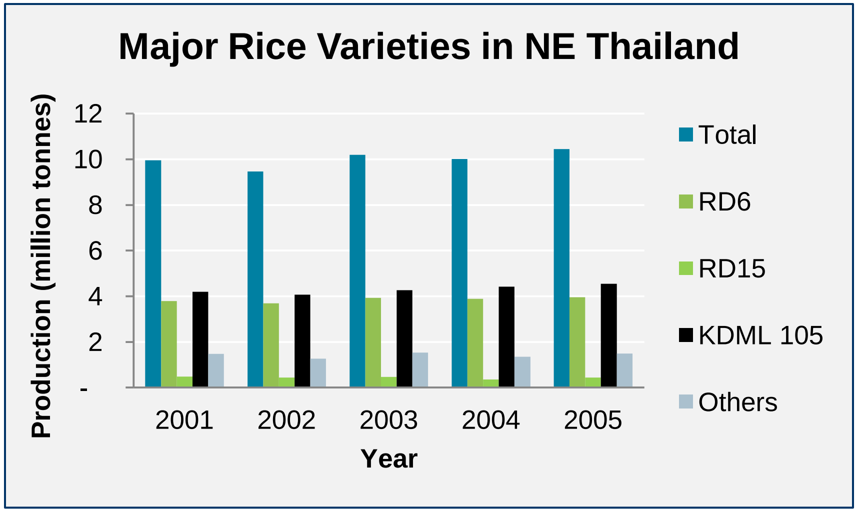
- To assess the impacts of future climate change on rice yield in Northeast of Thailand
- To identify and evaluate the potential management practices as agro adaptation measures

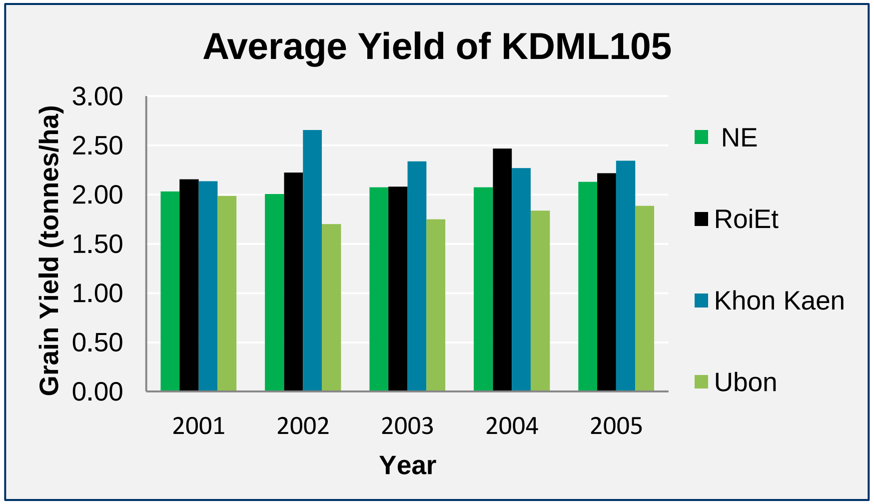
Study area

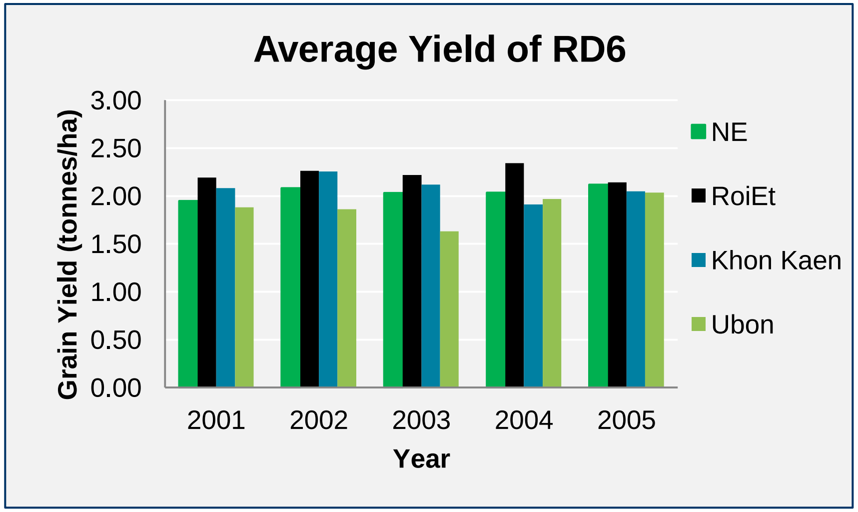


- Low soil fertility, poor physical endowment of the region
- Highly uneven distribution of rainfall
- Average yield of rice lower then the country average yield

Major rice varieties and their yields

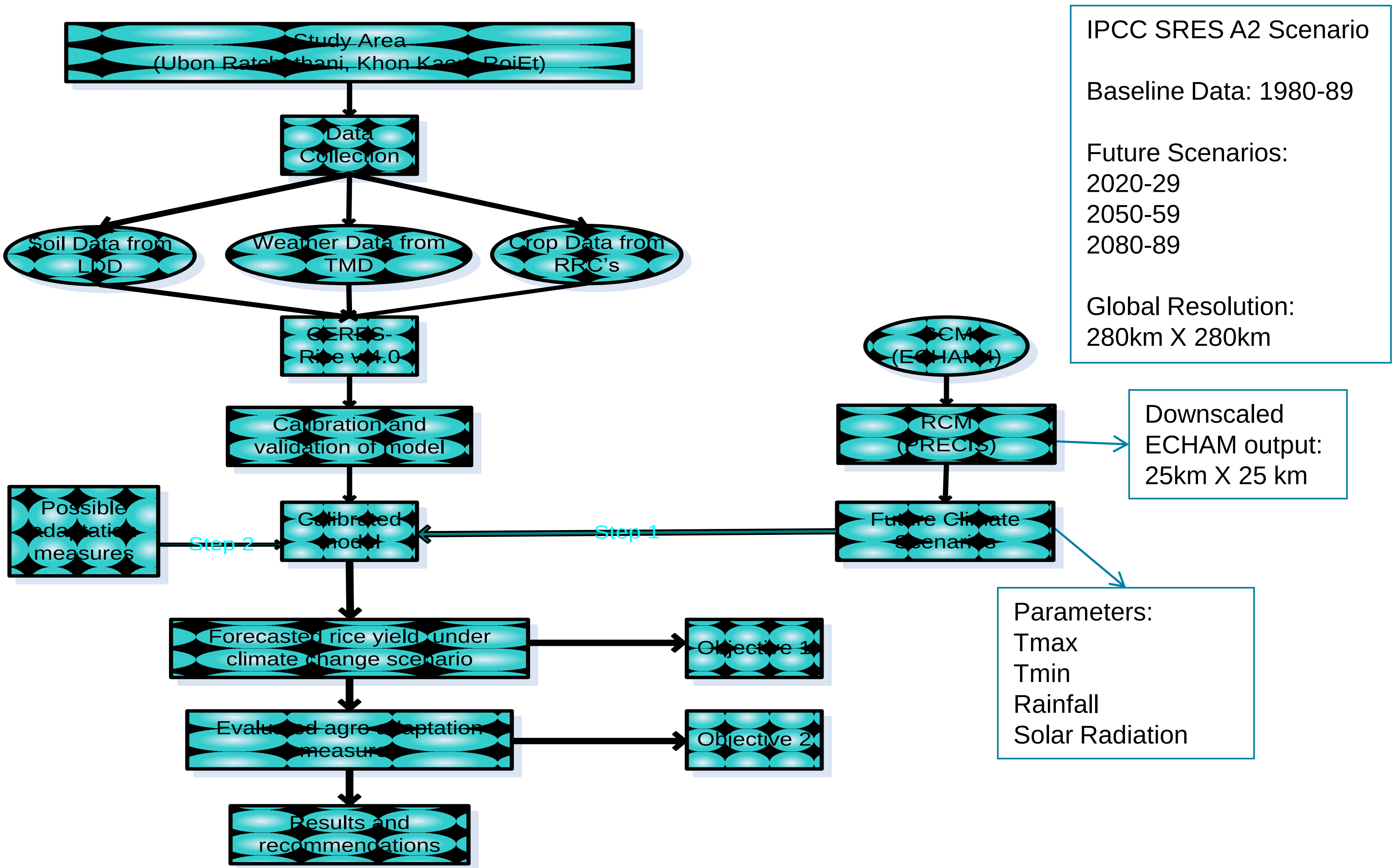




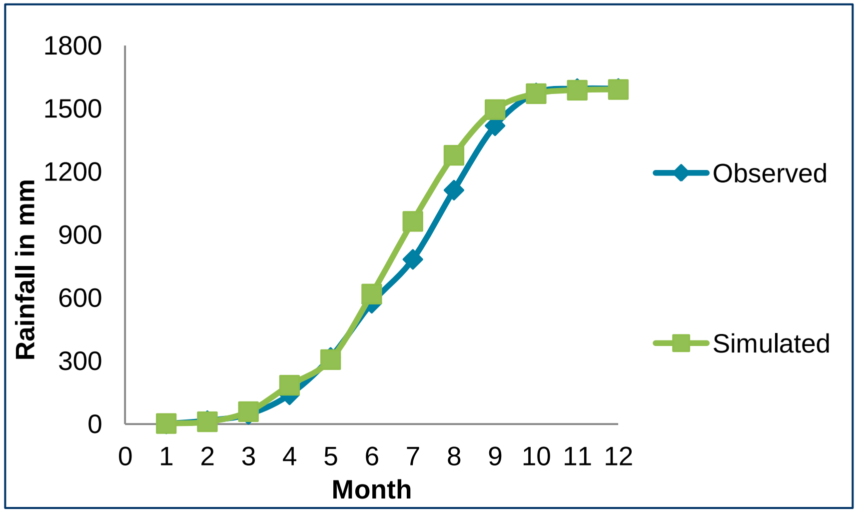


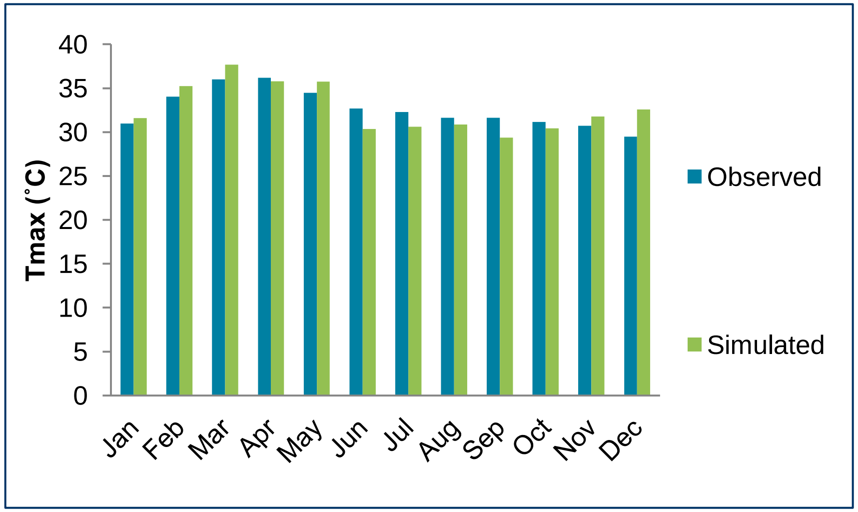
Source: Office of Agriculture Economics, 2007

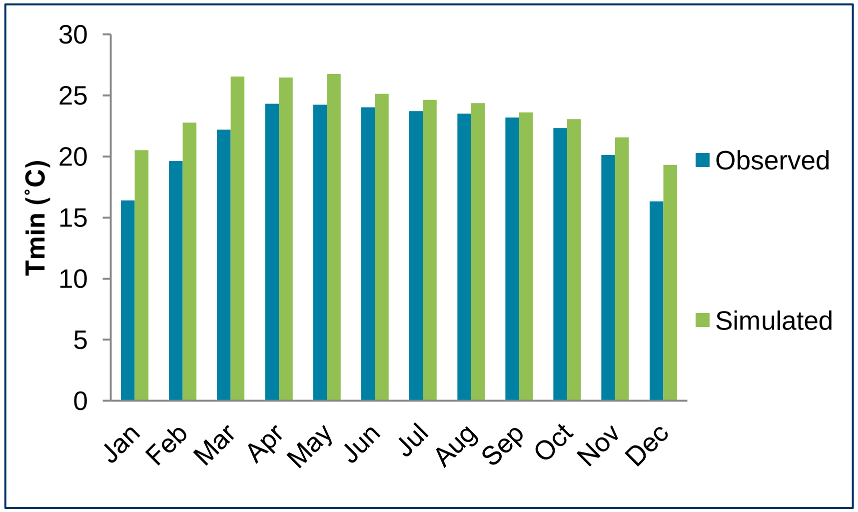
Research methodology



Observed & simulated weather (1980-89)



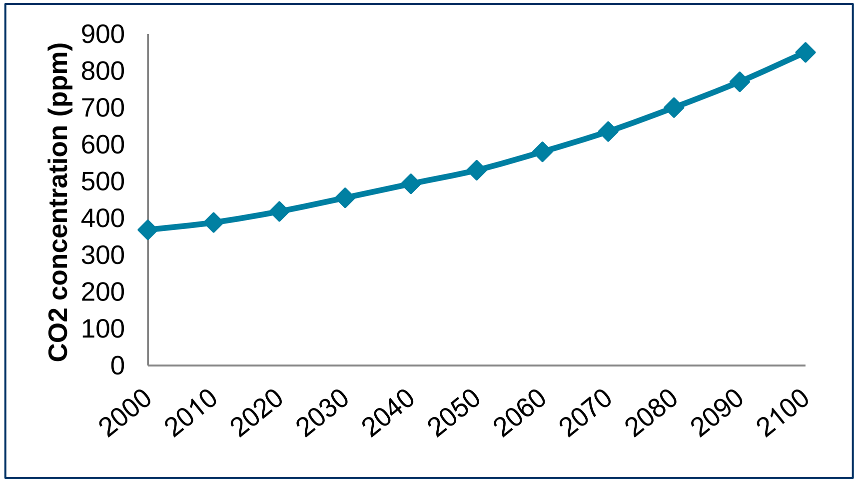


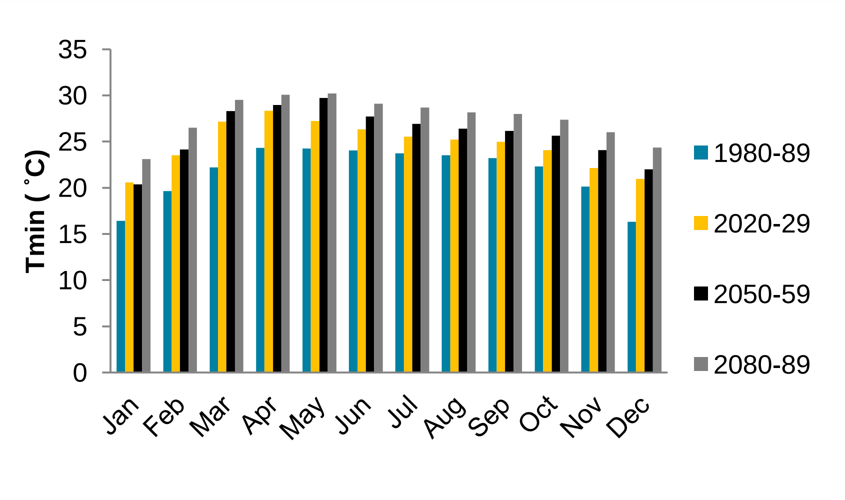


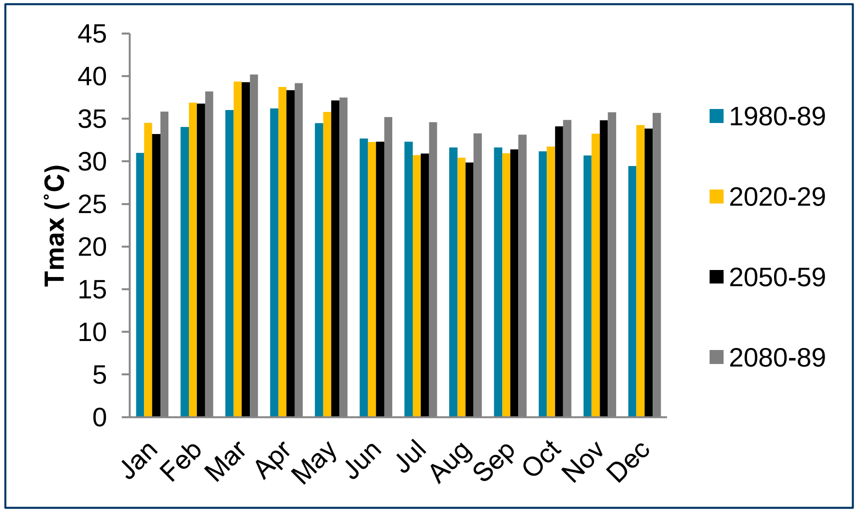
Future weather scenarios

IPCC SRES A2 Scenario

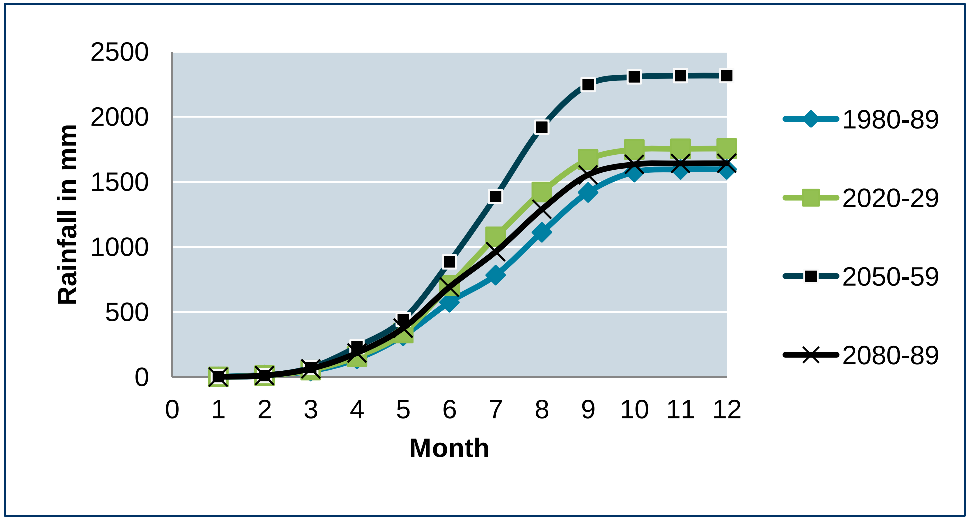
- A world of independently operating, self-reliant nations
- Continuously increasing population
- Regionally/nationally oriented economic development
- Slow and fragmented technological changes
- Slow and fragmented improvements to per capita income

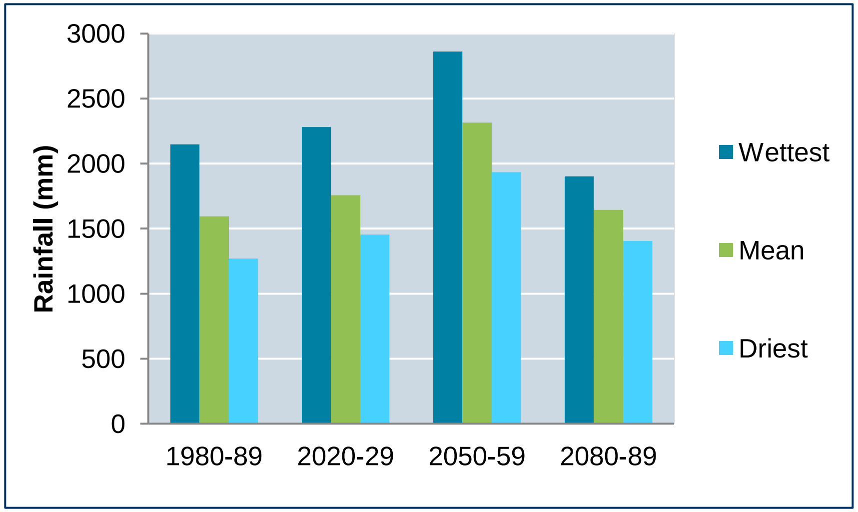


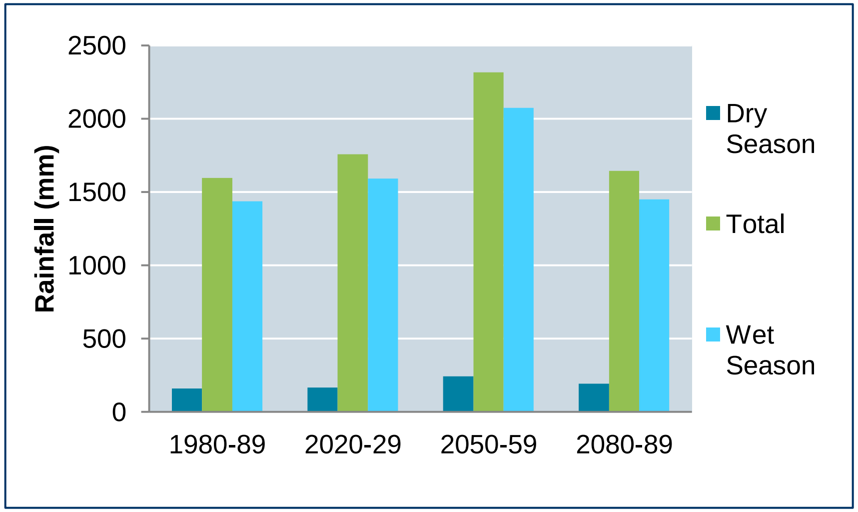




Future rainfall scenarios

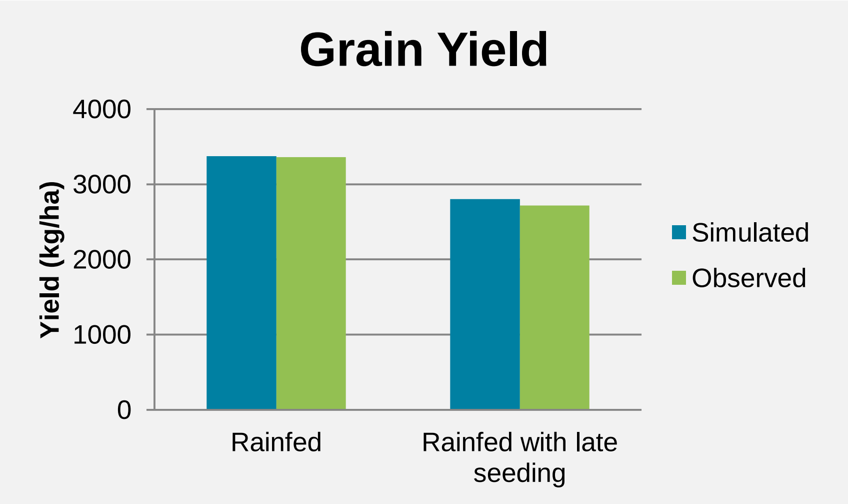


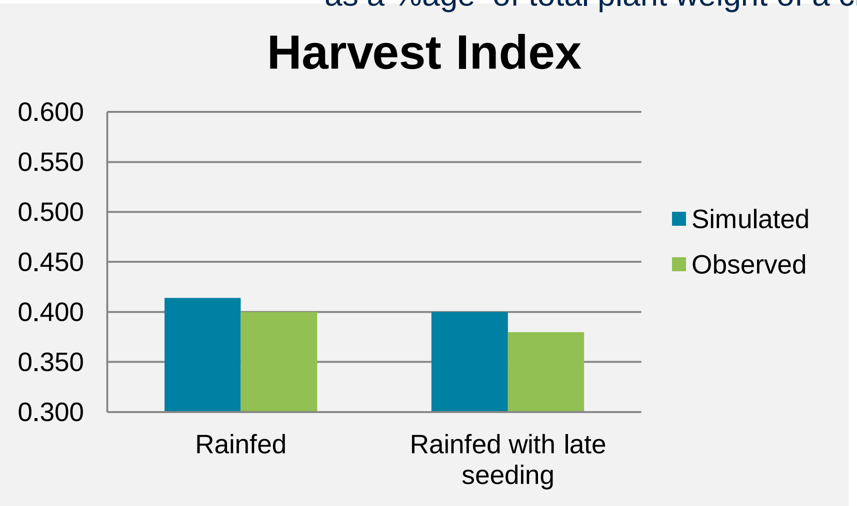


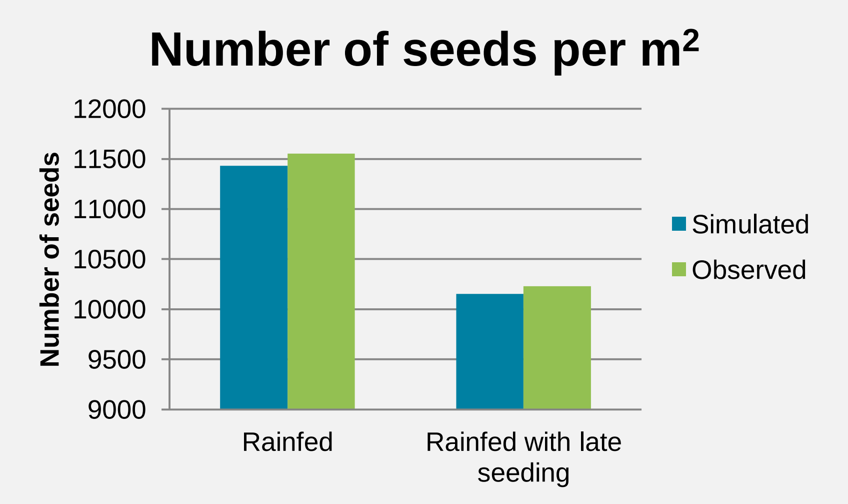


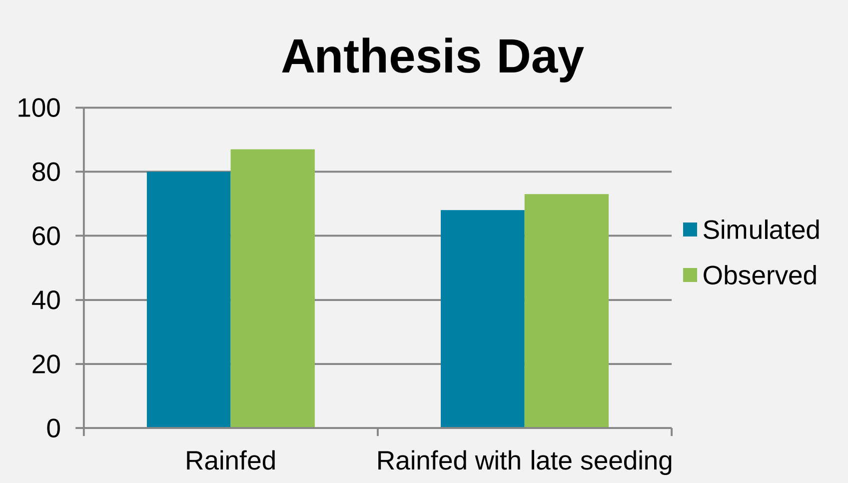
Calibration: KDML105 at Ubon Ratchathani

Harvest Index: weight of a harvested product as a %age of total plant weight of a crop



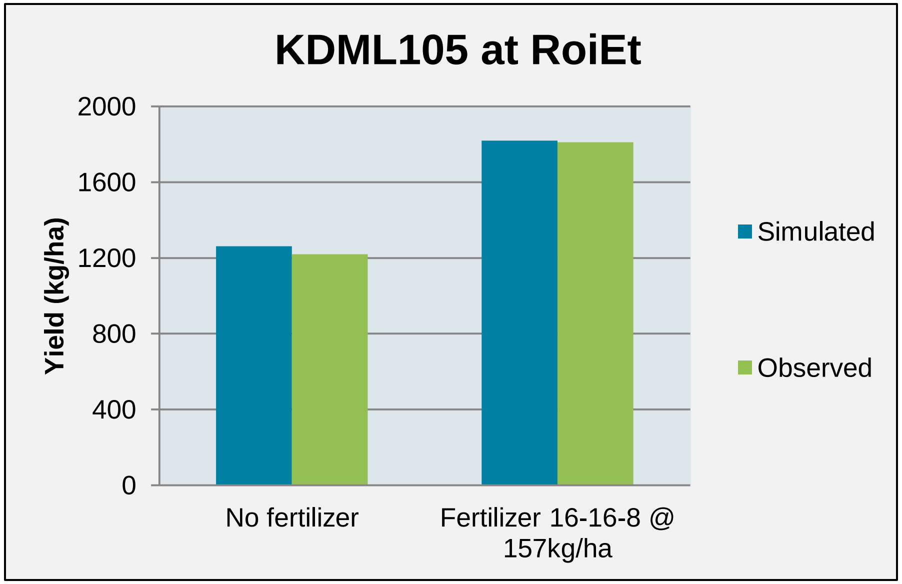


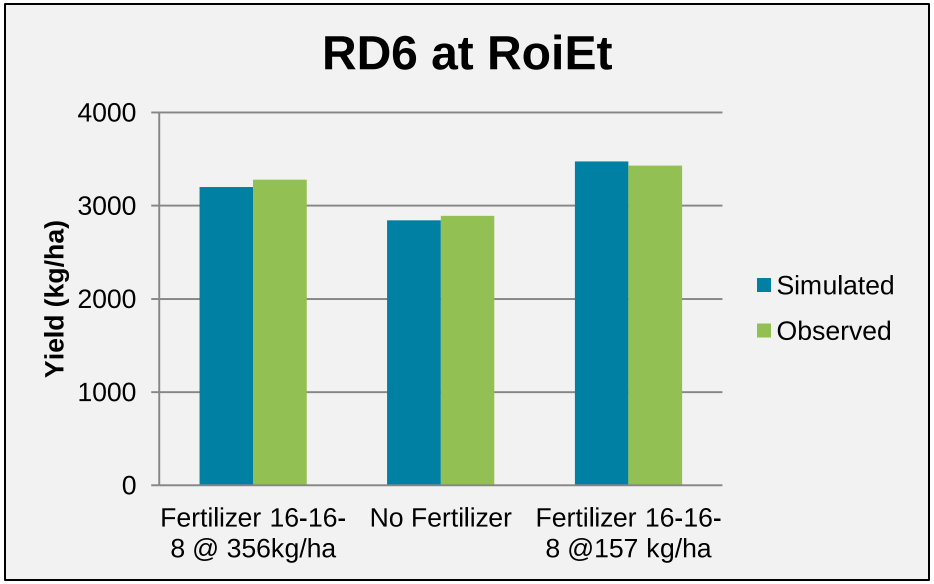




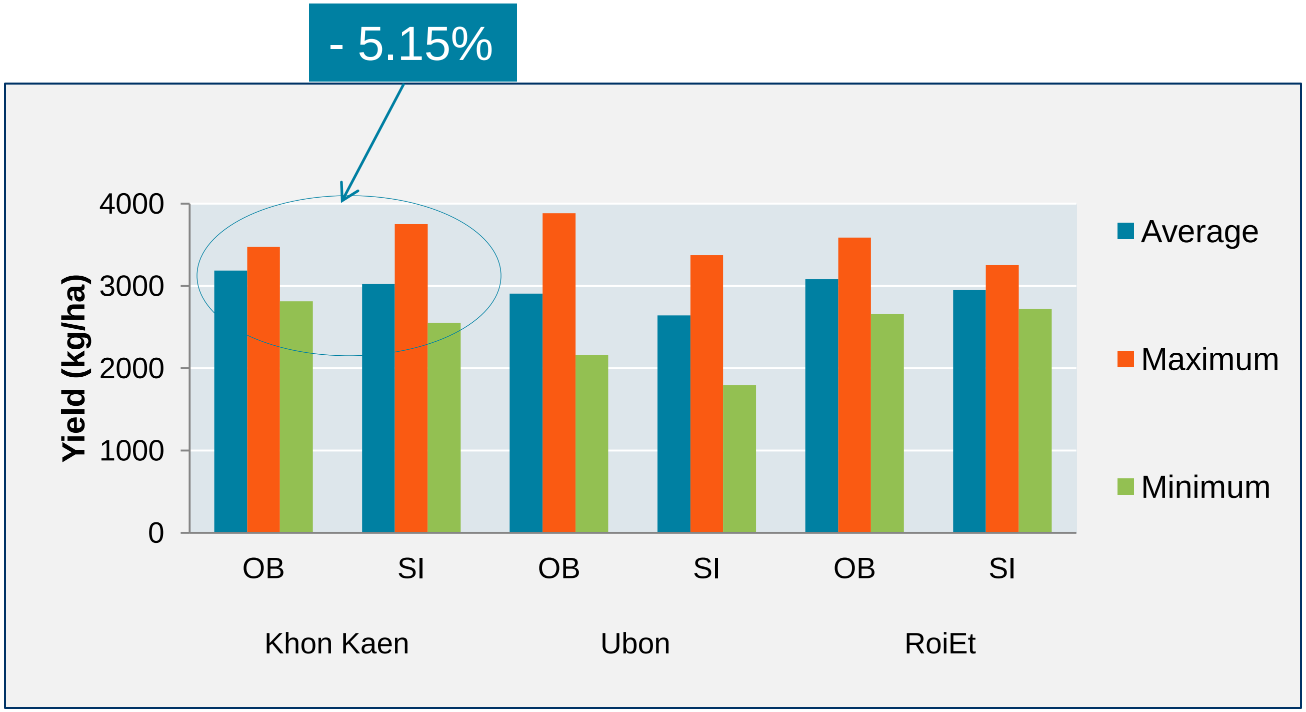
Anthesis day - day after planting

Yield results for experiments





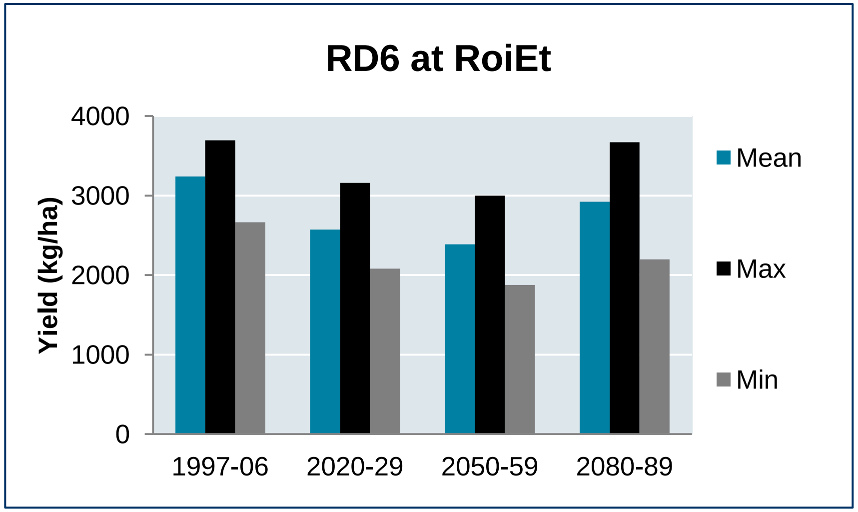
Comparison of baseline year (1980-89) yield

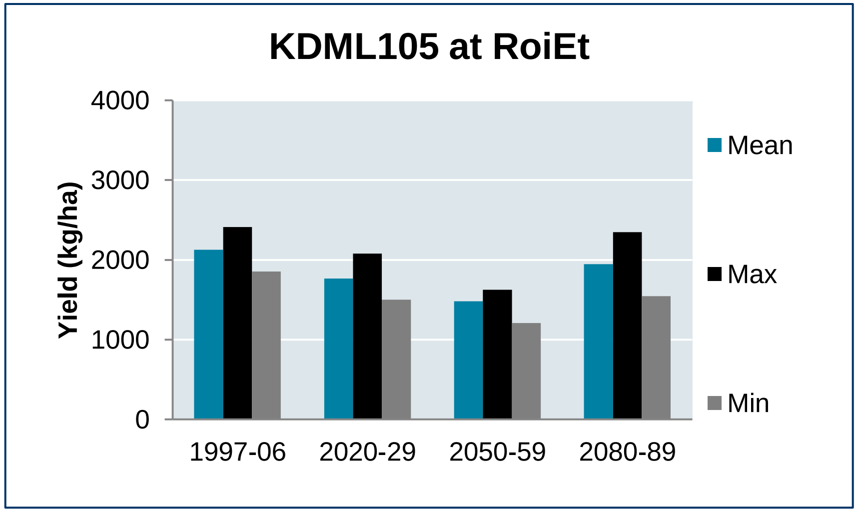


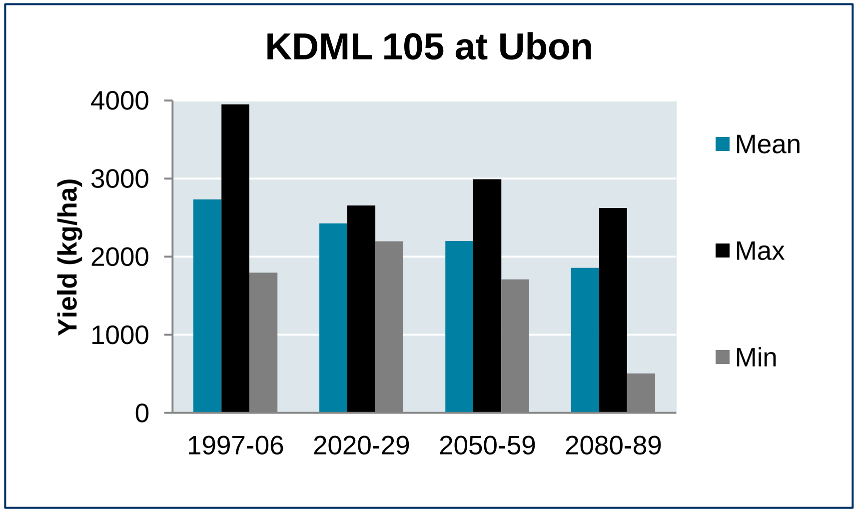
Effect of climate on yield components

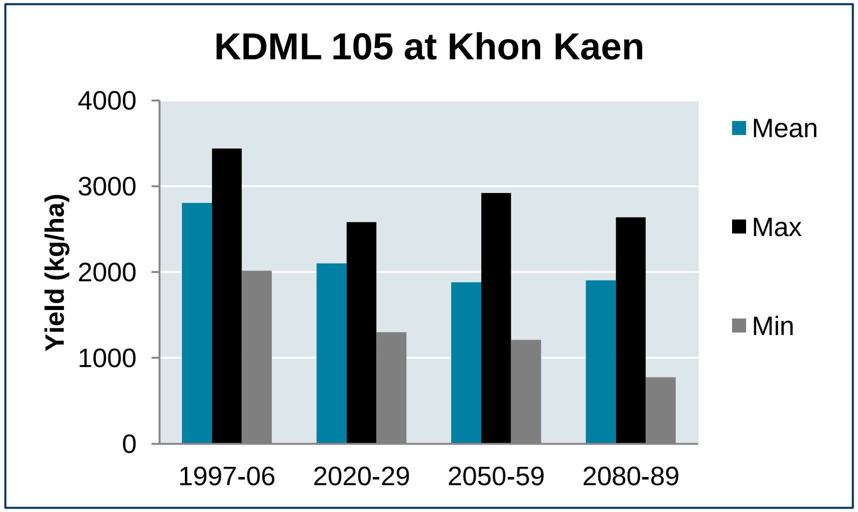
Period	Yield (kg/ha)	Panicle no. / m2	No. of grains/m2	Total Biomass (kg/ha)	Anthesis duration (days)	Maturity duration (days)	Harvest Index
KDML105 at Ubon Ratchathani							
1997-06	2732	33.4	10613	6353	81	110	0.43
2020-29	2427	31.7	8990	6742	87	113	0.36
2050-59	2200	27.3	8149	6463	96	120	0.30
2080-89	1855	36.2	6869	6625	85	107	0.28

Effect of future climate on rice yield

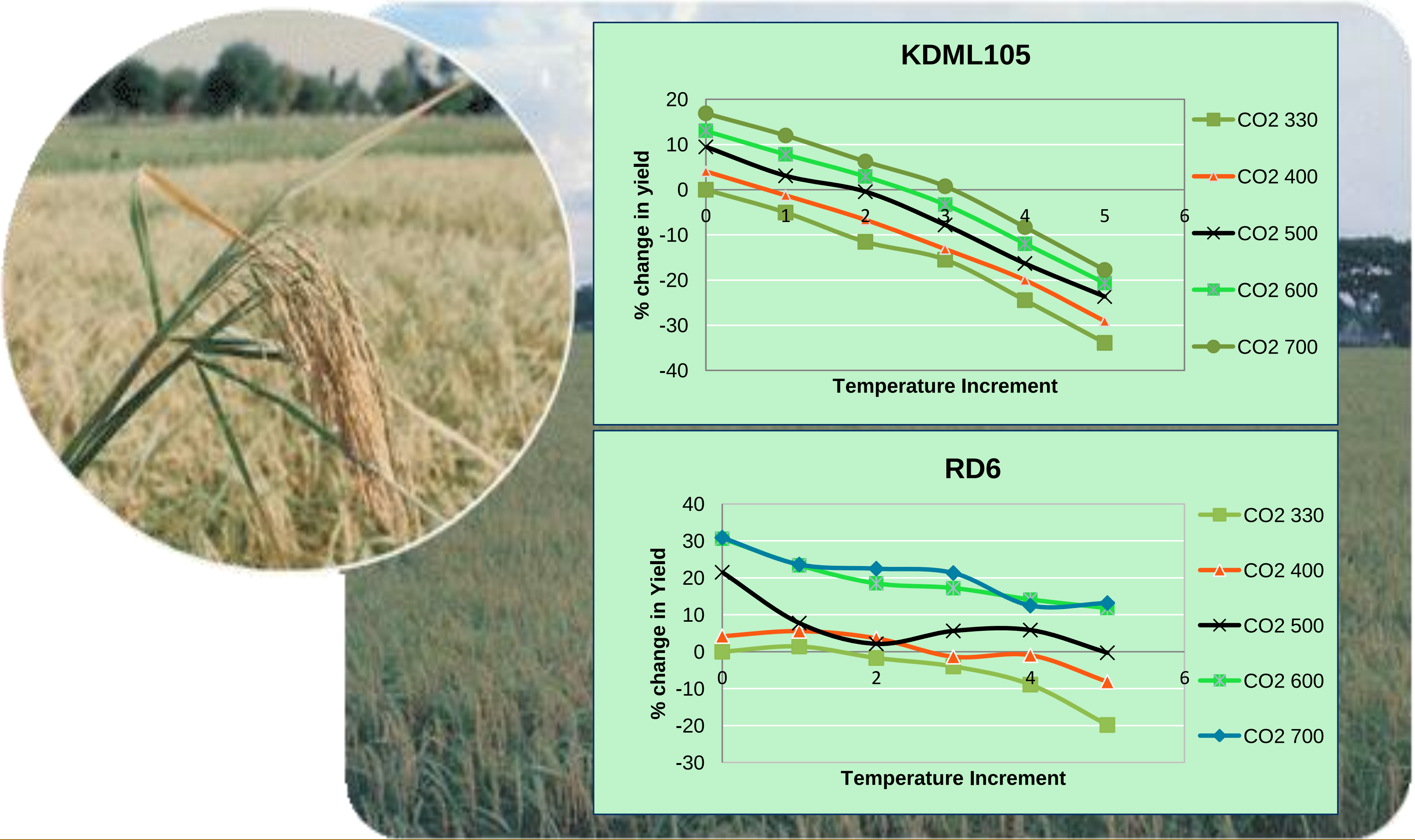








Effect of temperature and CO_2 on yield

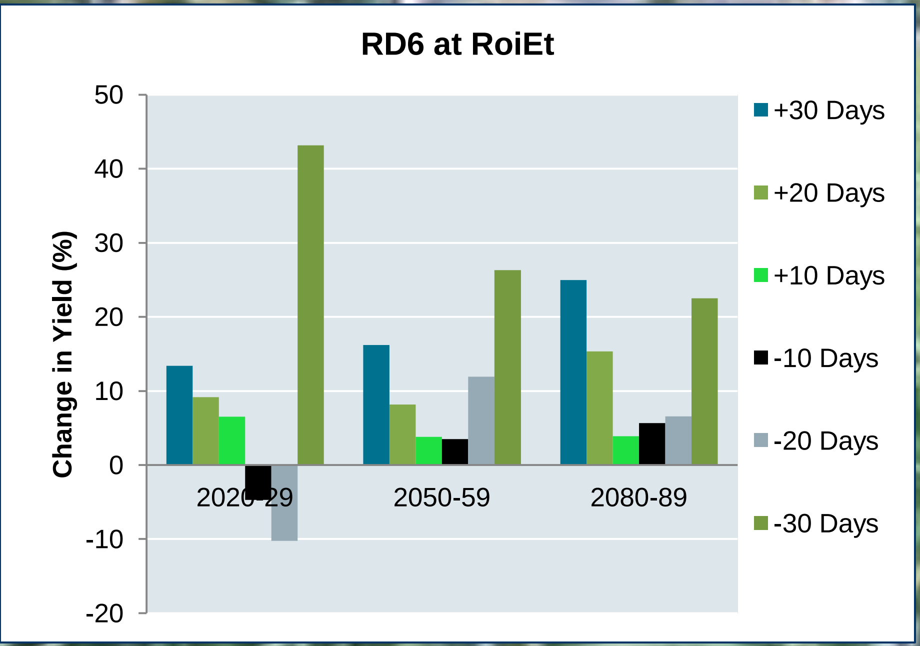


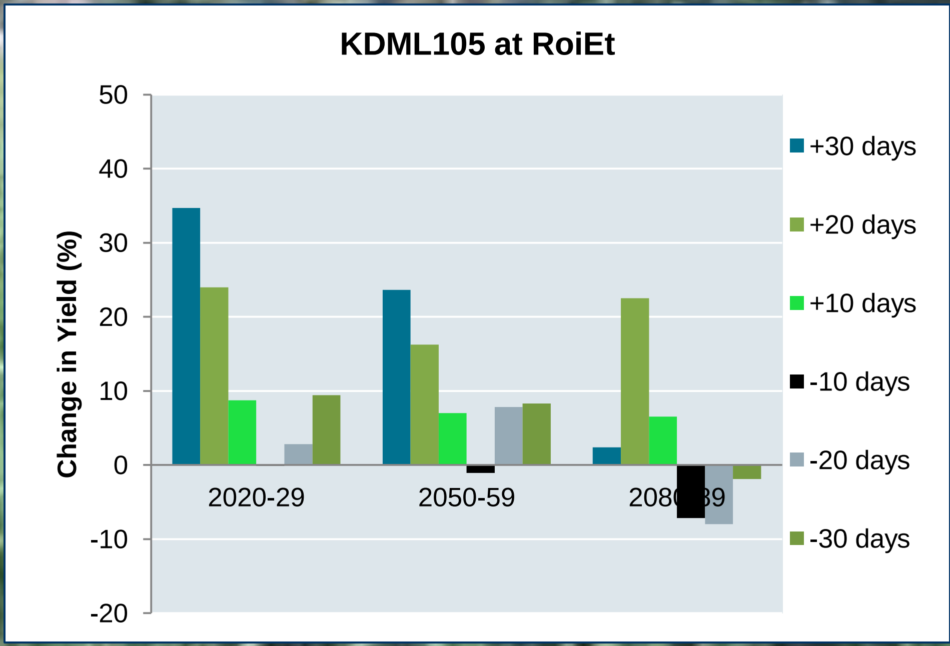
Adaptation Measures

To mitigate the negative effects of climate change alternate management practices were investigated as adaptation measures

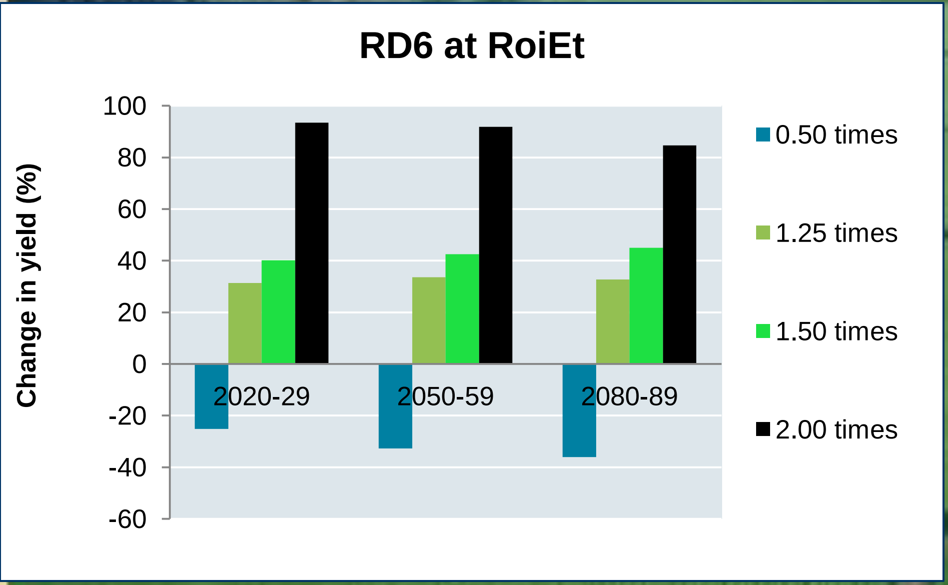
- Different sowing dates
- Different rate of Nitrogen
- Different time of N application
- Hybrid rice cultivars

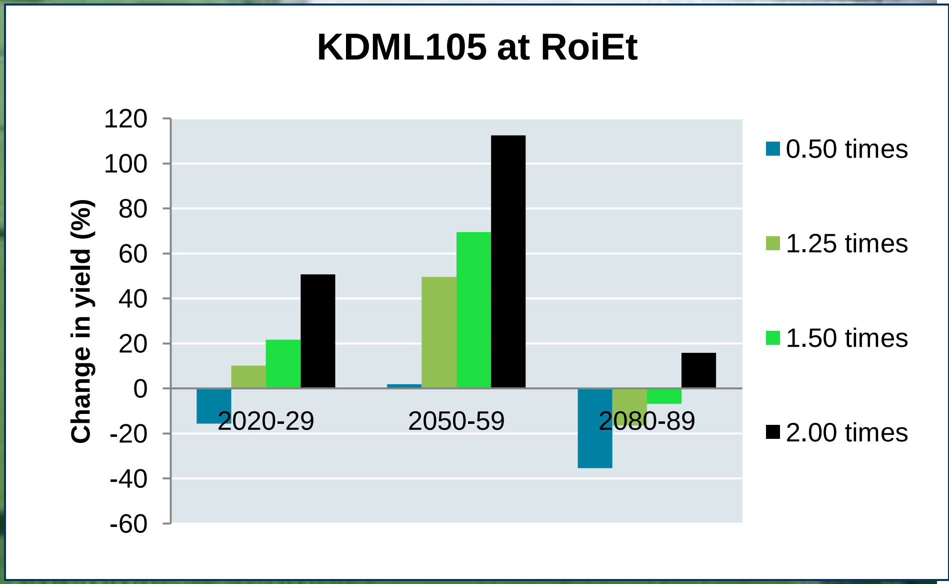
Alternate sowing dates



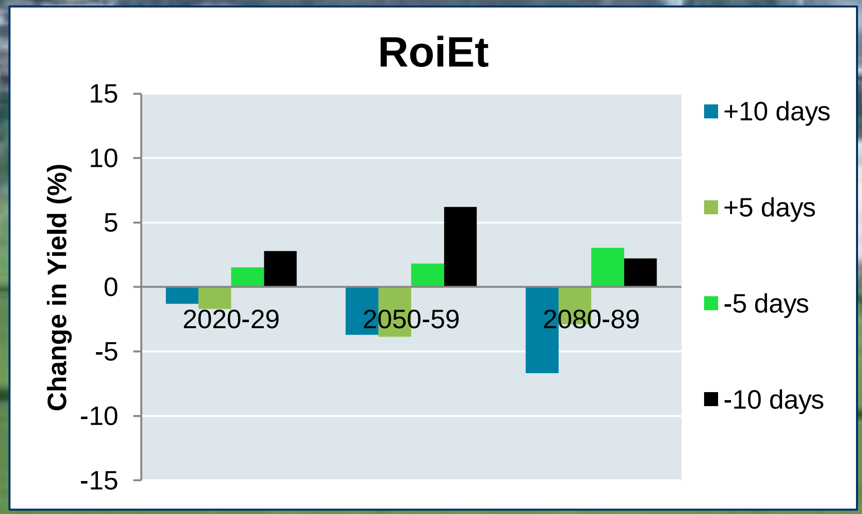


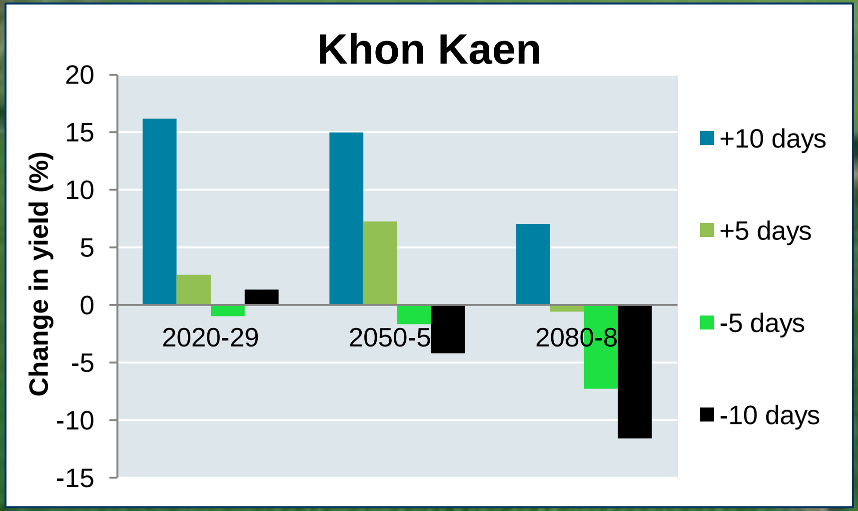
Effect of different N rates

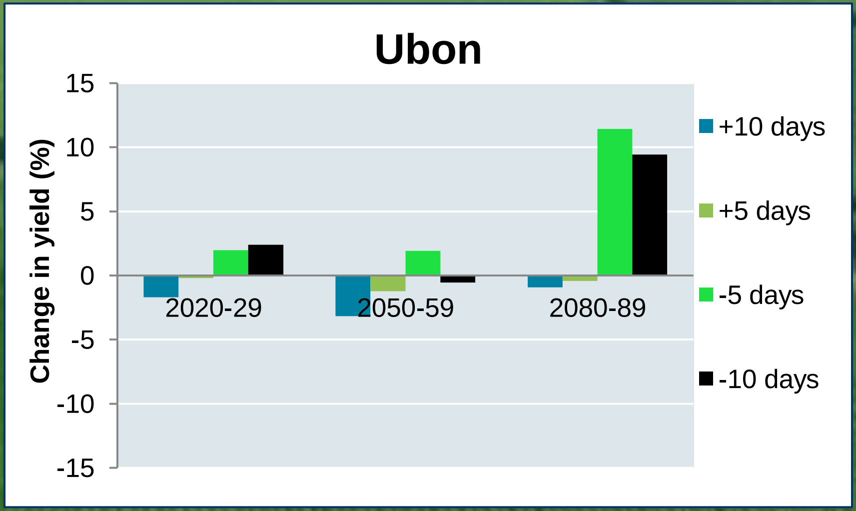




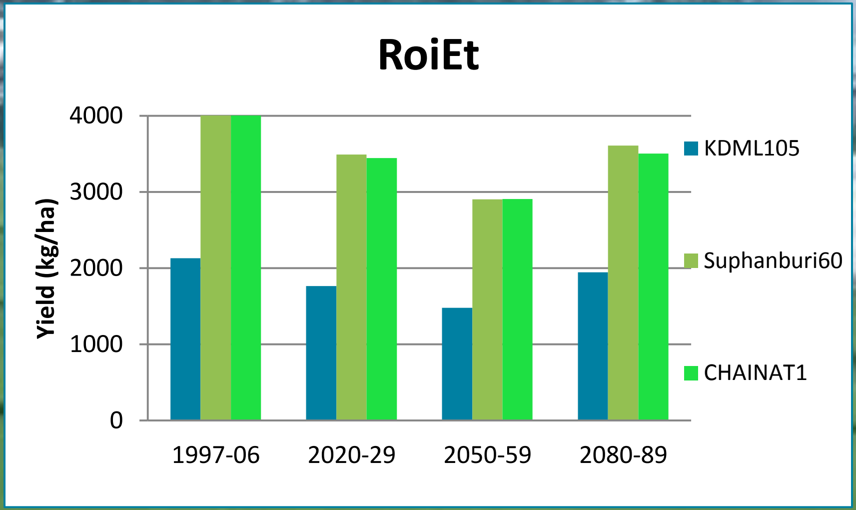
Effect of Change in N Application Time

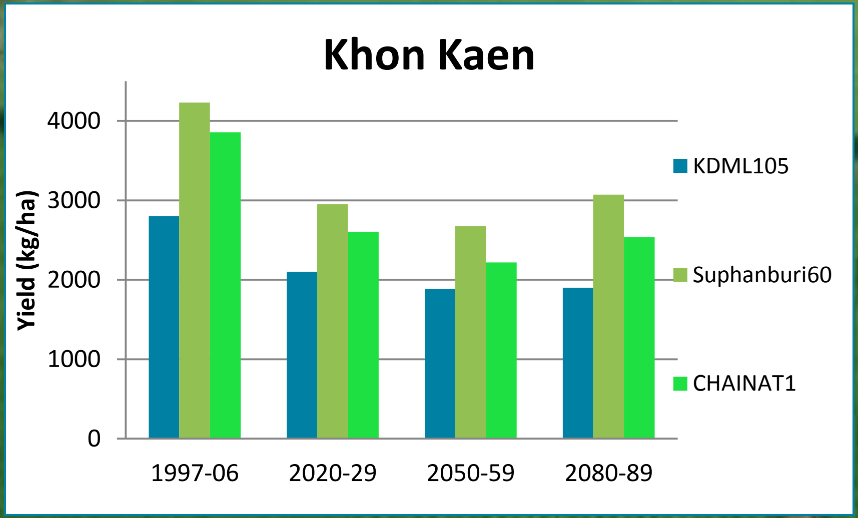


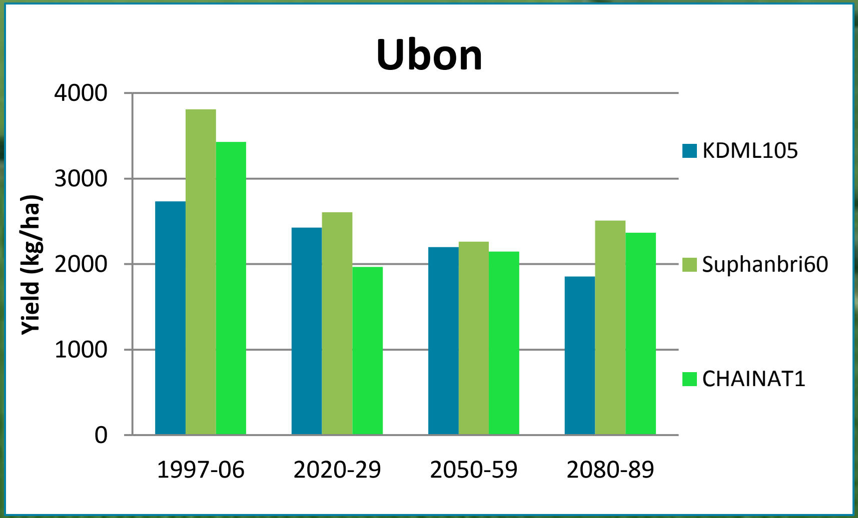




Effect of Using Hybrid Cultivars







Conclusions

- Simulated and observed weather
  - in good agreement in terms of seasonal pattern
- Temperature and CO_2 under future scenarios and rainfall pattern will change
  - Increase in temperature will effect rice yield negatively
  - increase in CO_2 concentration effect yield positively
- Rice yield will decline under the future weather scenarios
- Rainfed rice production under climate variability
  - large yearly fluctuations in the yield
- Alternate management practices will help to mitigate the negative effects of climate change
  - Different sowing dates
  - Nutrient management
- Hybrid varieties show the positive effects under future climate scenarios
  - High temperature tolerance
  - High yield potential

Publication in Scientific Journal

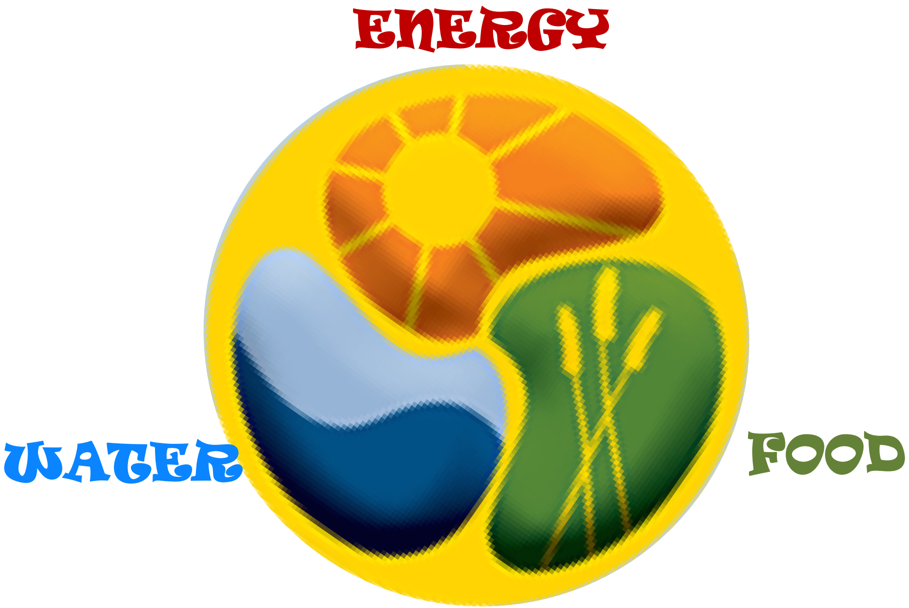
- Babel, M. S., Agarwal, A., Swain, D. K. and S. Herath (2011). Evaluation of climate change impacts and adaptation measures for rice cultivation in Northeast Thailand. *Climate Research*, Vol. 46:137-146.

Final Reflections

AIT

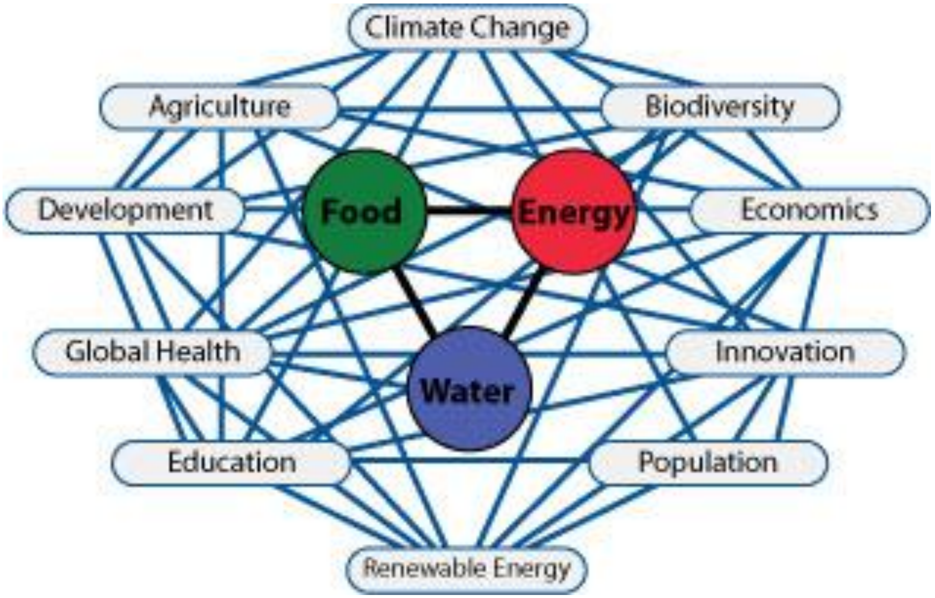
Asian Institute of Technology

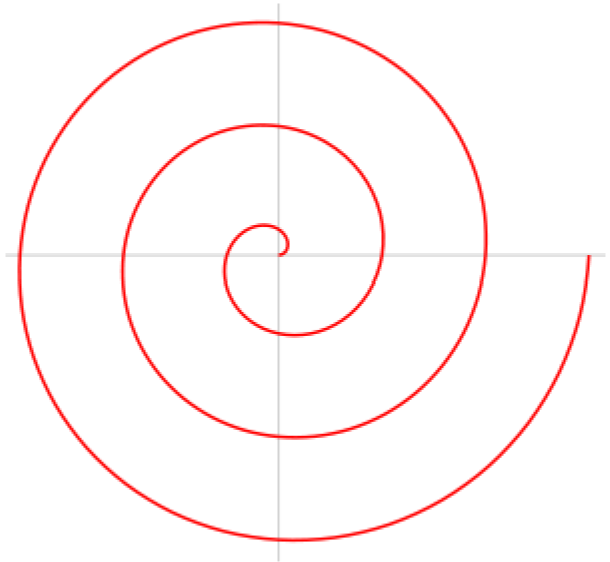
Food security and the 3-dimension nexus



Developing and applying a *long-term, concerted and sustained strategy* on **food security** can be achieved only by **understanding how the three dimensions are entangled**

problems in one area easily spill over on the next...

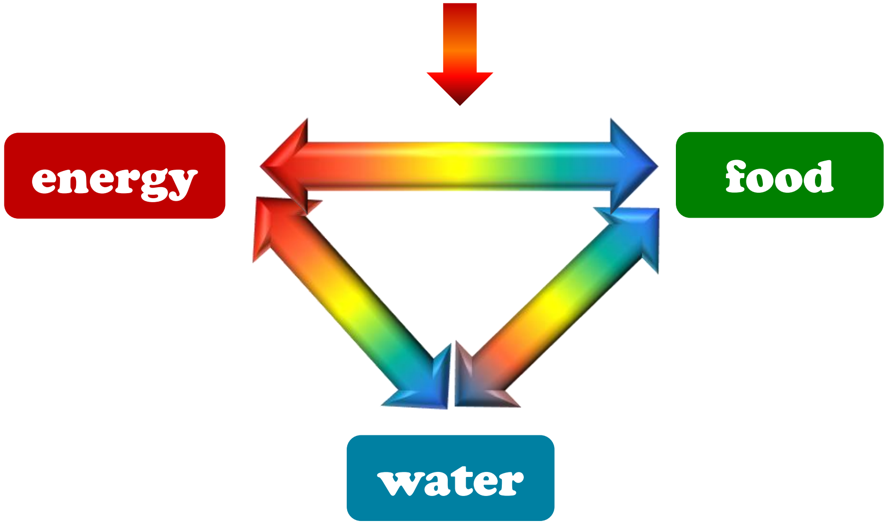




generating a mutually reinforcing spiral of insecurity

the time to act is... NOW

The triangle is now beginning to shrink and the relationship getting even tighter



If policymakers and those in power do not consider this relationship when planning and budgeting, **the relationship will become impossible to manage**

what should be done?

Enhance the Coordination of Water and Energy Policies

Far better coordination is required to establish **markets** and **investment conditions** and **regulatory mechanisms**, which optimize water and energy use and reuse

There are both conflicts and synergies with considerable implication for policy

what should be done?

Improve education about the **Water/Energy/Food** Nexus

develop a comprehensive understanding of the water/food/energy nexus at the local, national, regional, and international levels

the farmers know….

the linkage is generally only understood in rural agricultural communities

but they do not have choices…

they are market takers, not market makers…

what should be done?

Conduct National Water/Energy/Food Sustainability

Assessments

what should be done?

Enable, Incentivize, and Encourage

Reuse

Water reuse for **food production** and **energy production** should be a priority for governments and their water agencies.

what should be done?

Efficiency gains in water use will be the new paradigm

- **Australia**'s continued growth is sustained with only 30 percent of the water it had ten years ago, and where irrigation efficiencies are 85-90 percent
- **Phnom Penh** can reduce non-revenue water to less than 6 percent

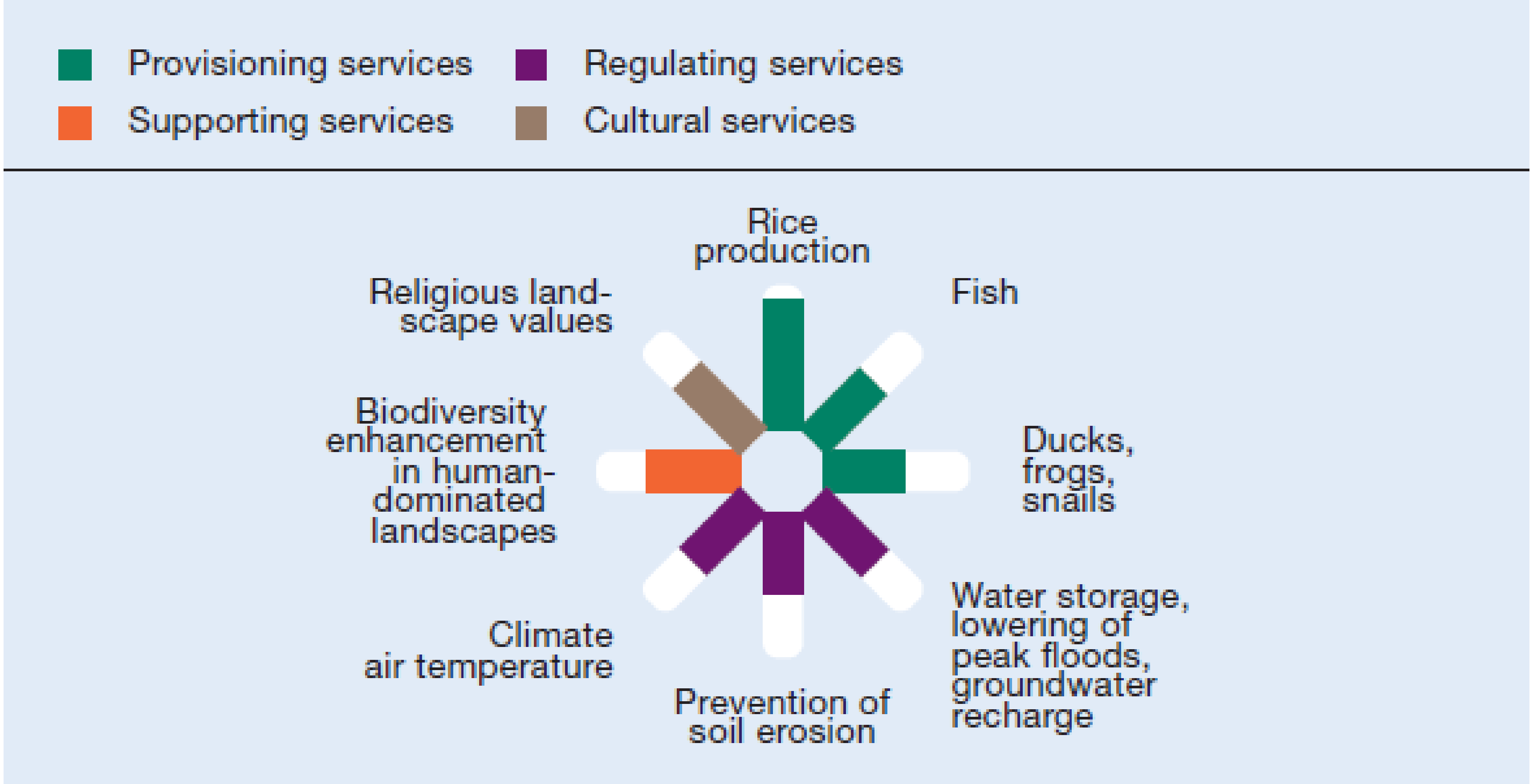
Asia needs to aggressively adopt policies that dramatically improve water use efficiencies across the range of users.

- **Increase the productivity** of water
  - A 35% increase in water productivity could reduce additional crop water consumption from 80% to 20%
- **Upgrade rainfed systems** — a little water can go a long way
- **Small Scale Irrigation** – is this the Future?
  - Private and informal irrigation is important in terms of both food production and food security
- **Adapt yesterday’s irrigation** to tomorrow’s needs
  - Modernization, a mix of technological and managerial upgrading to improve responsiveness to stakeholder needs, will enable more productive and sustainable irrigation

Pathways to improving water productivity

- Improvement with respect to **evapotranspiration**
  - Improving soil fertility
  - Using international trade to increase global water productivity
  - Reducing evaporation
- Improving the **productivity of water deliveries**
- Increasing the **productivity of livestock**
- Increasing **productivity in fisheries and aquaculture**
- Applying **integrated approaches** to increasing the value per unit of water
- Adopting an integrated basin perspective for **understanding water productivity tradeoffs**

Integrated and multiple-use systems—in which water serves crops, fish, livestock, and domestic purposes—can increase the value derived per unit of water used



Source: IWMI 2007

Strategies to increase water productivity must also consider what happens to

drainage flows

Drainage flows are desirable when they are a source of water for downstream farmers, reach shallow groundwater for home gardens and domestic wells or support other important ecosystem services

what should be done?

Create Sustainable Management Approaches through

Stakeholder Input

To sustain food, energy, and water security:
Governments, **water users**, and the **private sector** will need to partner together to assume and share the costs, risks, results, and impacts of investment in water

what should be done?

Develop Proper **Pricing**

Creating the proper pricing structure for food, energy, and water will encourage sustainable use of water and energy

"The **water-food-energy triangle** does not necessitate theorems, nor does it harbor any myths…

Among other things, it is also an **early warning system** asking us to act now for sustaining Asia's water future."

Thank you

msbabel@ait.asia

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