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

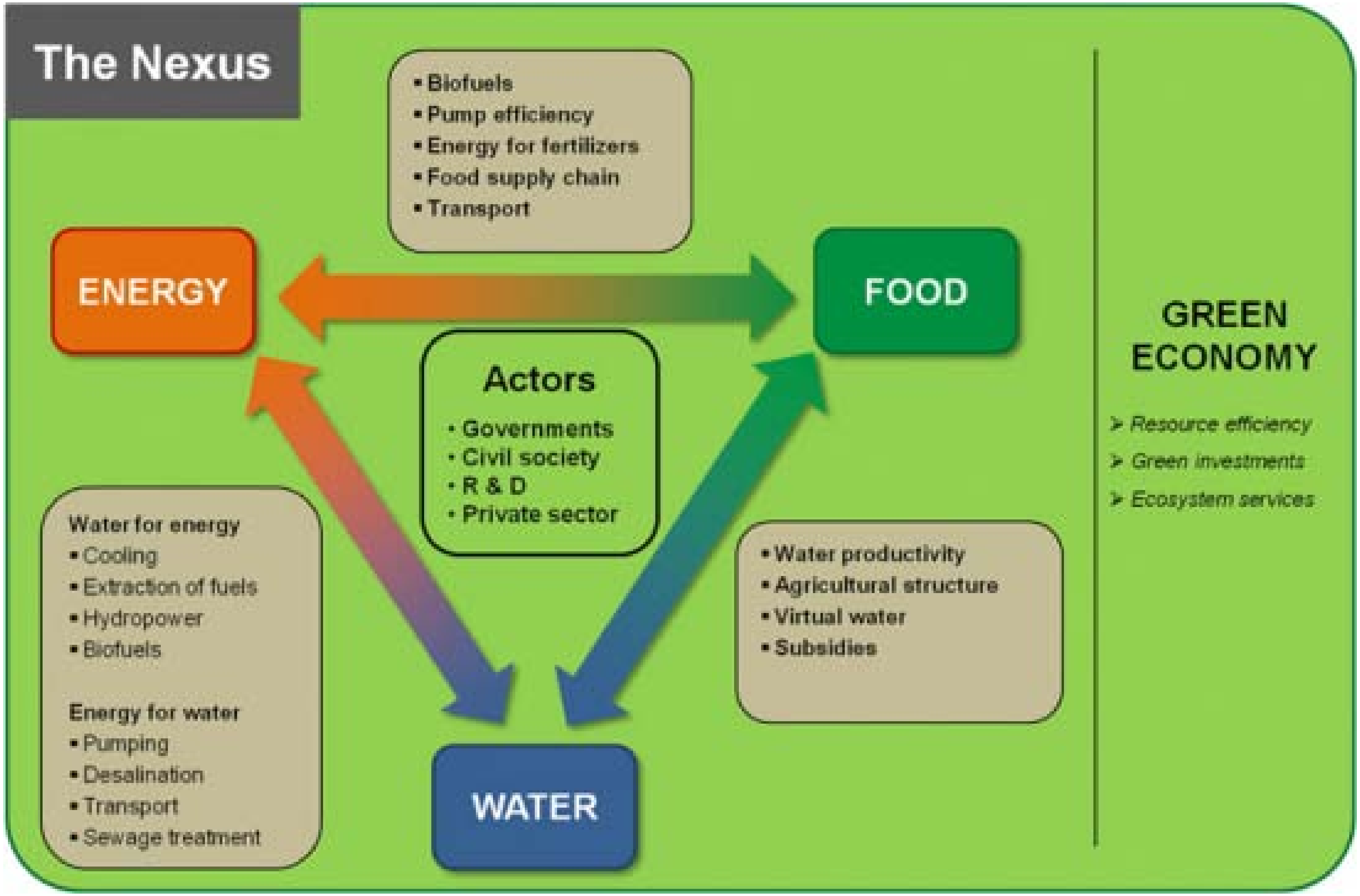
Imagine a canal 10 m deep, 100 m wide and 7.1 million km long (enough to go around the world 180 times). That is the amount of water it takes each year to produce food for today's 6.5 billion people….

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
   - Bio-fuel and hydrology
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

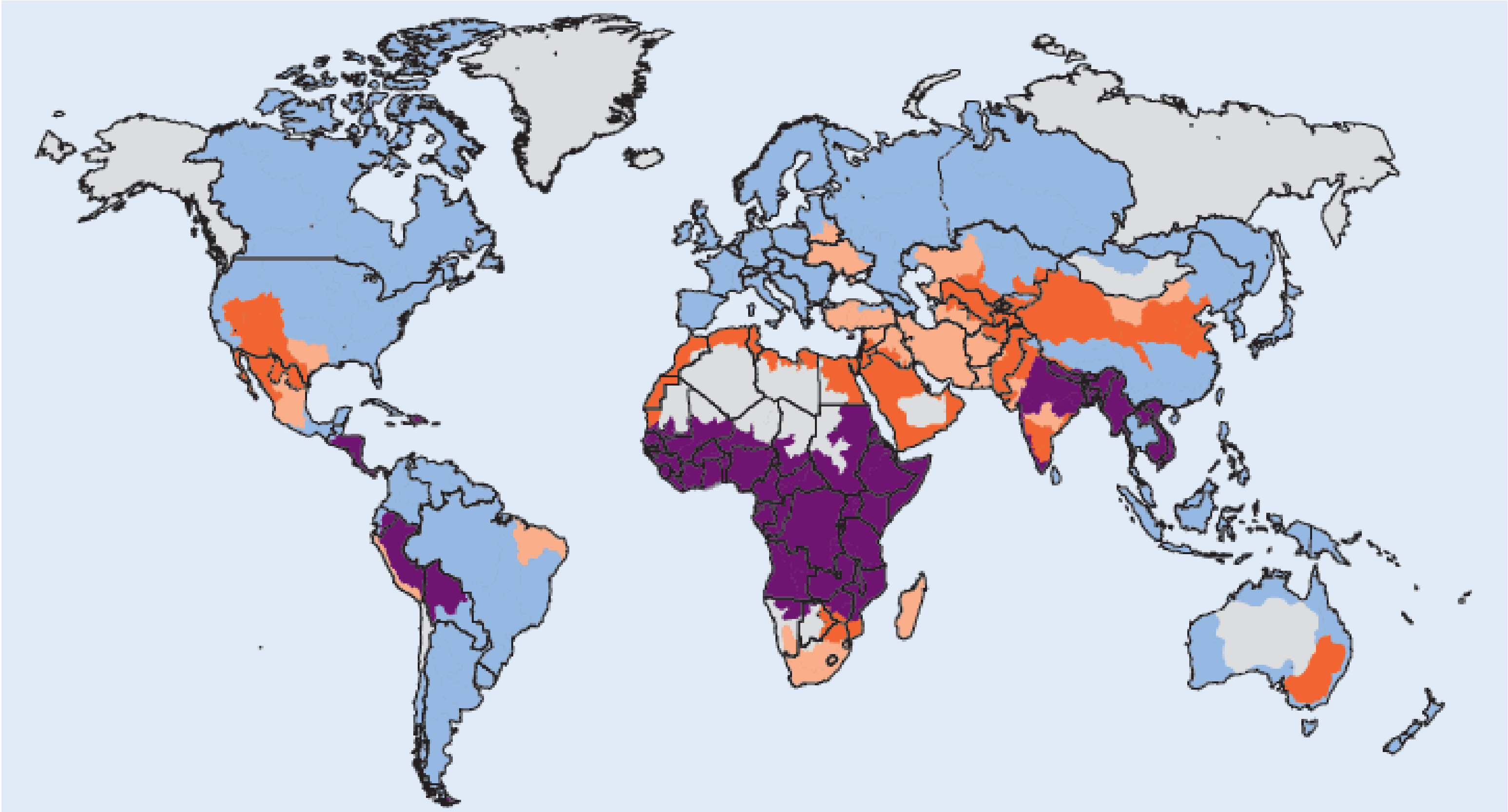
"One of the many things I learned as president was the **centrality of water** in the social, political and economic affairs of the country, the continent and the world."
– Nelson Mandela, at the World Summit in Sustainable Development, 2002

"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

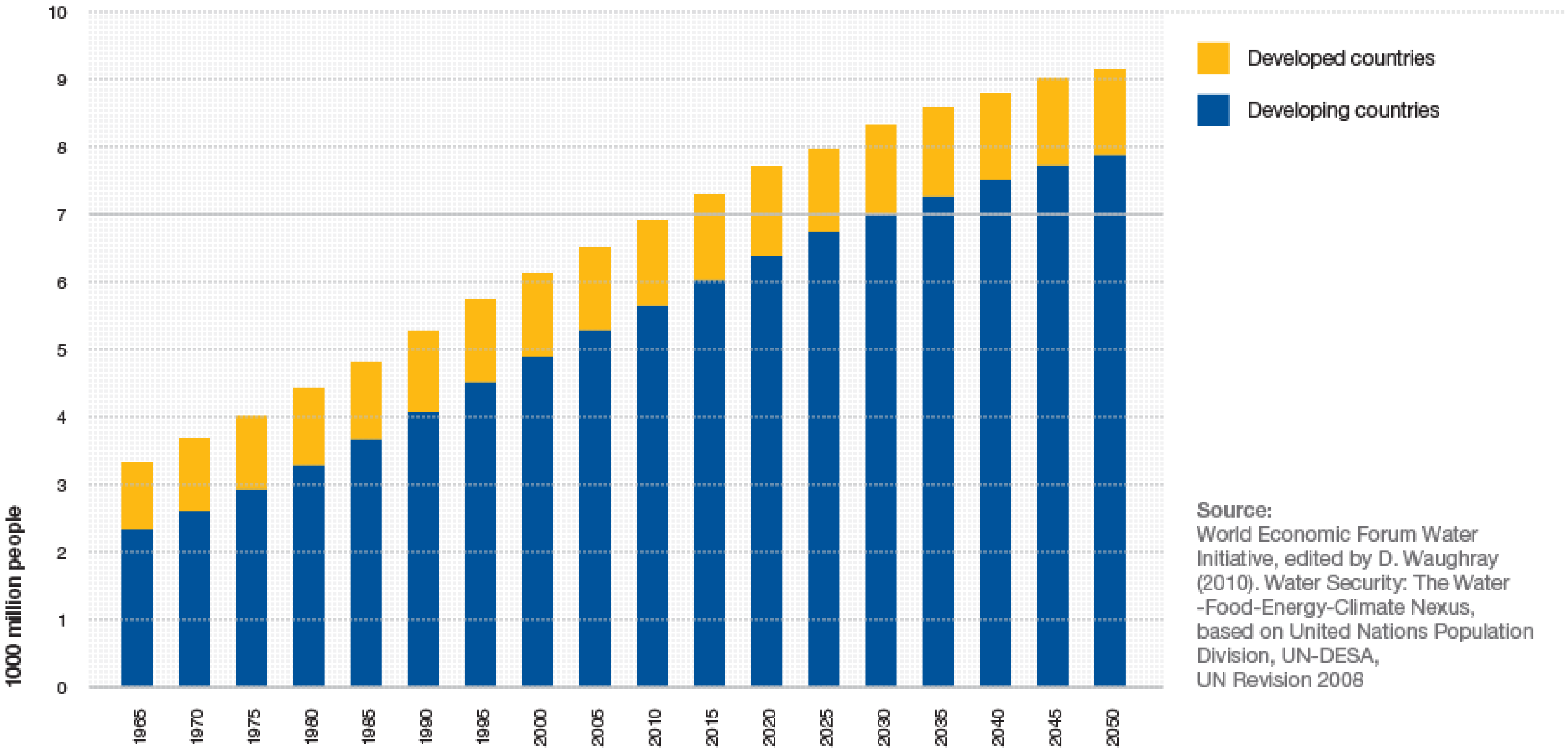


Source: IWMI 2007

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

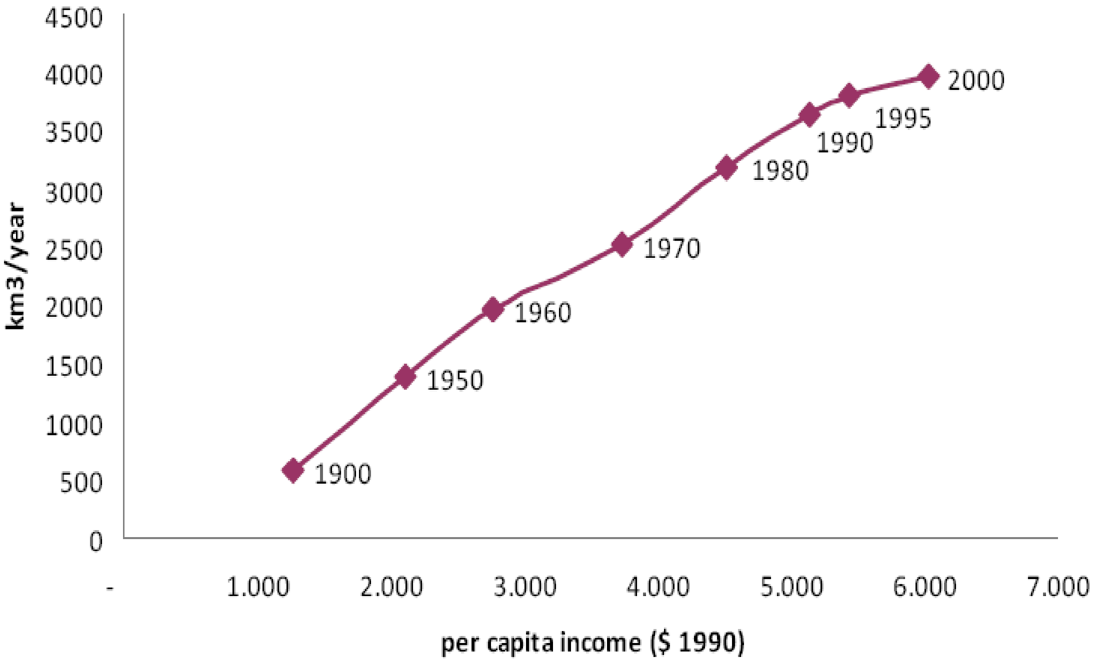
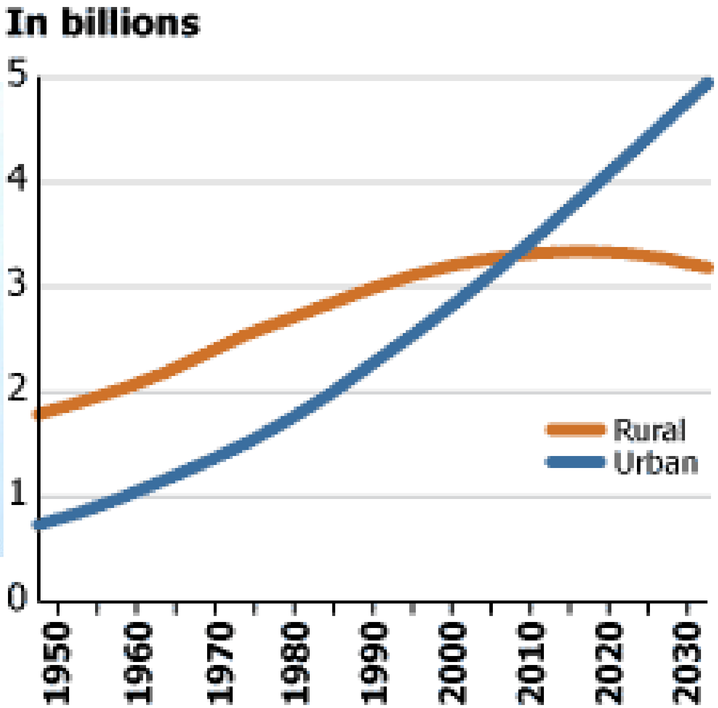
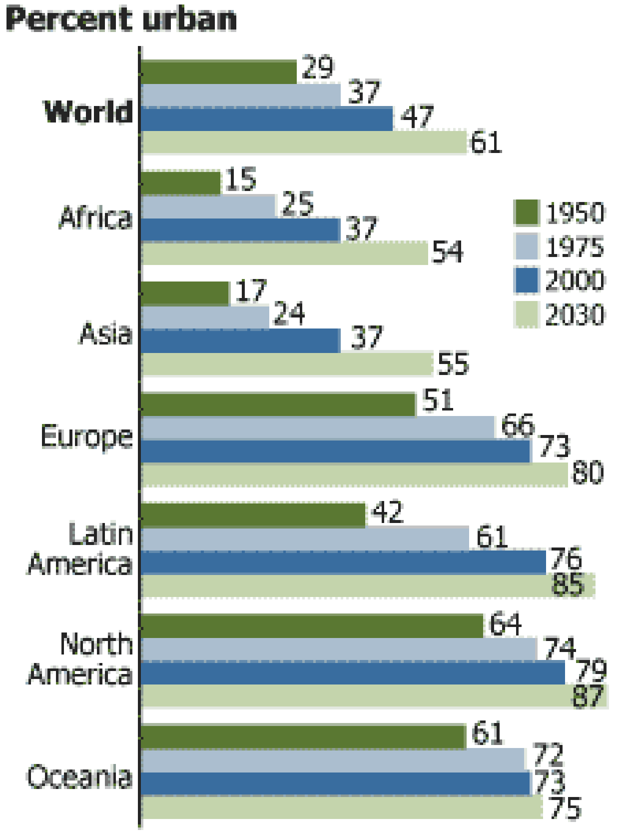


Figure 1: Worldwide water withdrawal, 1900-2000

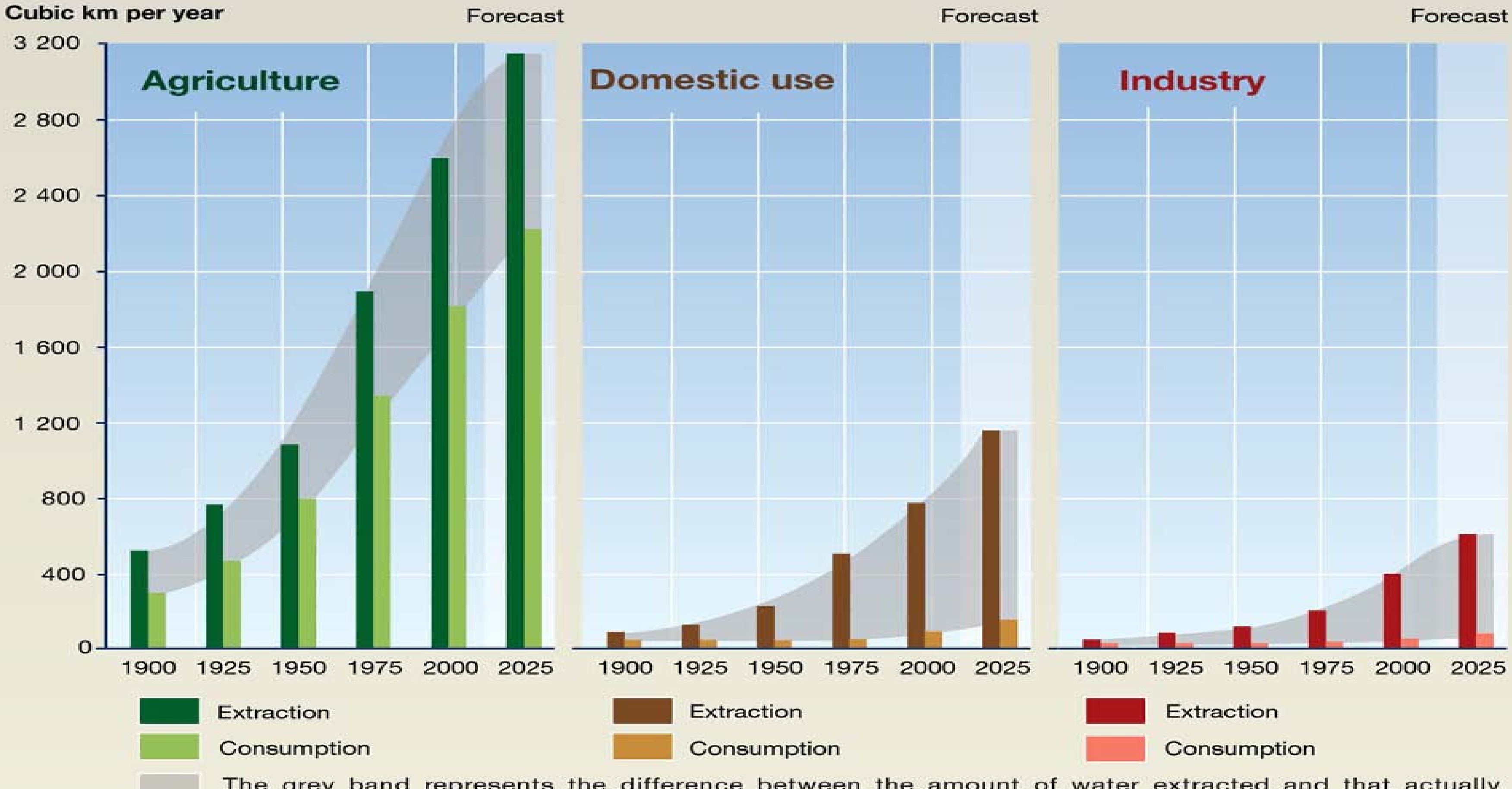
- More than half of the world's population now lives in an urban environment
- 17 out of 24 megacities with > 10 million people are in developing countries





Source: World Economic Forum 2011

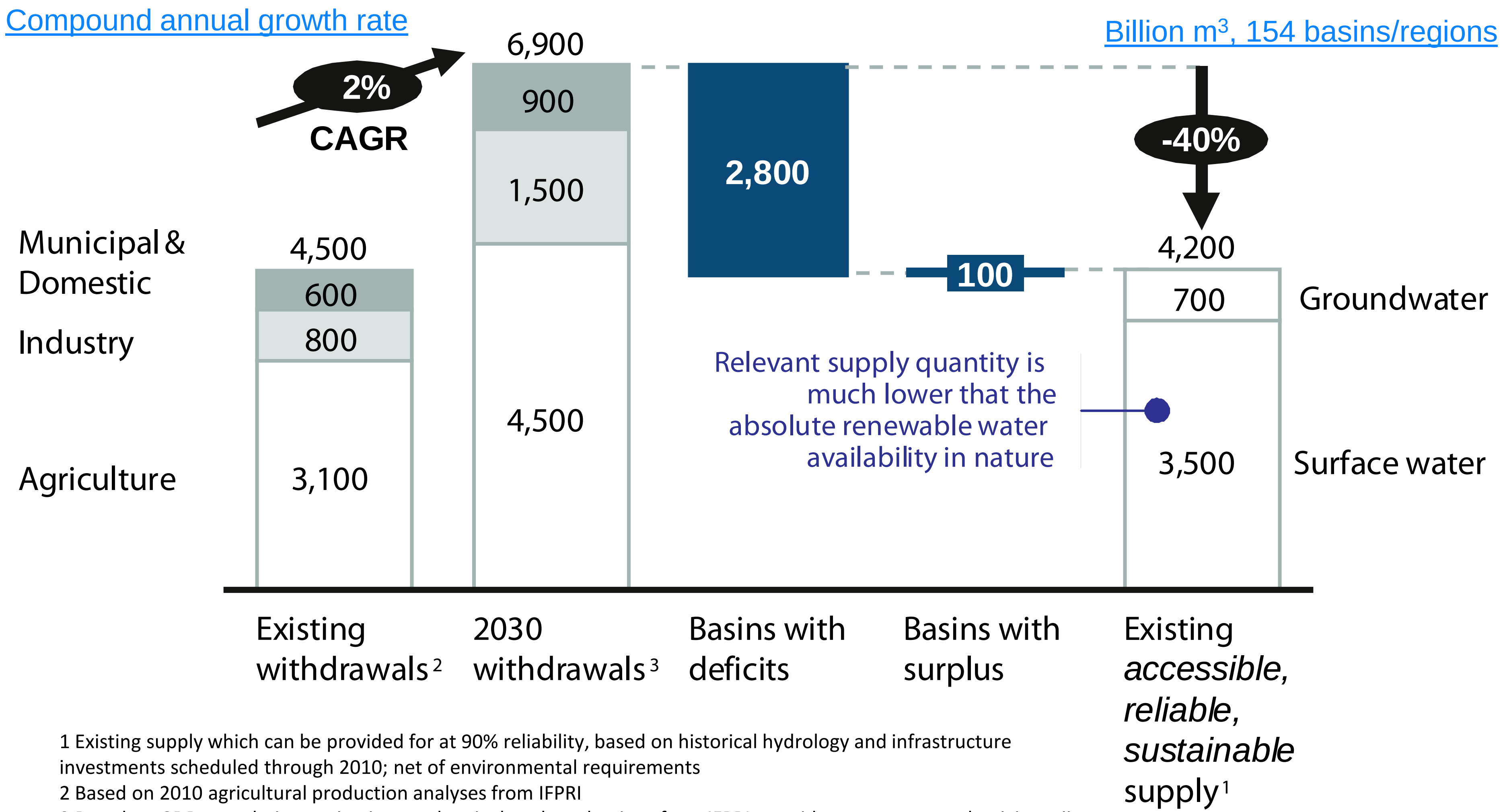
Trends in global water demand



The grey band represents the difference between the amount of water extracted and that actually consumed. Water may be extracted, used, recycled (or returned to rivers or aquifers) and reused several times over. Consumption is final use of water, after which it can no longer be reused. That extractions have increased at a much faster rate is an indication of how much more intensively we can now exploit water. Only a fraction of water extracted is lost through evaporation.

Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999.

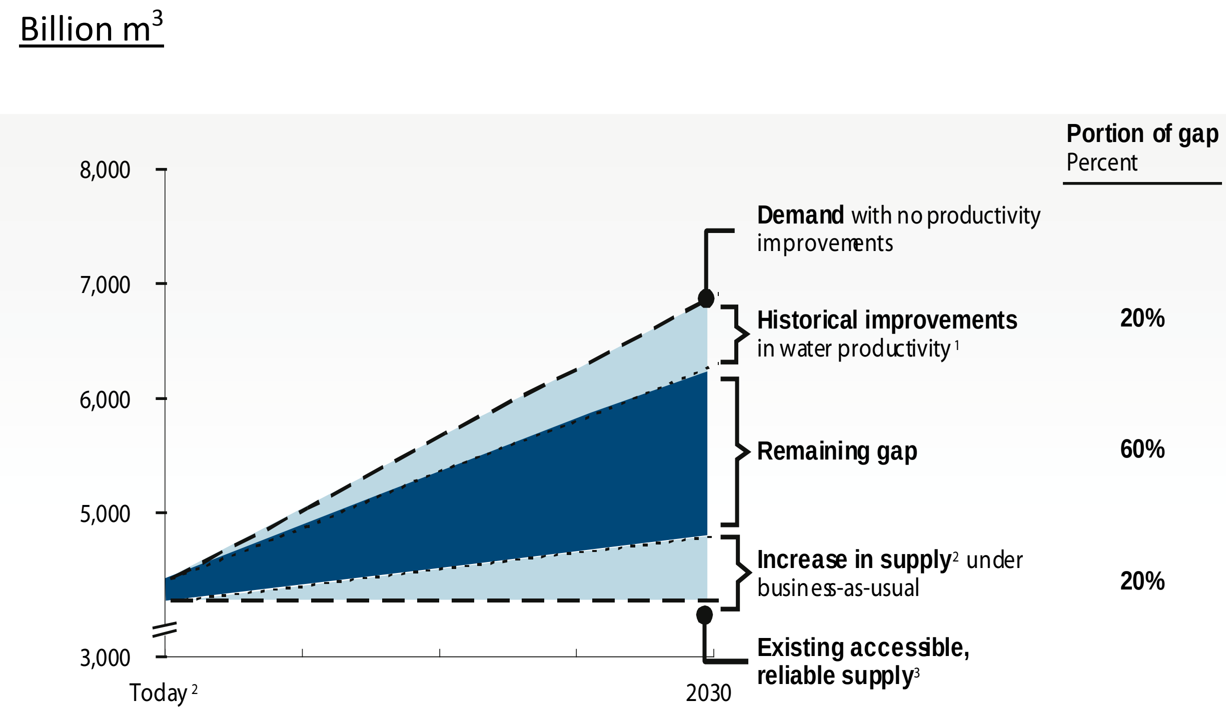
Aggregated global gap between existing accessible, reliable supply[1] and 2030 water withdrawals, assuming no efficiency gains



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

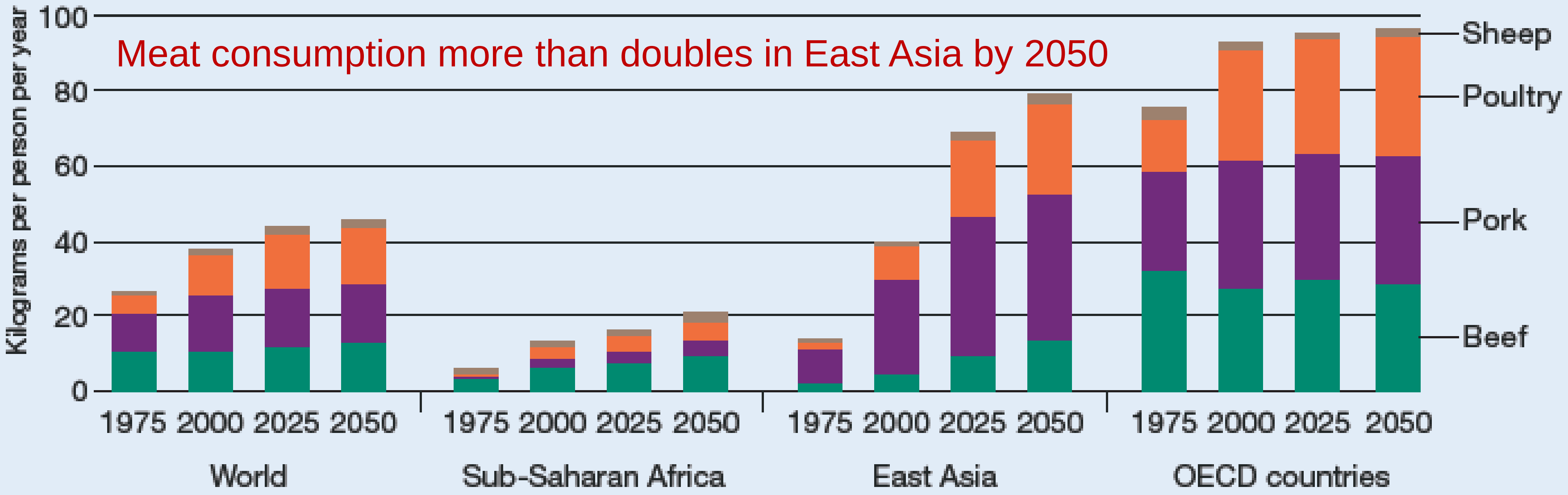


- If these trends are insufficient to close the gap:
  - Depletion of fossil reserves
  - Water for environment is drained
  - Demand will go unmet

Climate Change will exacerbate the problem

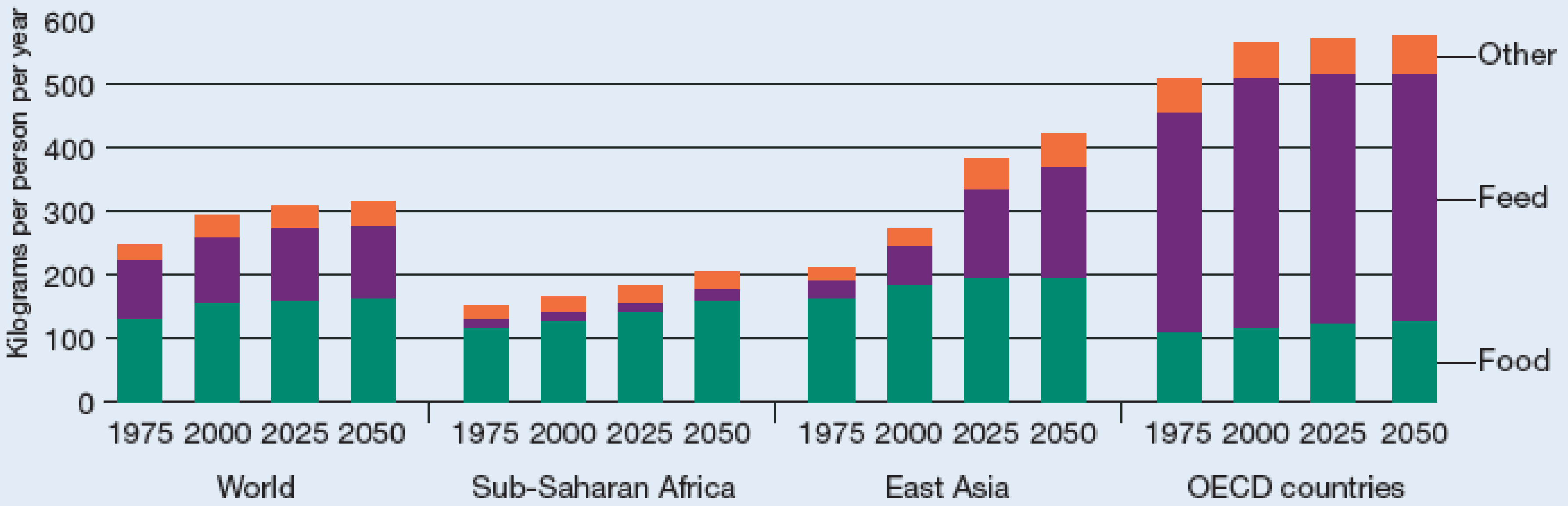
SOURCE: 2030 Water Resources Group - Global Supply and Demand model; IFPRI; FAOSTAT

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



Source: for 1975 and 2000, FAOSTAT statistical database; for 2025 and 2050, International Water Management Institute analysis done for the Comprehensive Assessment of Water Management in Agriculture using the Watersim model; chapter 3.

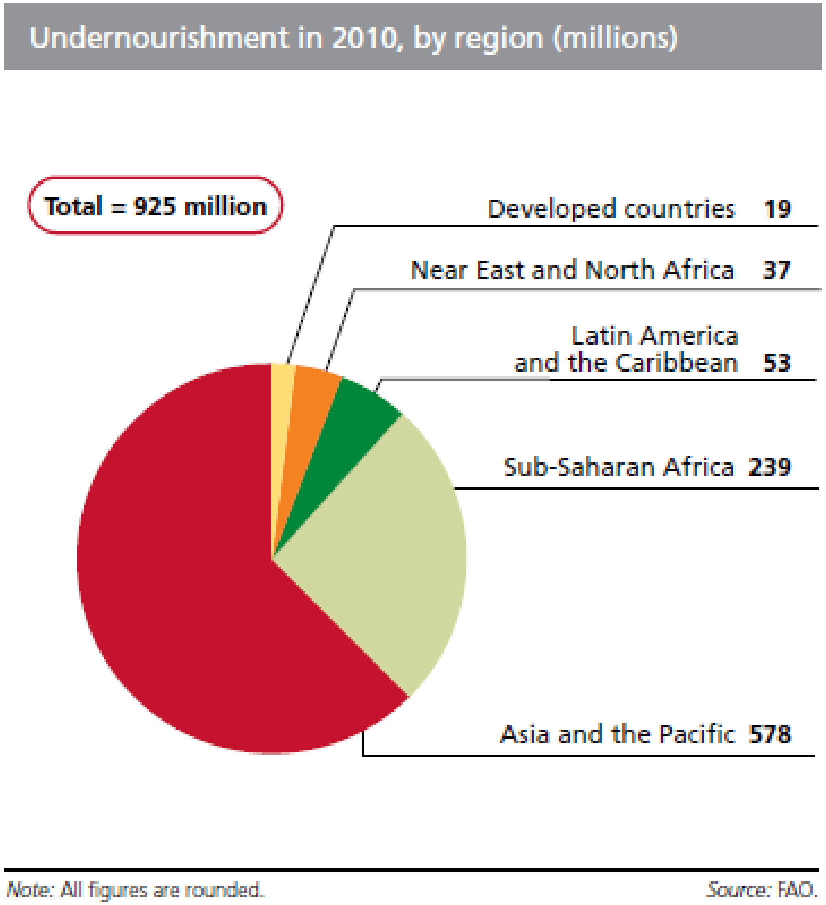
Global demand for meat will double from 229 million tonnes in 1999-2001 to 465 million tonnes in 2050.



Source: for 1975 and 2000, FAOSTAT statistical database; for 2025 and 2050, International Water Management Institute analysis done for the Comprehensive Assessment of Water Management in Agriculture using the Watersim model; chapter 3.

Feed demand drives future demand for grains

Source: IWMI 2007



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

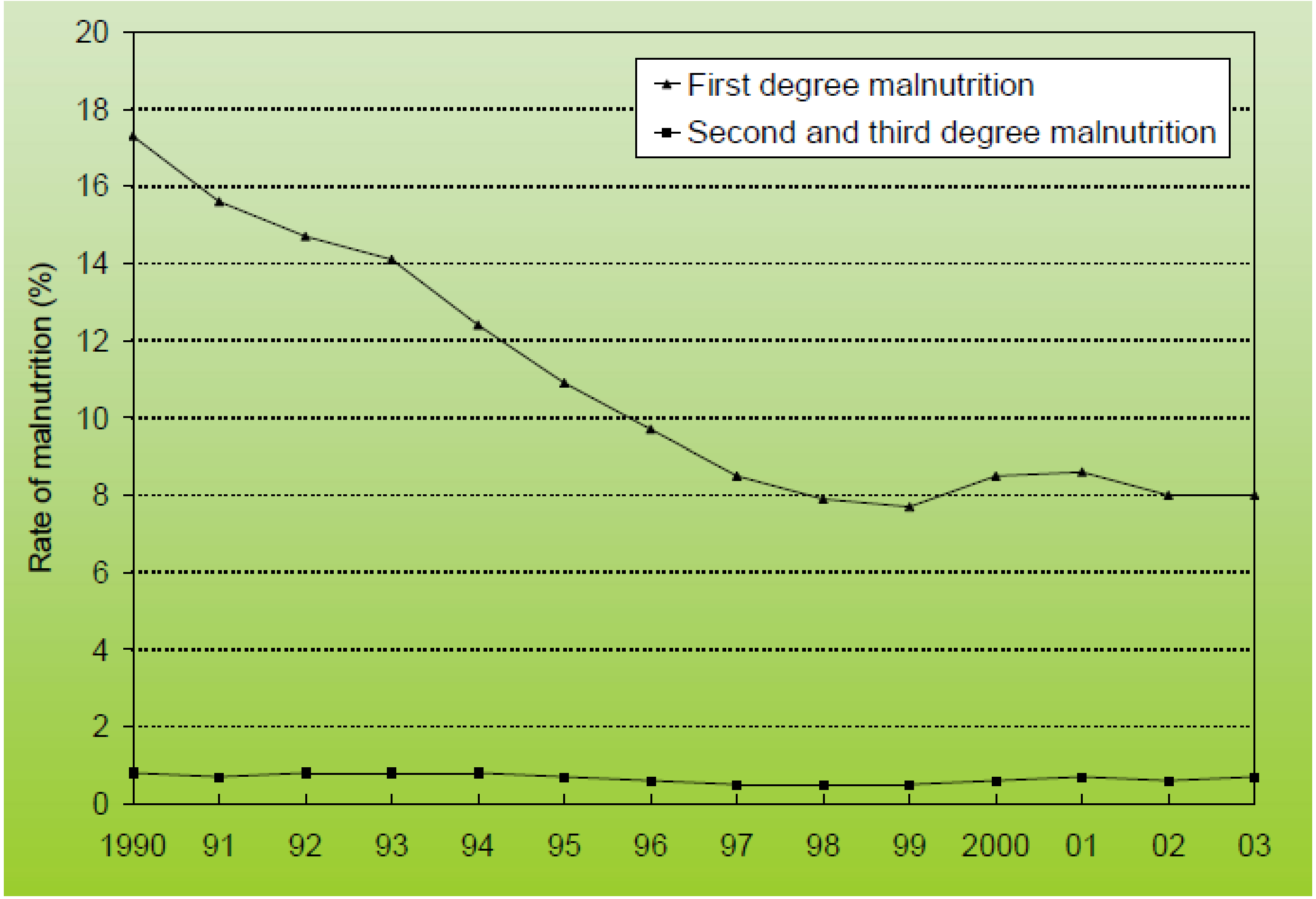
Total population: 2005-07: 66.5 million
Source: FAO, 2010

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

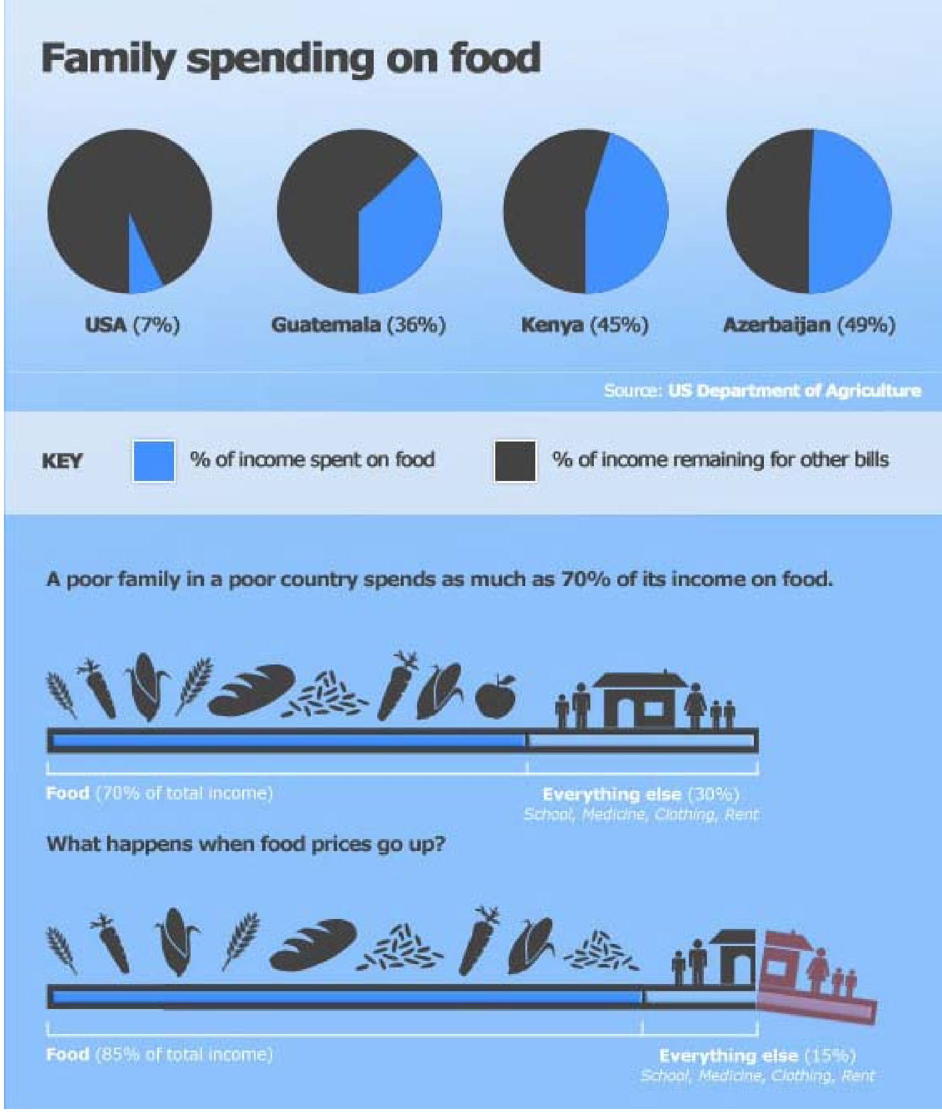
Thailand is also one of the world's leading producers of sugarcane, cassava, longan, durian, mangosteen and longkong

Malnourishment in Thailand



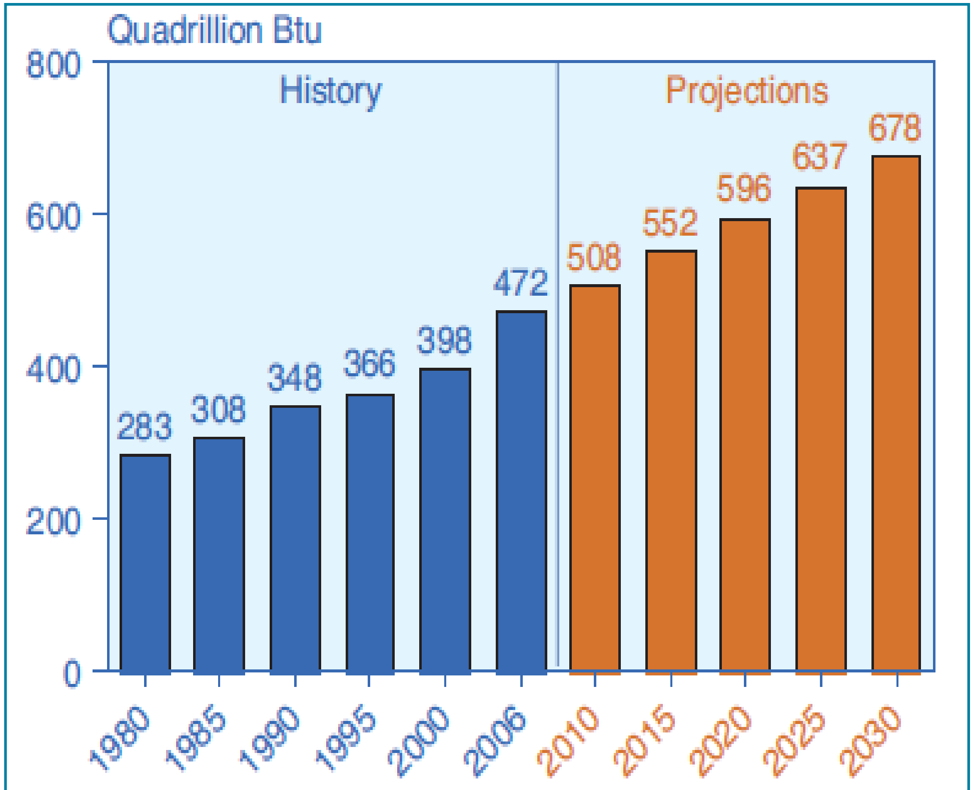
Source: Thailand Environment Institute

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

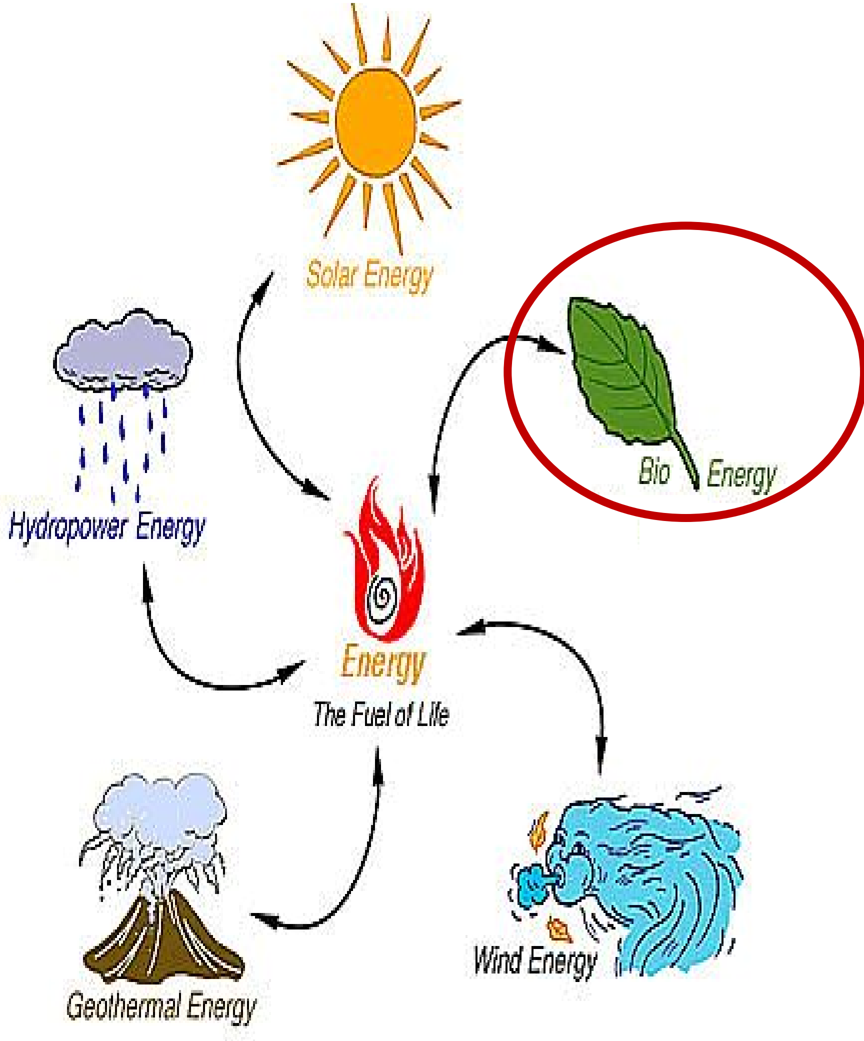


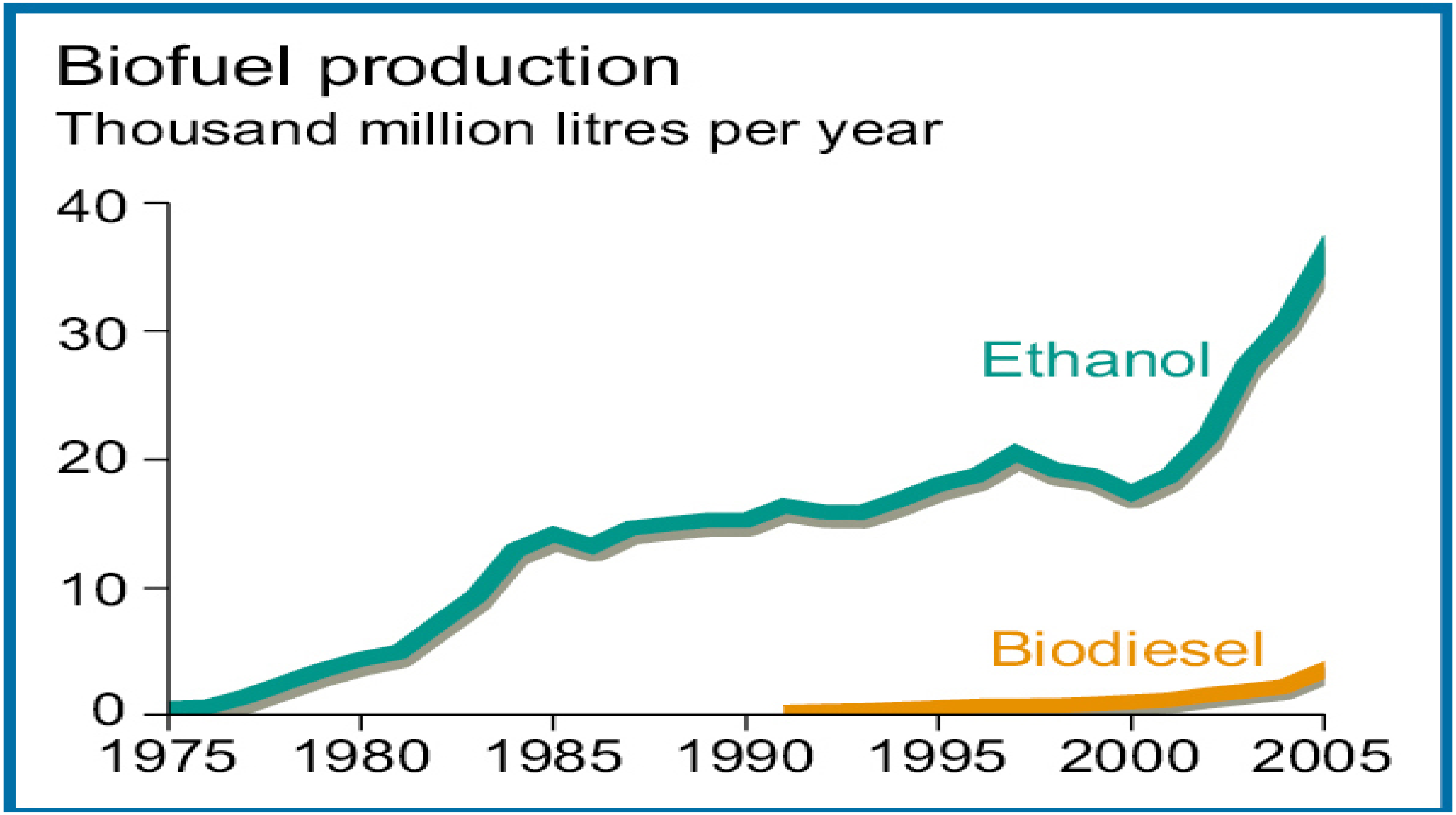
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

1 Btu (British Thermal Unit) = 1 055 Joules

OECD= Organization for Economic Co-operation and Development

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





World bio-fuel production over 1991 – 2005
(Source: Licht, 2007/ 2009)

Global bio-ethanol projections

Country	Bio-ethanol production (million litres)			Share of global bio-ethanol production (%)			Energy share in gasoline type fuel use (%)		
	2005-07 average[a]	2008	2017	2005-07 average[a]	2008	2017	2005-07 average[a]	2008	2017
United States	21478	38394	52444	42.71	49.83	41.34	2.63	4.55	6.03
Brazil	17396	22110	40511	34.60	28.69	31.93	32.31	40.43	56.62
China	5564	6686	10210	11.07	8.68	8.05	1.66	1.98	4.03
EU27	2049	4402	11883	4.07	5.71	9.37	1.00	2.19	4.88
India	1411	1909	3574	2.81	2.48	2.82	1.73	2.65	5.61
Canada	762	1383	2730	1.52	1.79	2.15	1.26	2.34	4.07
Columbia	272	497	796	0.54	0.64	0.63	3.34	5.21	4.99
Thailand	**285**	**408**	**1790**	**0.57**	**0.53**	**1.41**	**1.26**	**2.08**	**11.70**
Other countries*	1066	1266	2922	2.13	1.65	2.3			
Total	**50,283**	**77,055**	**126,860**				**3.78**	**5.46**	**7.63**

Source: OECD/FAO (2008); [a] estimated value

*Other countries include South Africa, Indonesia, Vietnam, Australia, Philippines, Turkey, Malaysia, Ethiopia, Tanzania, Mozambique and Peru

Global bio-diesel projections

Country	Biodiesel production (million litres)			Share of global biodiesel production (%)			Energy share in diesel type fuel use (%)		
	2005-07 average[a]	2008	2017	2005-07 average[a]	2008	2017	2005-07 average[a]	2008	2017
EU27	5095	6580	13271	66.95	53.61	54.49	2.12	2.98	4.99
United States	1429	2017	1731	18.78	16.43	7.11	0.28	0.47	0.46
Australia	199	911	994	2.61	7.42	4.08	1.82	8.21	8.15
Indonesia	241	753	2984	3.17	6.14	12.25	0.28	0.66	7.88
Brazil	158	760	2519	2.08	6.19	10.34	0.29	1.15	3.61
Malaysia	148	443	1137	1.94	3.61	4.67	0.40	0.43	0.80
India	277	317	385	3.64	2.58	1.58	0.59	0.88	0.88
Columbia	10	218	388	0.13	1.78	1.59	0.00	4.04	5.29
Canada	46	207	660	0.60	1.69	2.71	0.22	1.05	2.78
Thailand	**0**	**48**	**75**	**0.00**	**0.39**	**0.31**	**0.00**	**0.00**	**0.00**
Other countries*	7	19	213	0.09	0.15	0.88			
Total	**7,610**	**12,273**	**24,357**				**0.93**	**1.50**	**2.59**

Source: OECD/FAO (2008); [a] estimated value

*Other countries include Tanzania, Ethiopia, Mozambique, Vietnam, South Africa, Philippines, Turkey and Peru

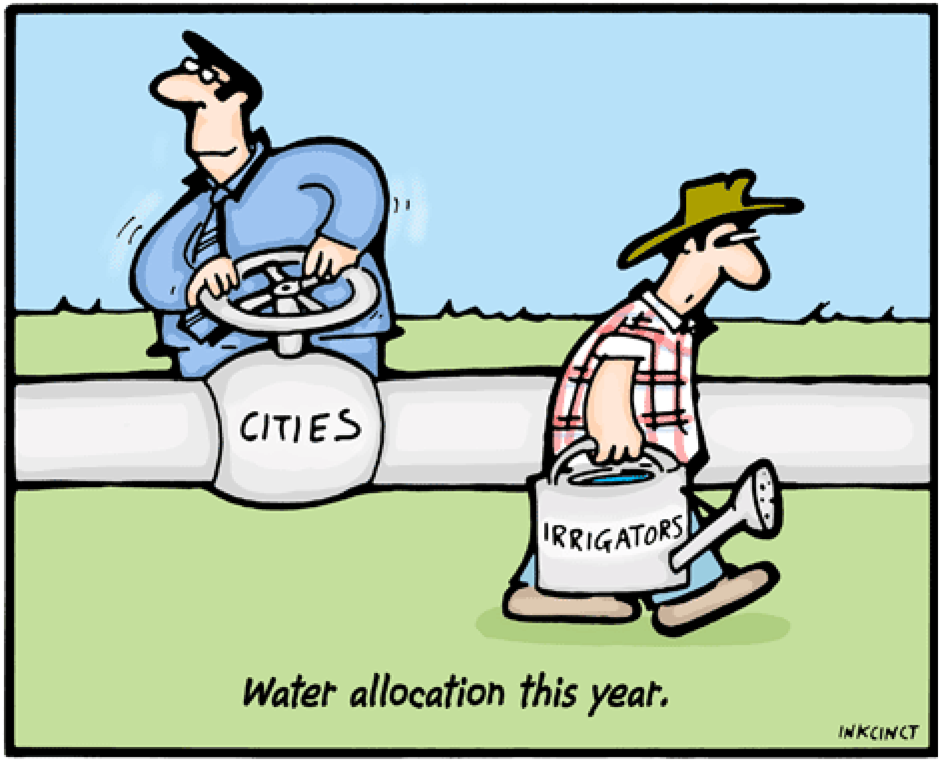
Crops used for bio-fuel production in selected countries

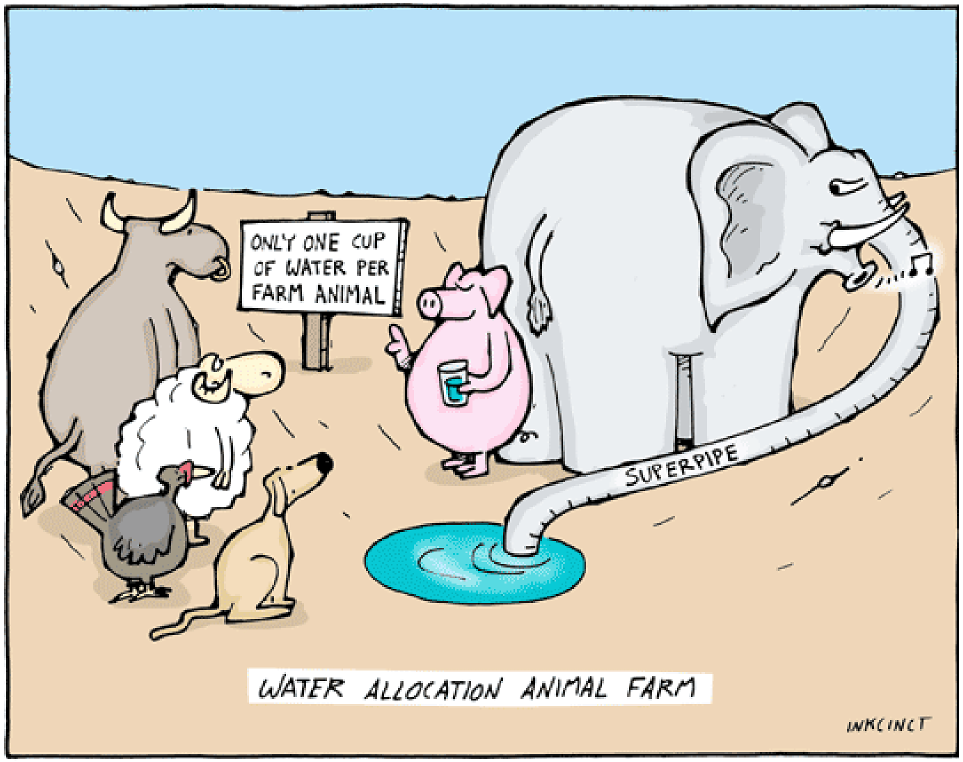
Country	Crops used for biofuel production	
	Bio-ethanol	**Biodiesel**
EU27	Rye, wheat, sugar beet, forestry	Rapeseed
United States	Corn (95%) , sorghum	Soya oil
Australia	Sugarcane	Soybeans
Indonesia	Sugarcane	Oil palm
Brazil	Sugarcane	Soya oil , castor oil, Oil palm
Malaysia		Oil palm
China	Corn, cassava, sugarcane	Jatropha
India	Sugarcane	Jatropha
Columbia	Sugarcane	Oil palm
Canada	Wheat and straw	Straw
Thailand	**Sugarcane, cassava**	**Oil palm, jatropha**
Tanzania	Sugar cane, wheat cassava	Jatropha, sunflower oil, coconut
Ethiopia	Molasses, cassava	Jatropha
Vietnam	Sugarcane, cassava	Jatropha
South Africa	Sugarcane	Jatropha
Philippines	Sugarcane	Coconut oil
Peru	Sugarcane	

Sources: Dufey (2006), APEC (2008) and http://www.bioenergywiki.net

Water allocation issues

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

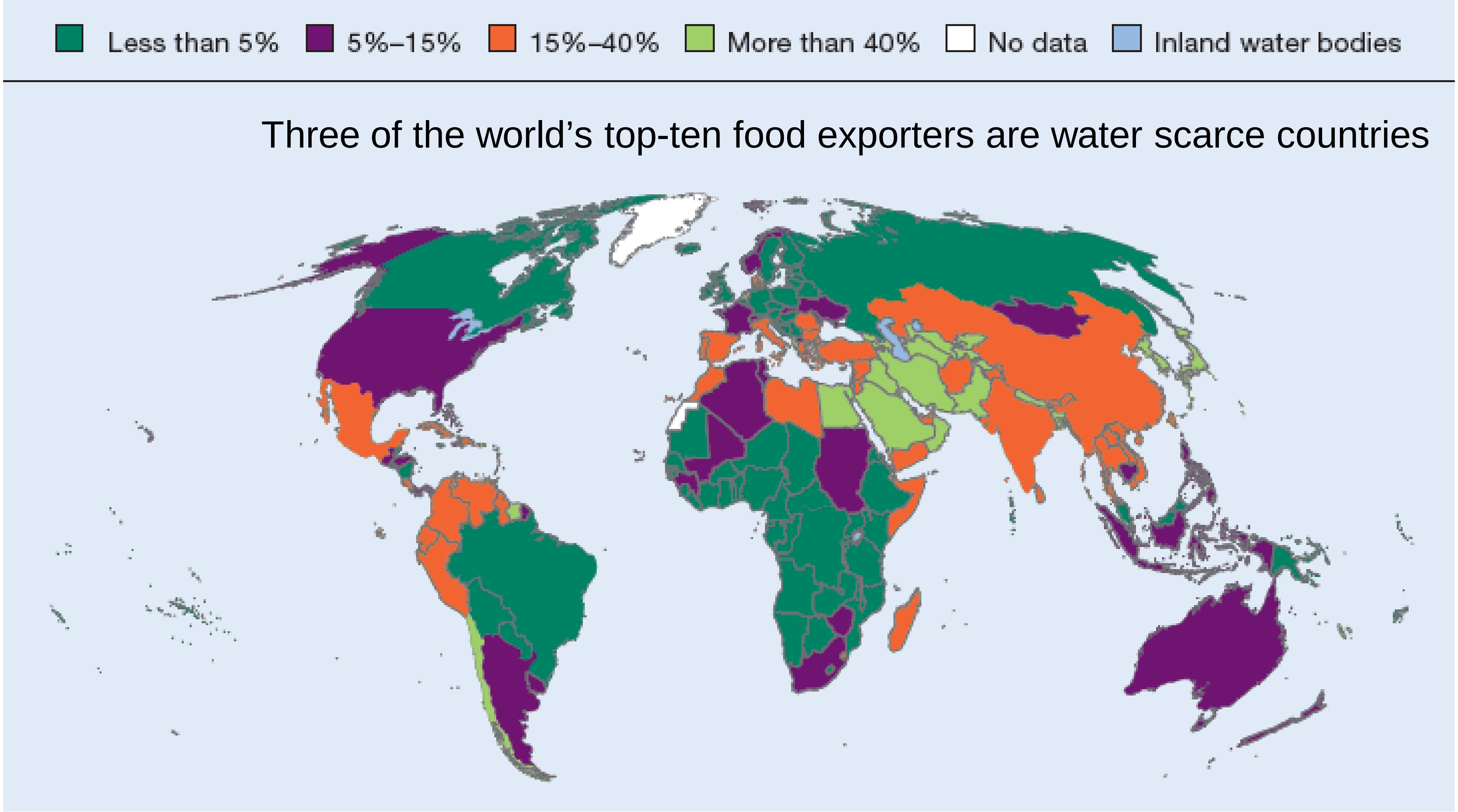




The challenge for global agriculture is to **grow more food** with **declining allocations of land and water**

1.2 Water and food issues

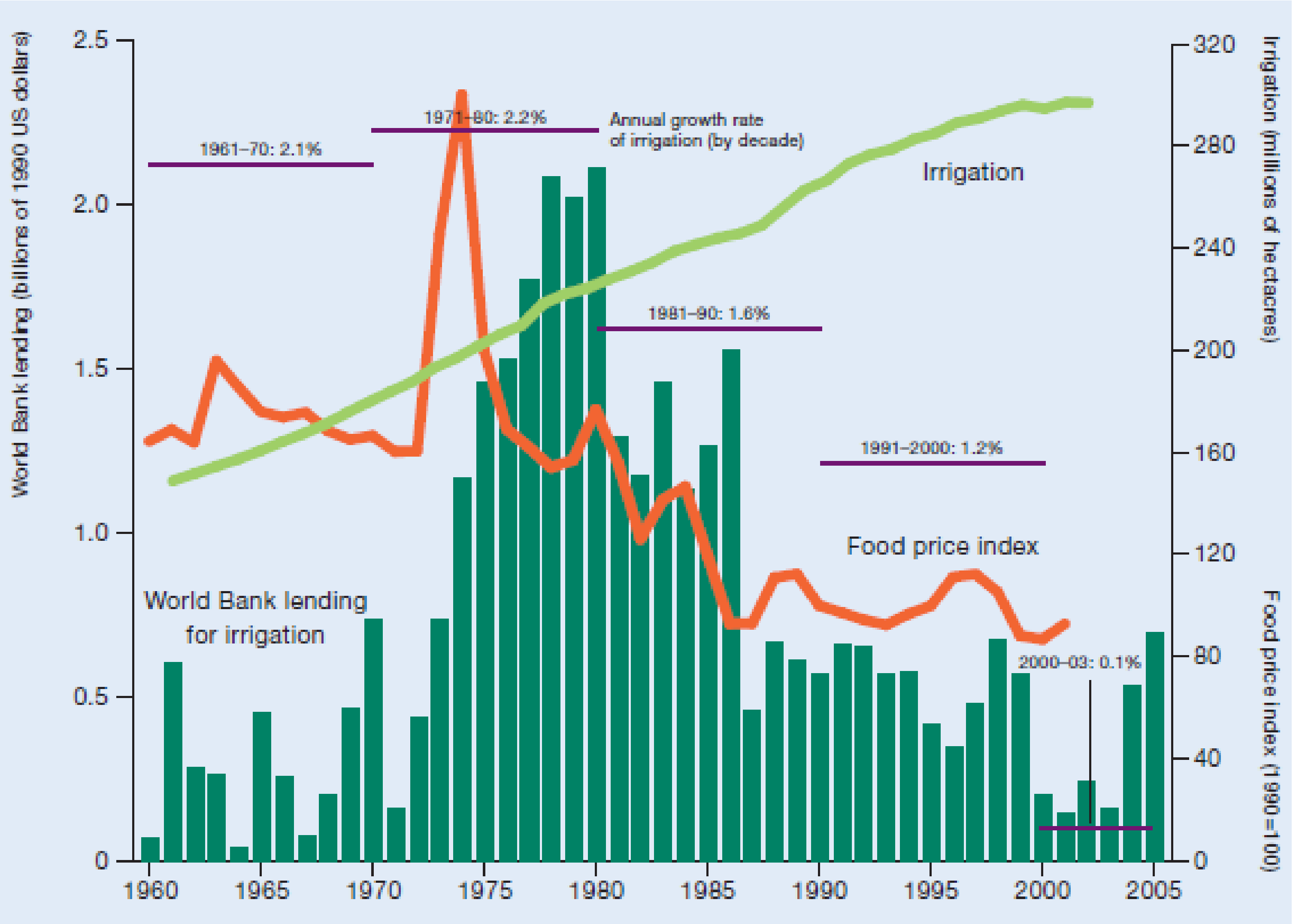
Area under irrigation as a share of cultivated land



Three of the top-ten food importers are water rich

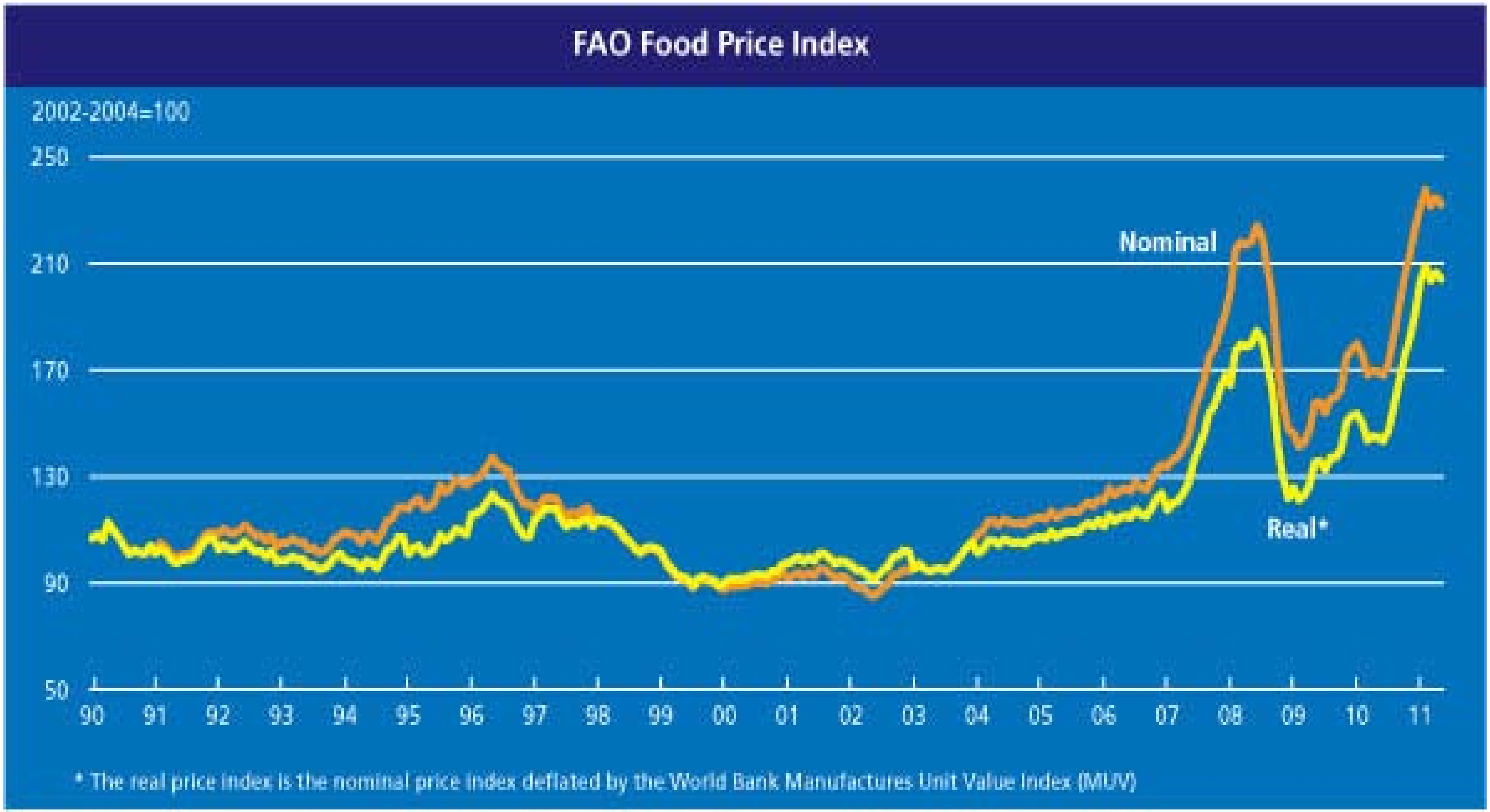
Source: IWMI 2007

Irrigation and food prices



Source: CPWFA 2007

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

generate ENERGY … is needed to generate WATER … is needed to

both challenges must be addressed together

Vicious Cycles

Water required for energy production by different processes

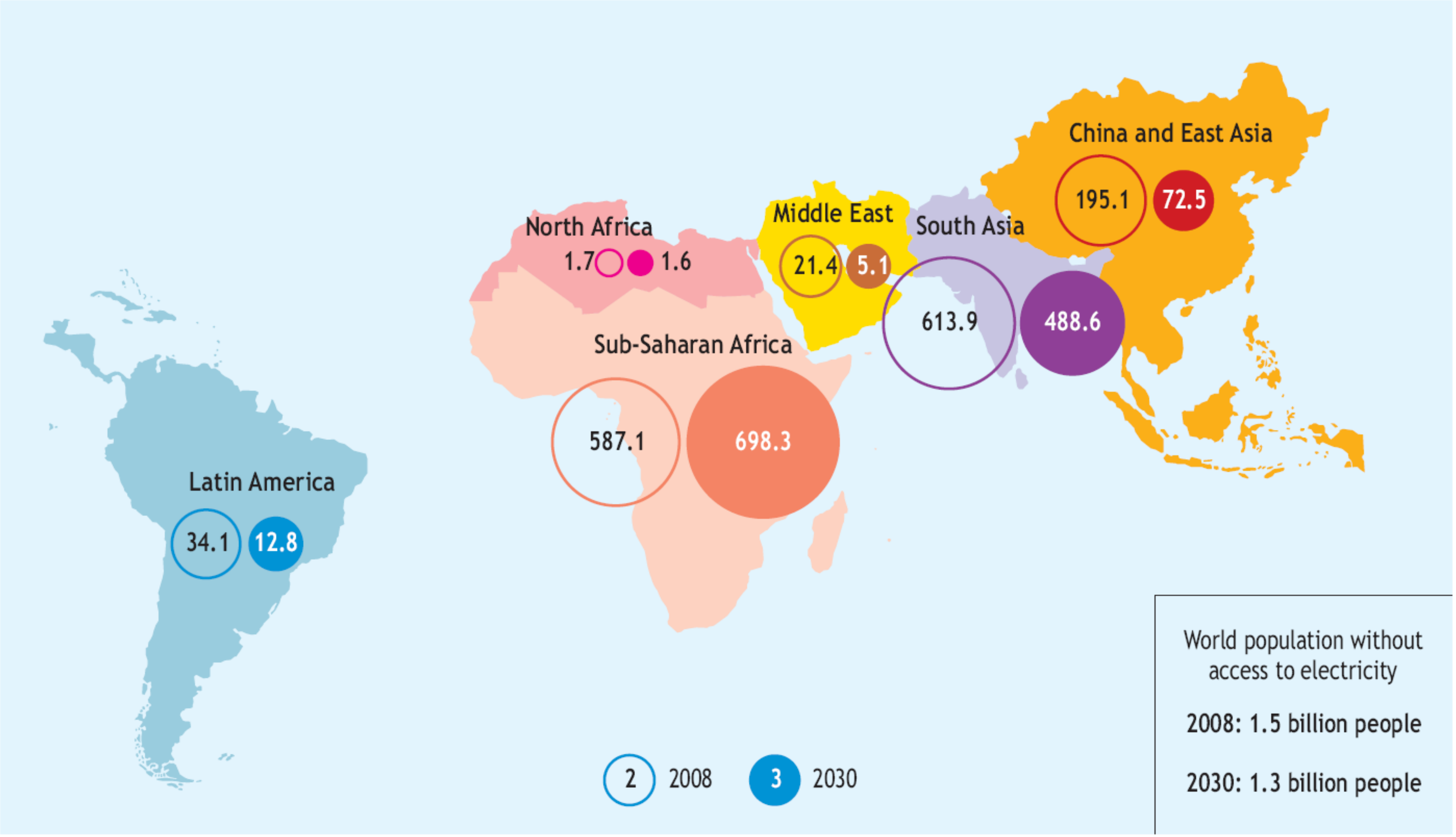
Water consumed to produce 1 MWh of electricity:[16]

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

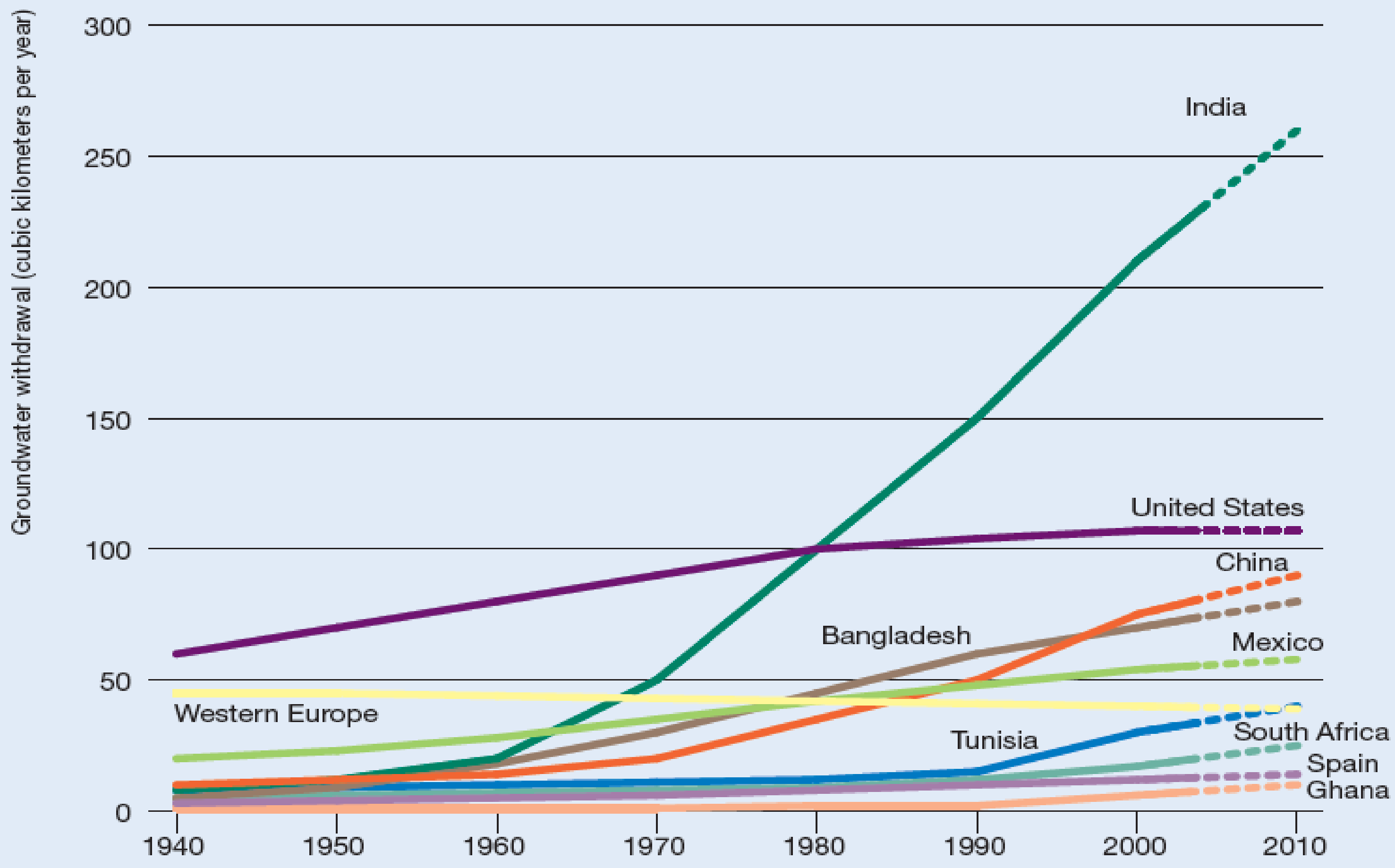
People without access to electricity (million)



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: Shah 2005.

Source: IWMI 2007

Electricity consumption in Indian Agriculture

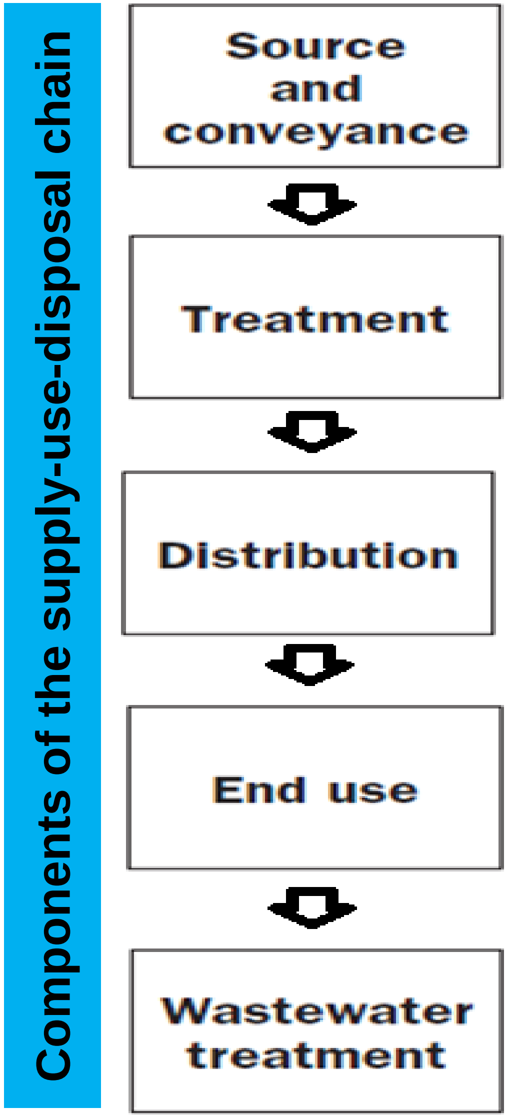
Electricity consumption	1980-81	1999-2000	Percentage change
Total electricty consumption (MkWh)	81 400	332 474	308
Electricity consumption in the agricultural sector			
Total (MkWh)	14 489 (17.8)	98 800 (29.7)	582
Per tube well (kWh)	3 346	8 100	142
Per 1000 ha of GCA(kWh)	80	520	550
Per Rs 1000 of agricultural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

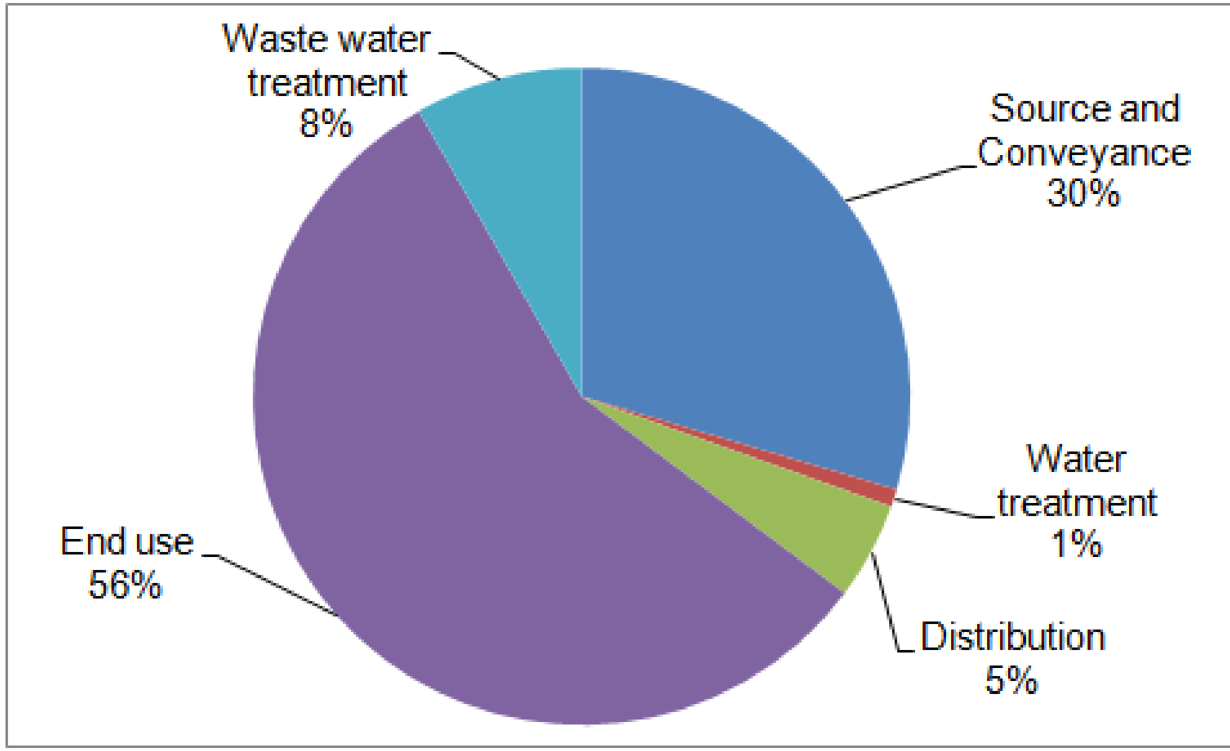
[a] Provisional

Note: Figures in parentheses denote percentage of total consumption.

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

MkWh = Million kilowatts-hour



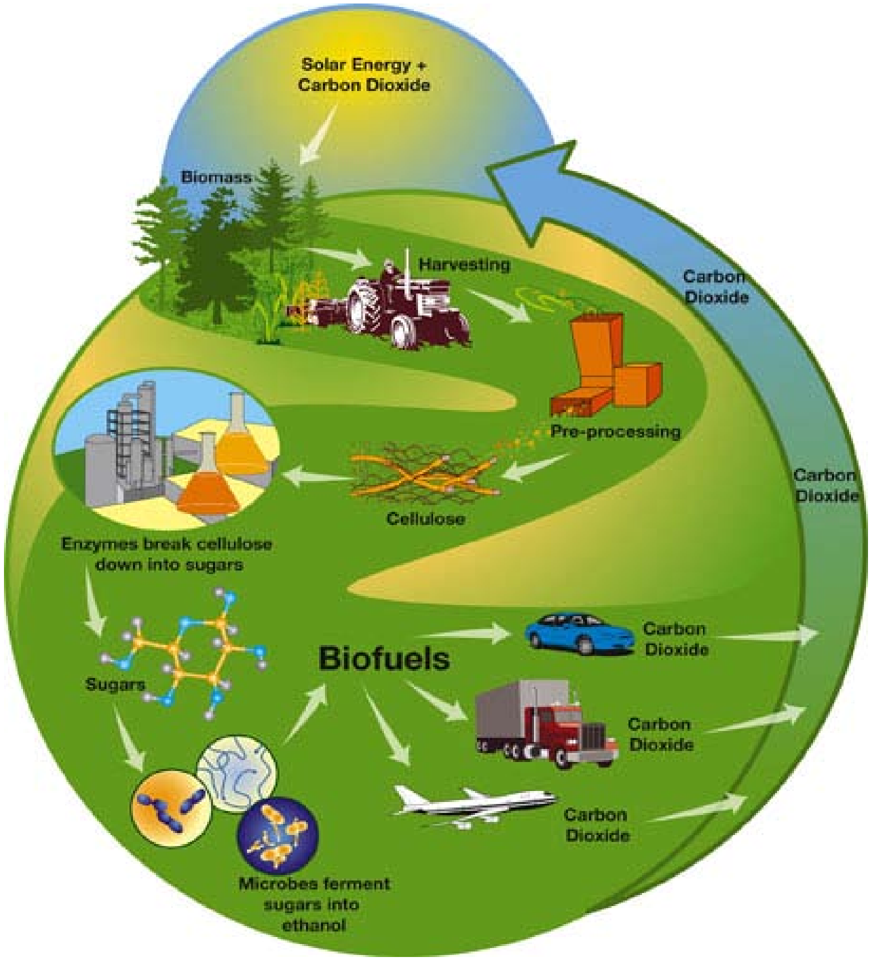


Estimated Energy Intensity Components of Water in San Diego

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

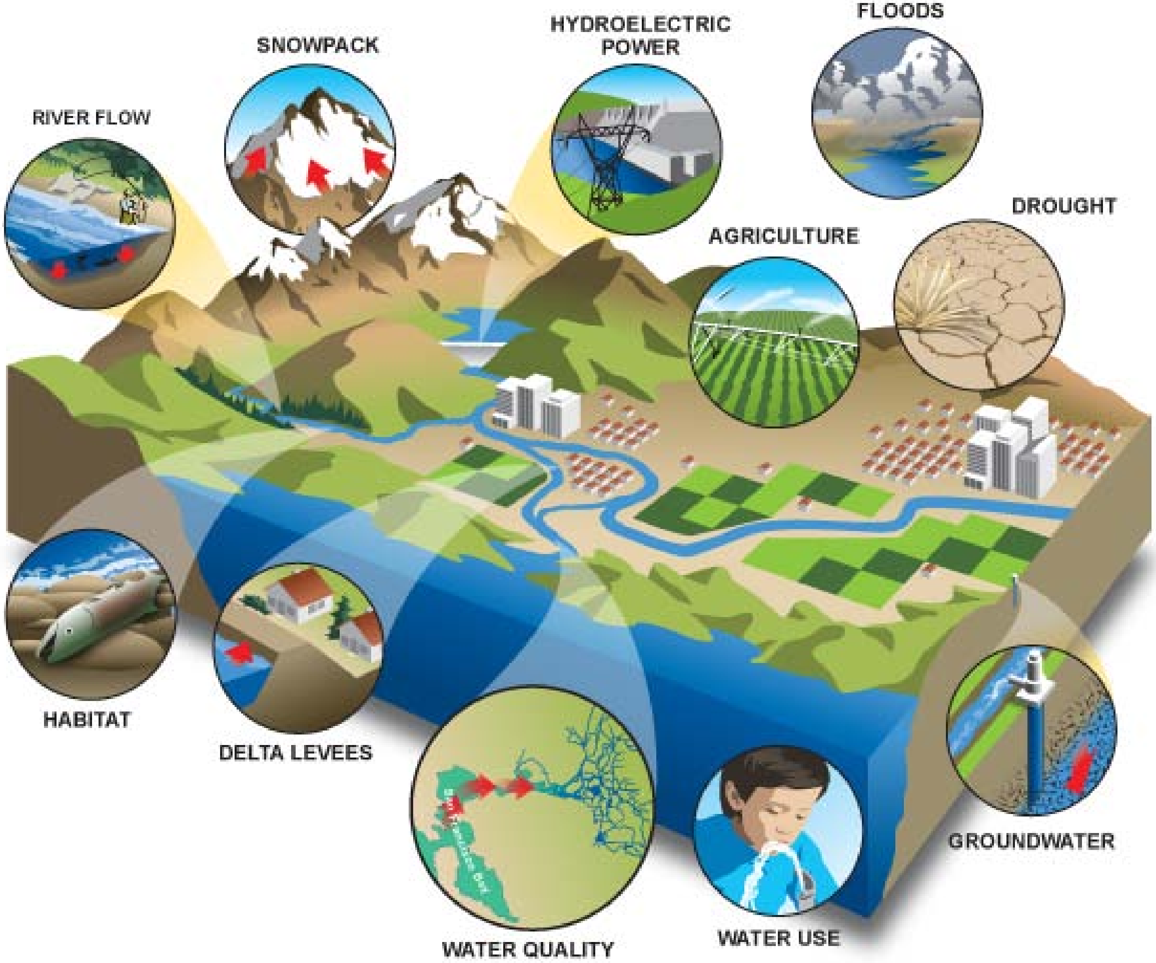
- **Increase in bio-fuel demand** could lead to **higher food prices** and adversely affect food availability and access
  - In 2006, a **rise in domestic food price** was observed when food grain was used for bio-fuel production in China
  - Substantial **increases in food prices** are foreseen in an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

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

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

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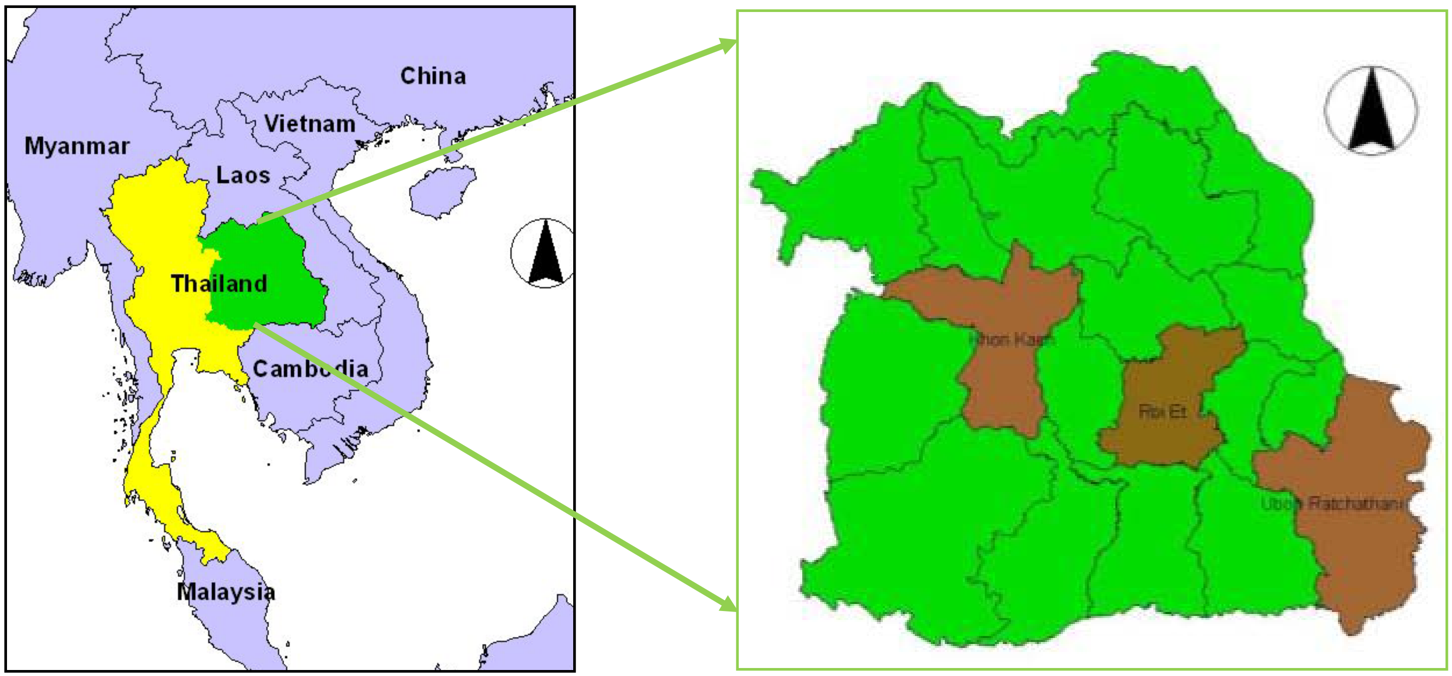
Objectives

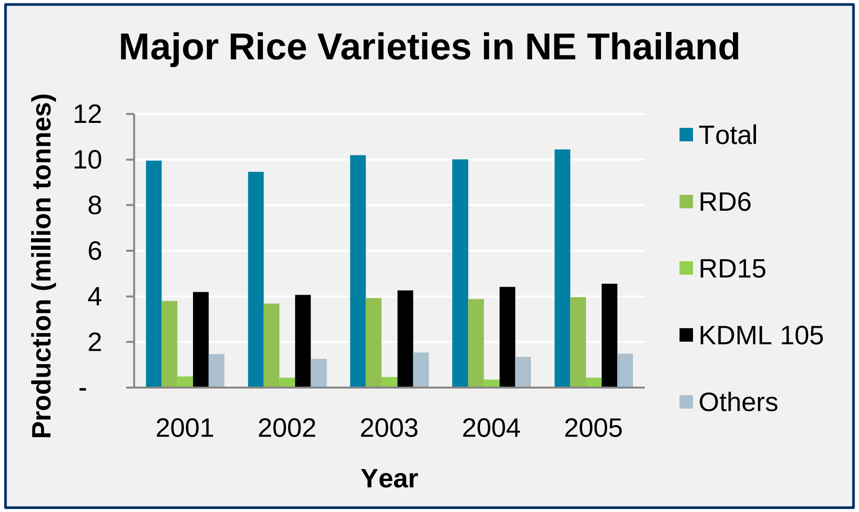
- To assess the impacts of future climate change on rice yield in Northeast of Thailand
- To identify and evaluate the potential management practices as agro adaptation measures

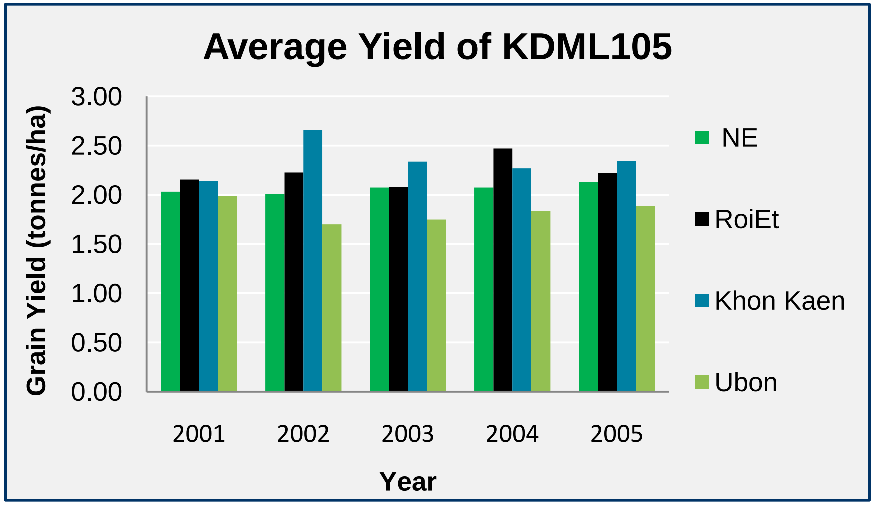
Study area

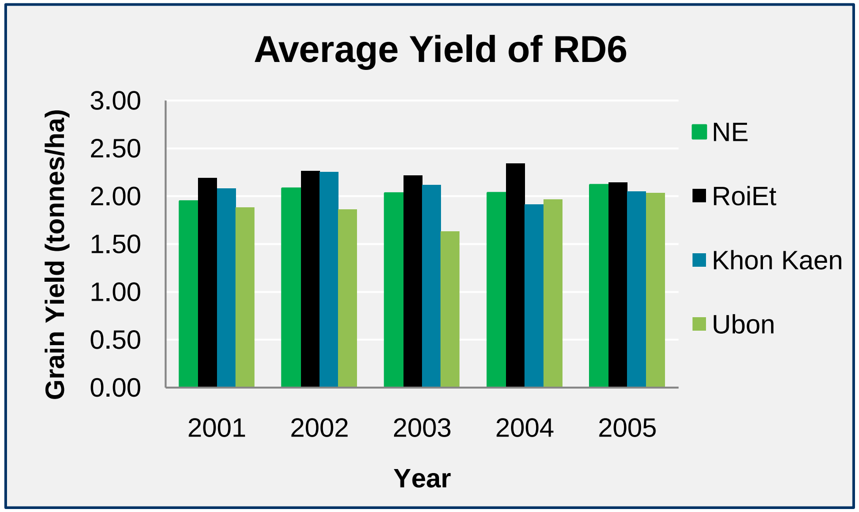


- Low soil fertility, poor physical endowment of the region
- Highly uneven distribution of rainfall
- Average yield of rice lower then the country average yield

Major rice varieties and their yields

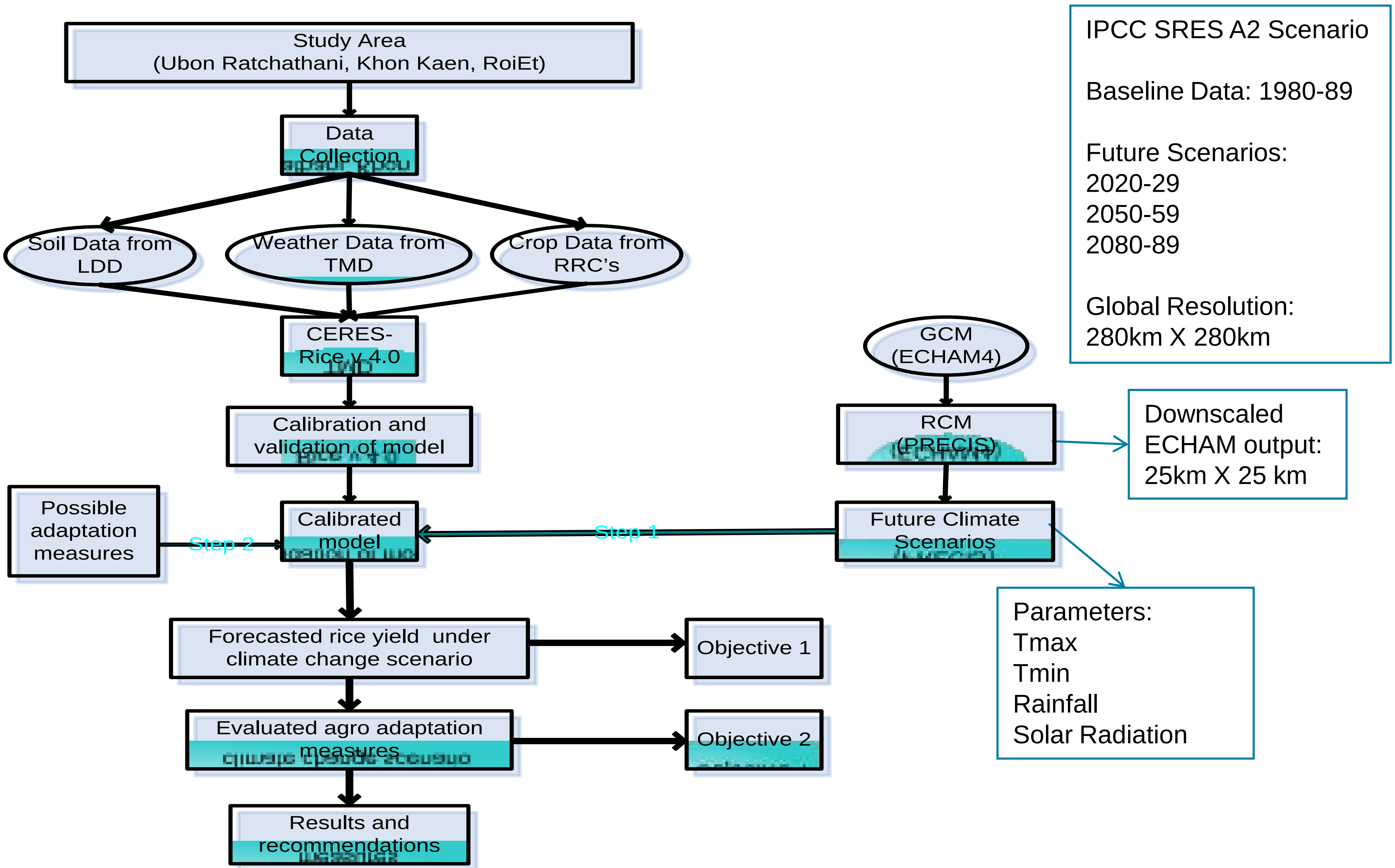




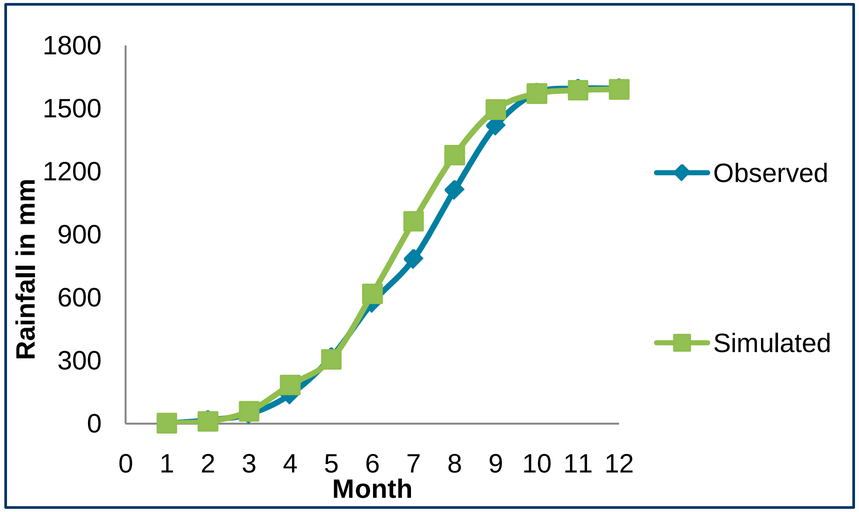


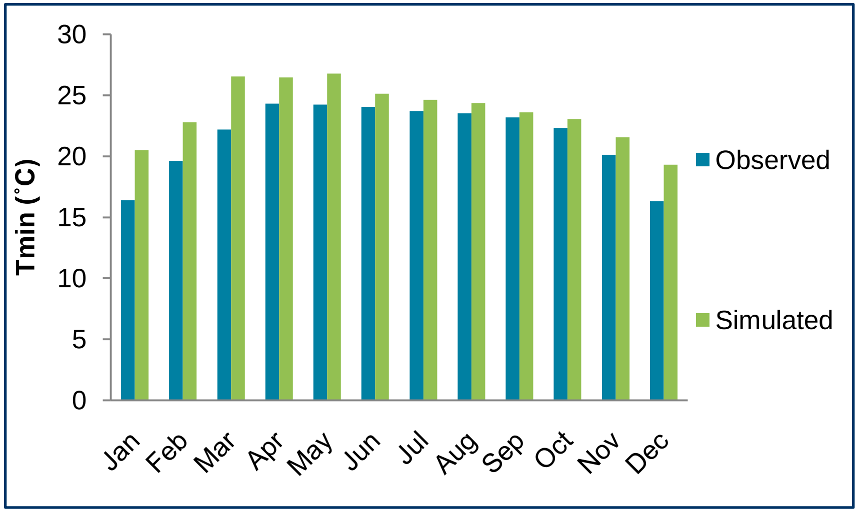
Source: Office of Agriculture Economics, 2007

Research methodology



Observed & simulated weather (1980-89)

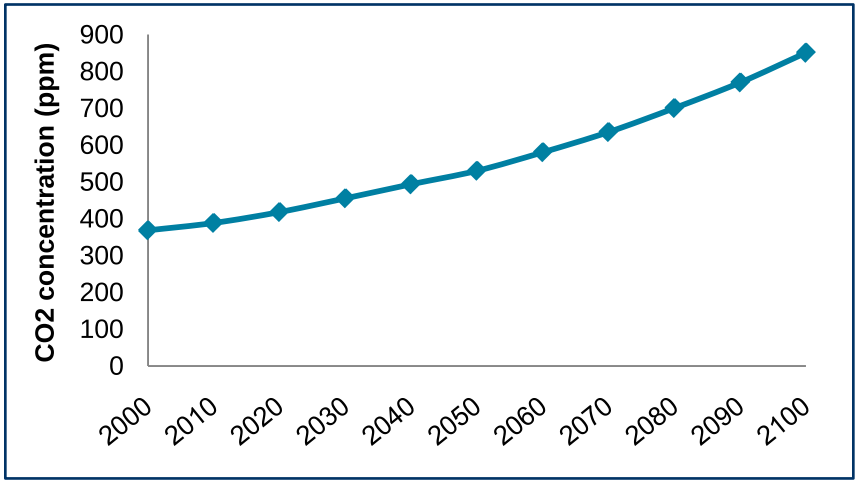


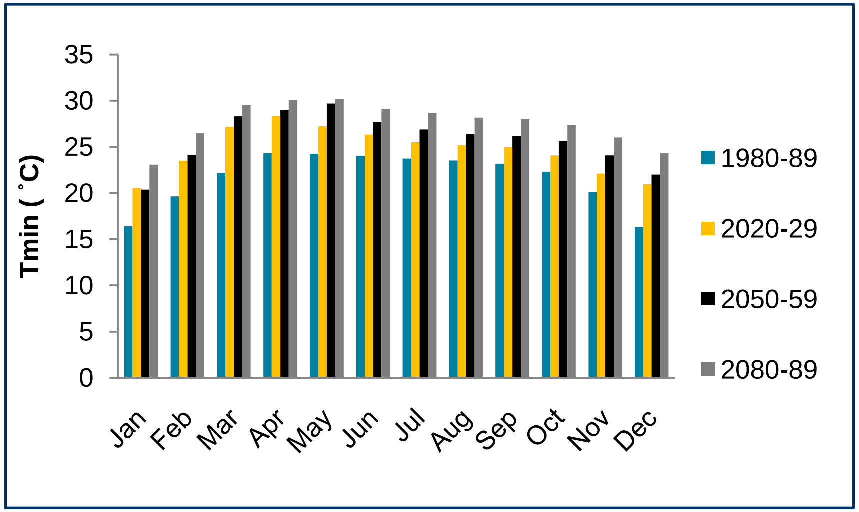


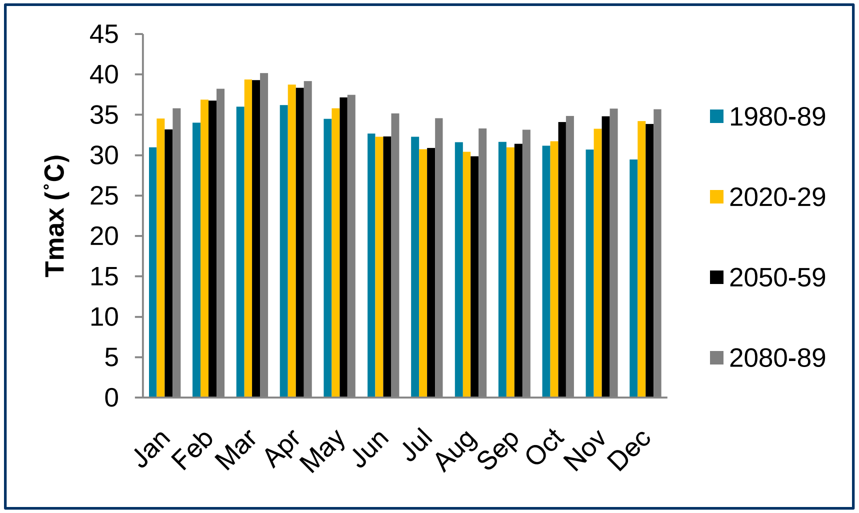
Future weather scenarios

IPCC SRES A2 Scenario

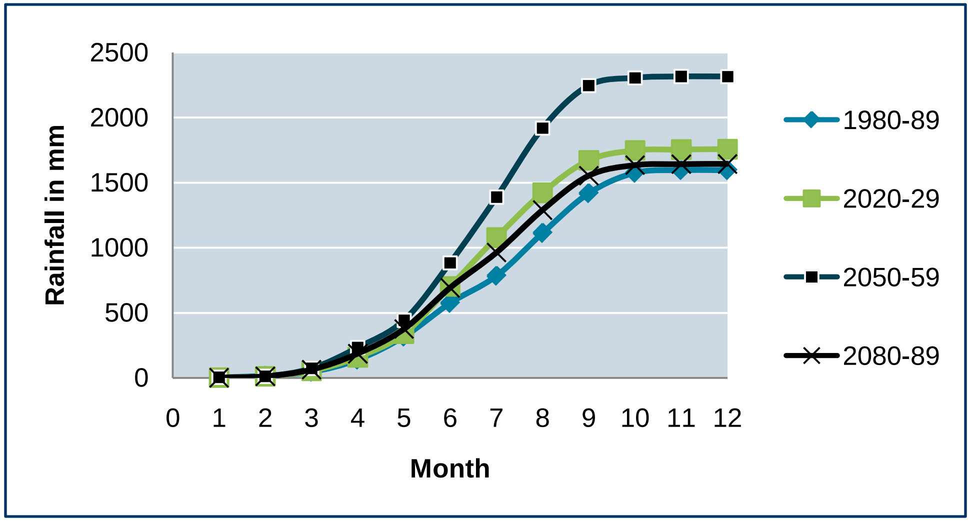
- A world of independently operating, self-reliant nations
- Continuously increasing population
- Regionally/nationally oriented economic development
- Slow and fragmented technological changes
- Slow and fragmented improvements to per capita income

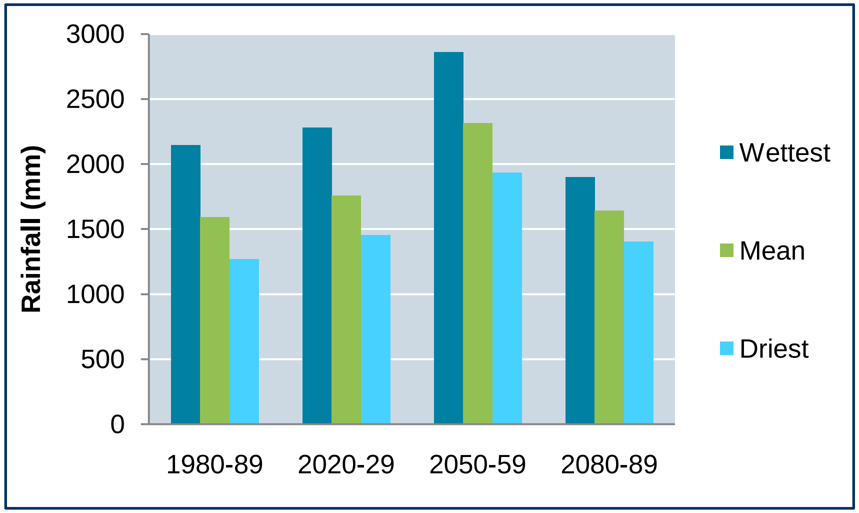


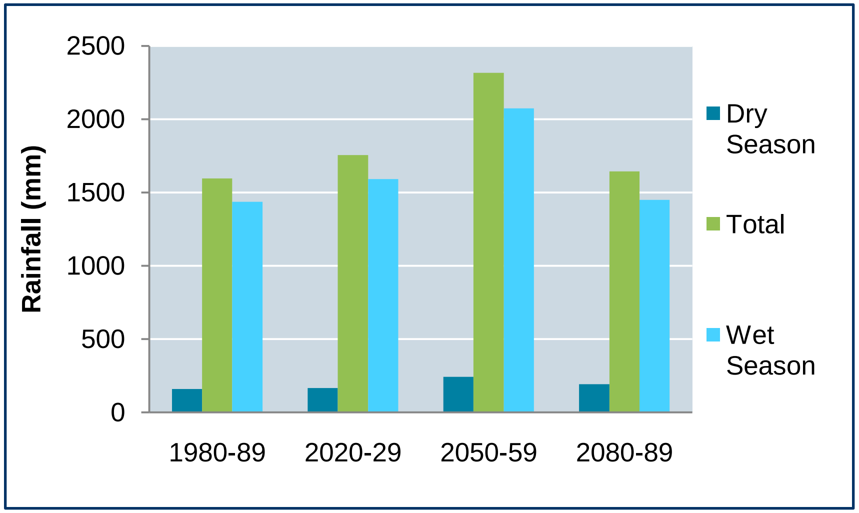




Future rainfall scenarios

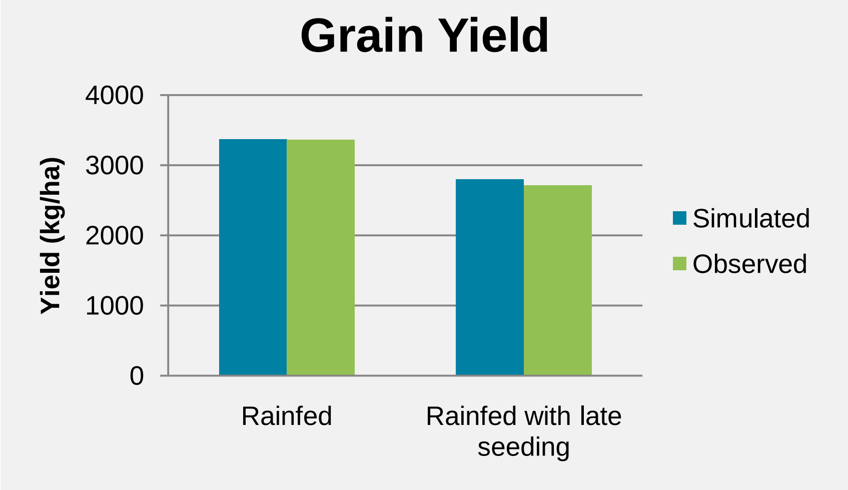


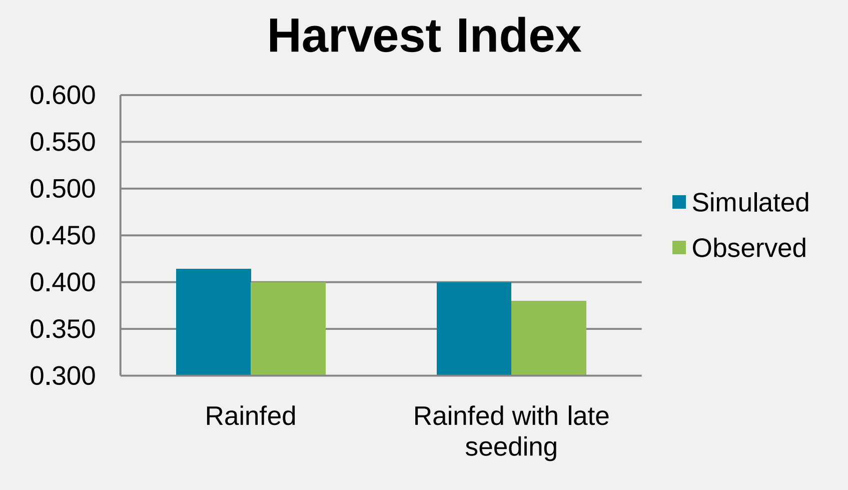


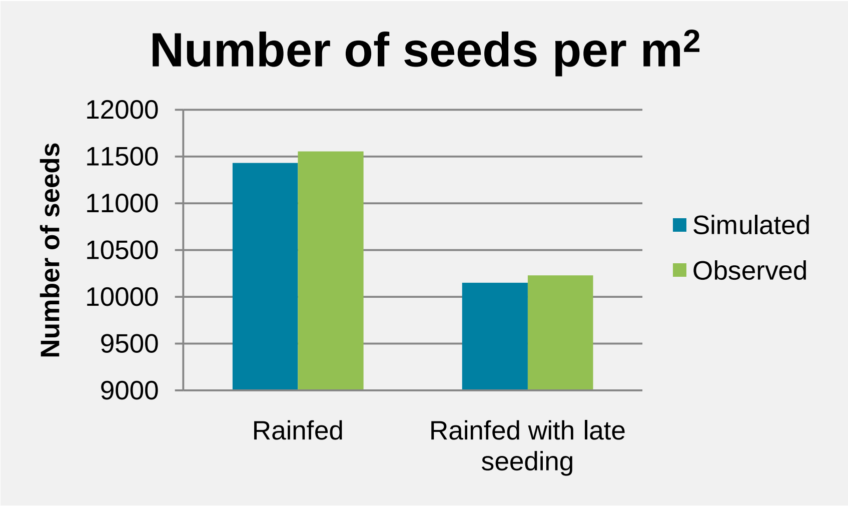


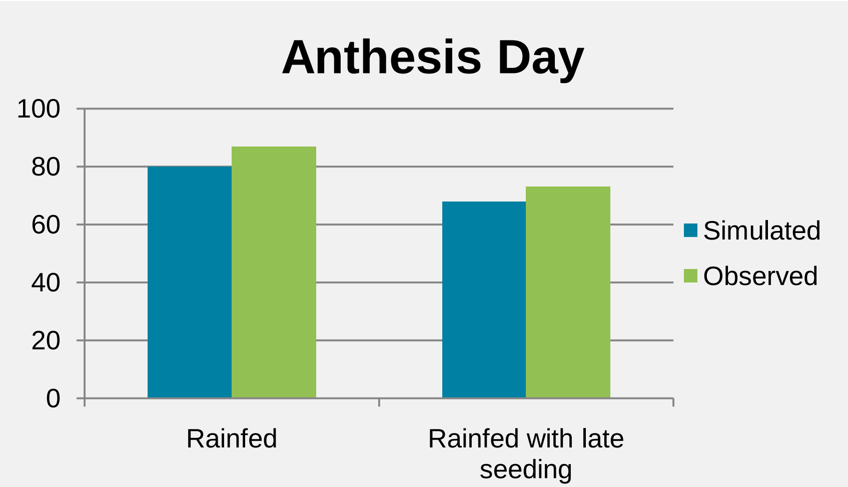
Calibration: KDML105 at Ubon Ratchathani

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



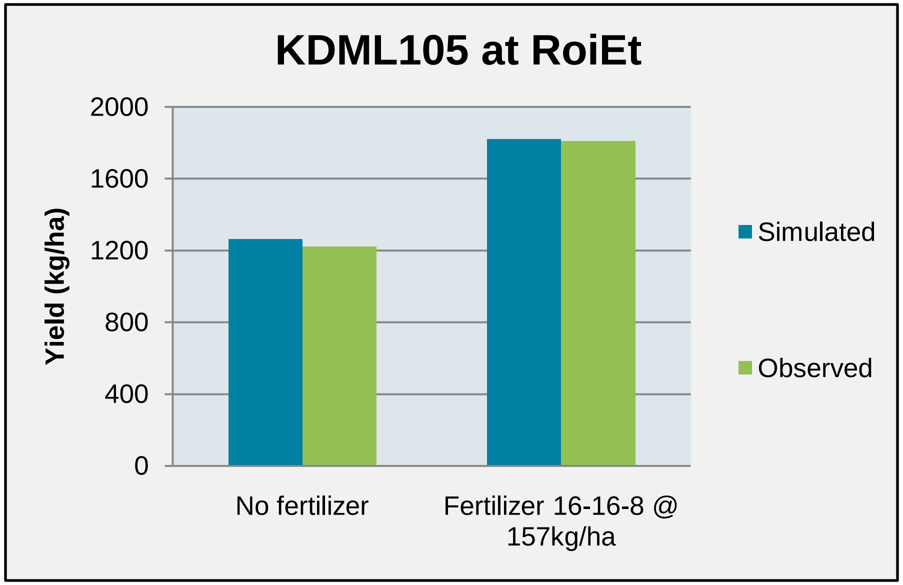


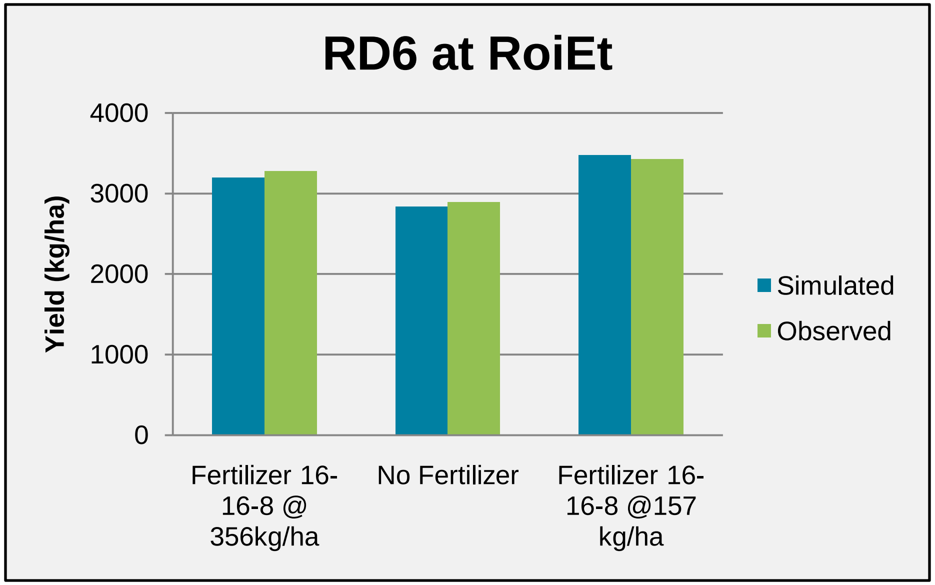




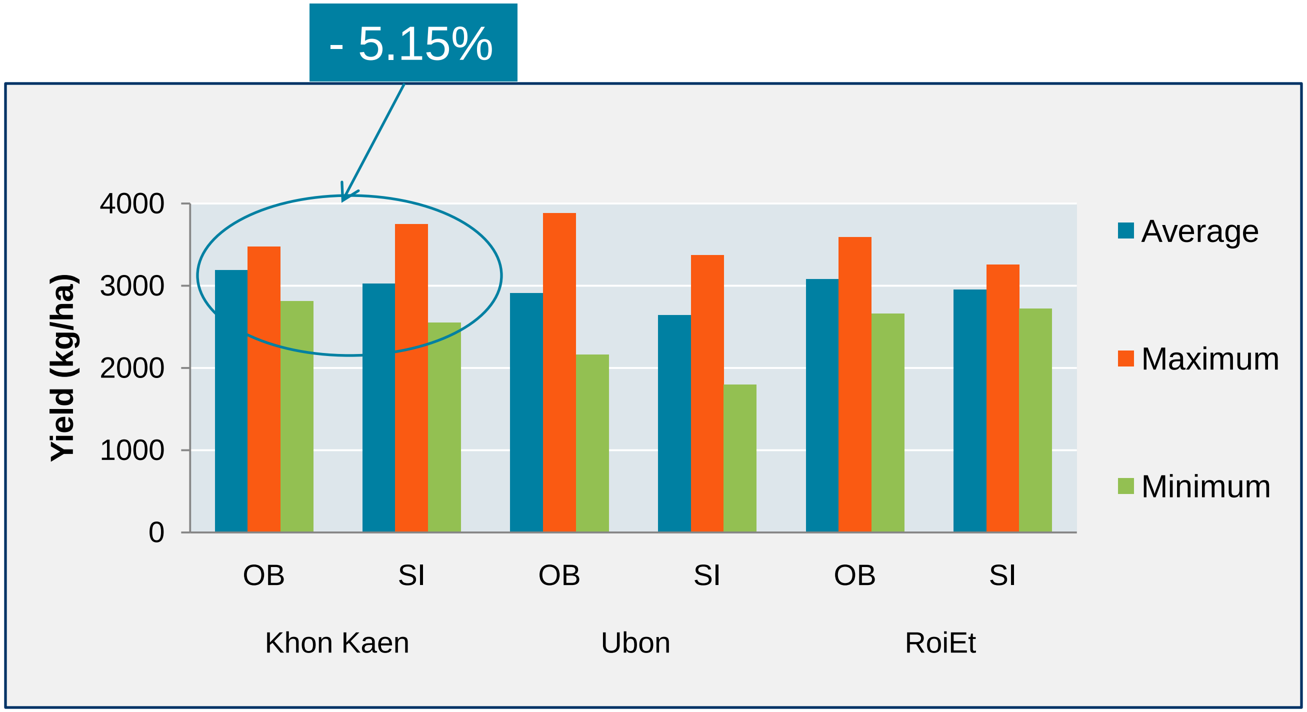
Anthesis day - day after planting

Yield results for experiments





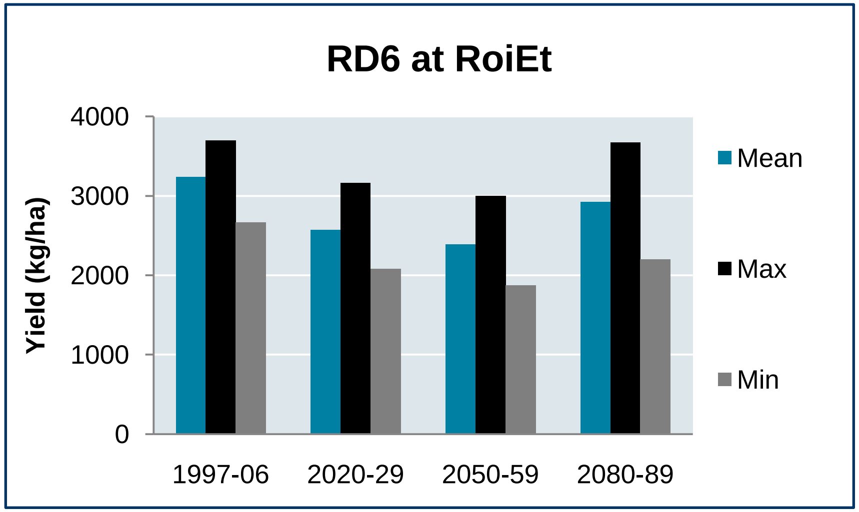
Comparison of baseline year (1980-89) yield

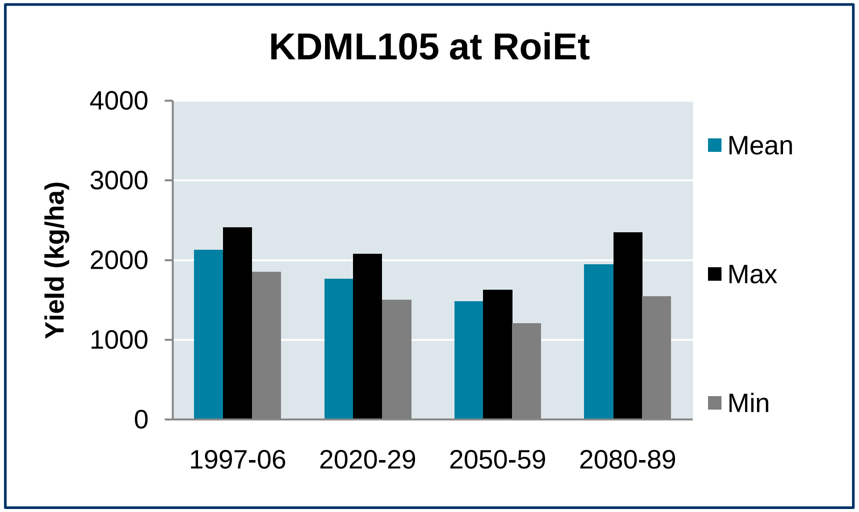


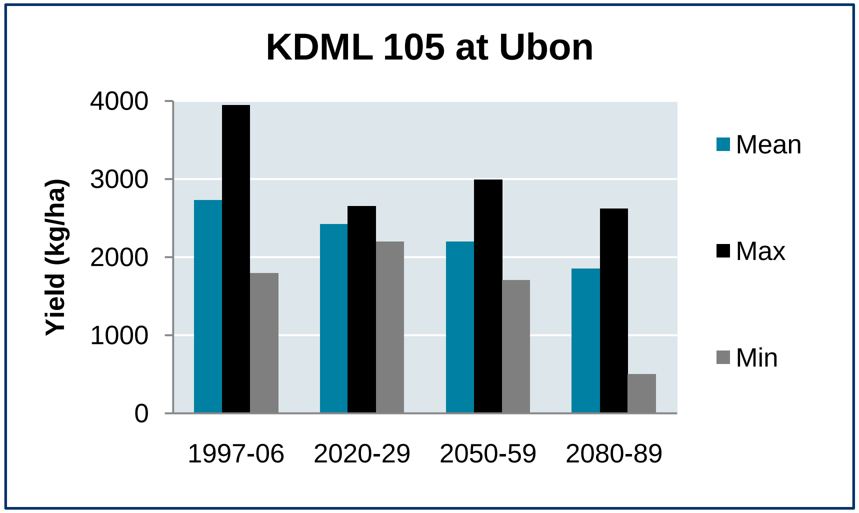
Effect of climate on yield components

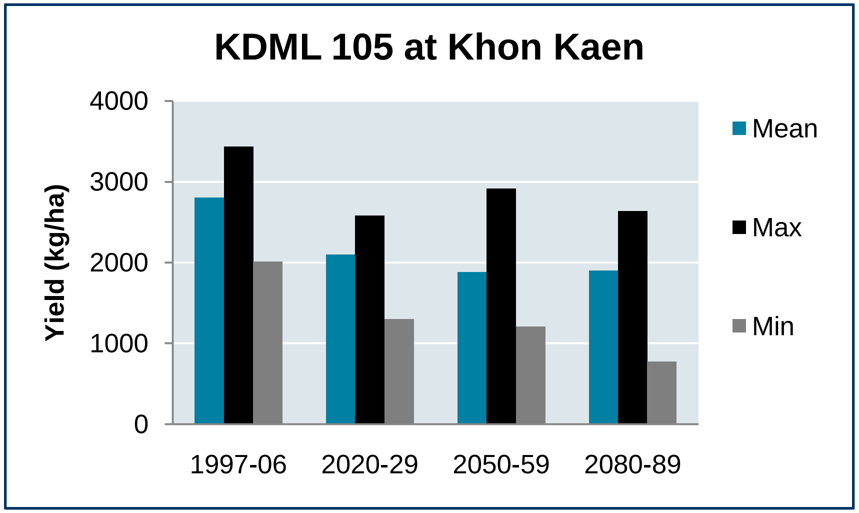
Period	Yield (kg/ha)	Panicle no. / m2	No. of grains/m2	Total Biomass (kg/ha)	Anthesis duration (days)	Maturity duration (days)	Harvest Index
KDML105 at Ubon Ratchathani							
1997-06	2732	33.4	10613	6353	81	110	0.43
2020-29	2427	31.7	8990	6742	87	113	0.36
2050-59	2200	27.3	8149	6463	96	120	0.30
2080-89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

Effect of future climate on rice yield

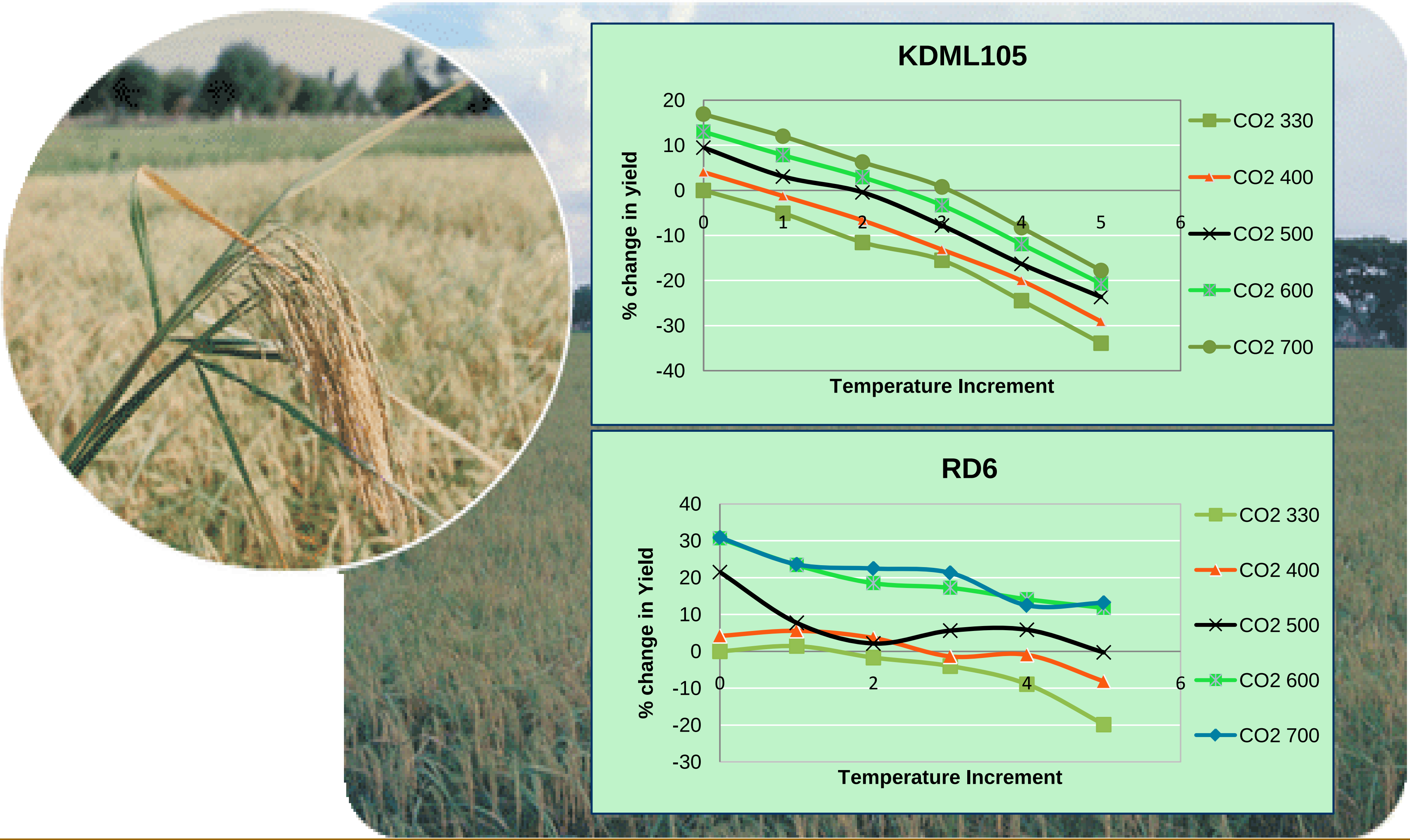








Effect of temperature and CO_2 on yield

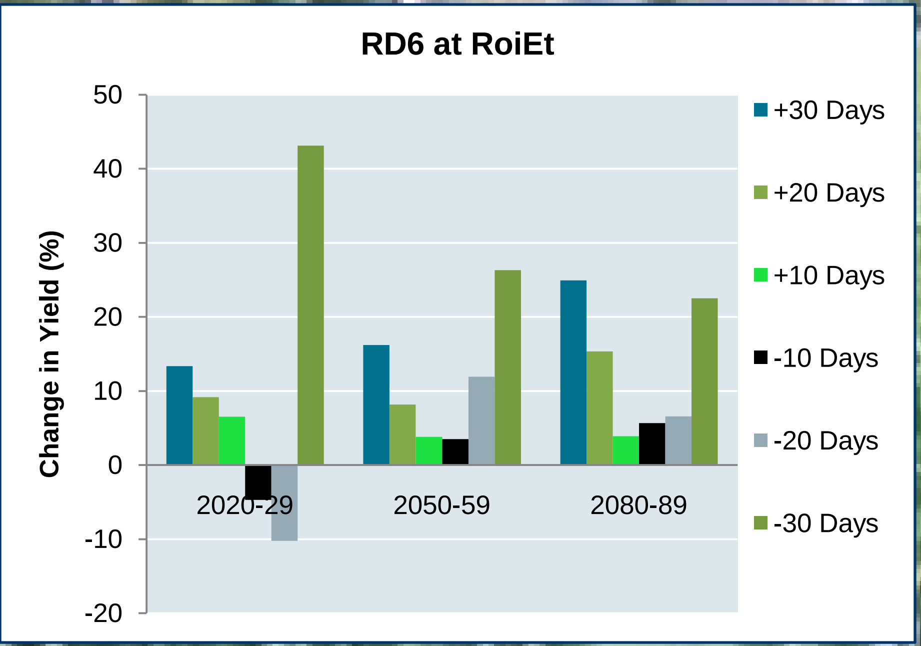


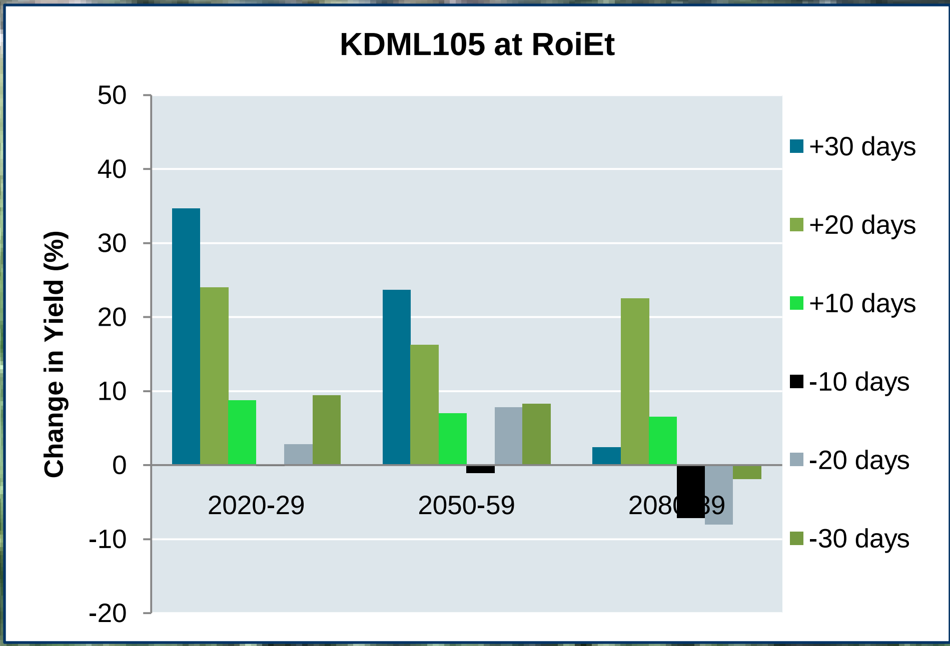
Adaptation Measures

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

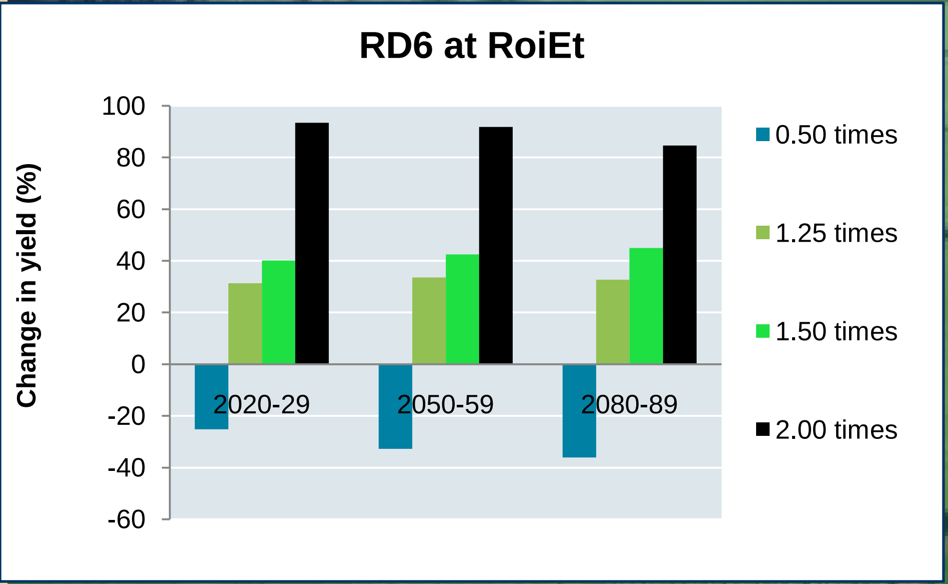
- Different sowing dates
- Different rate of Nitrogen
- Different time of N application
- Hybrid rice cultivars

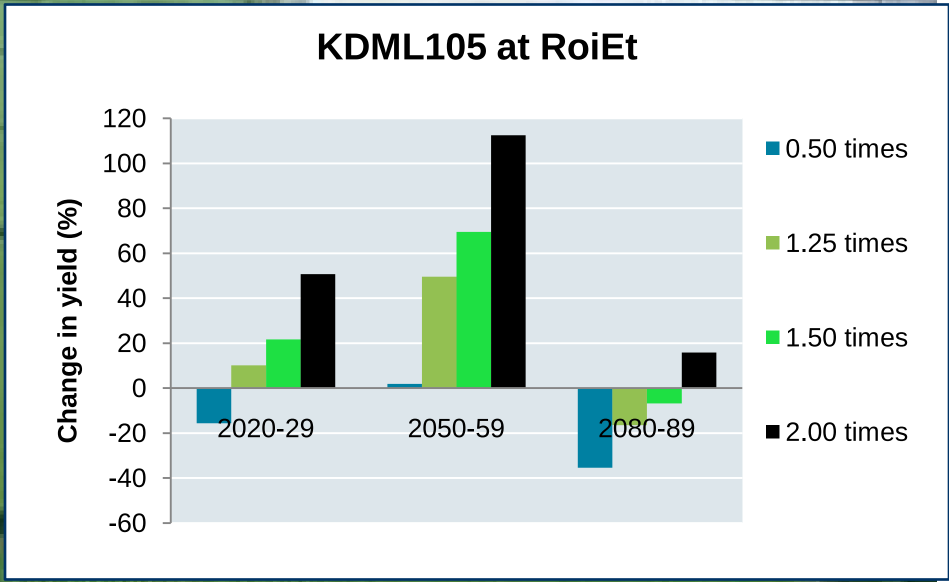
Alternate sowing dates



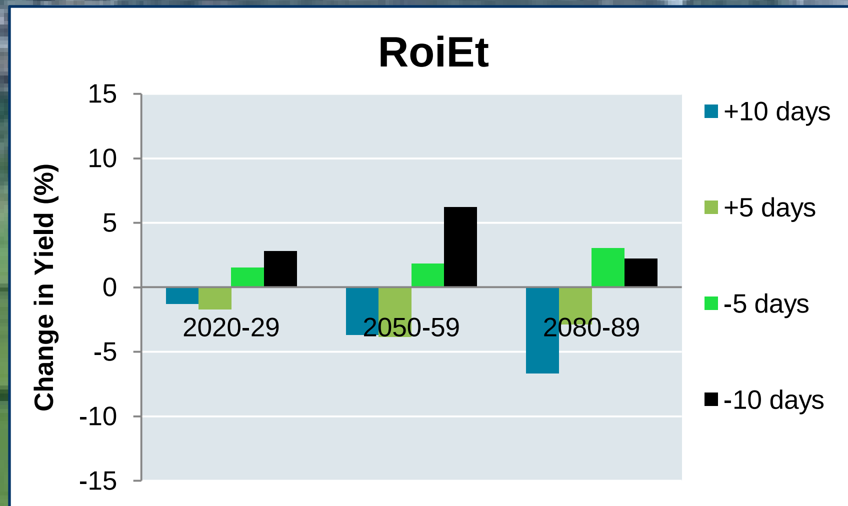


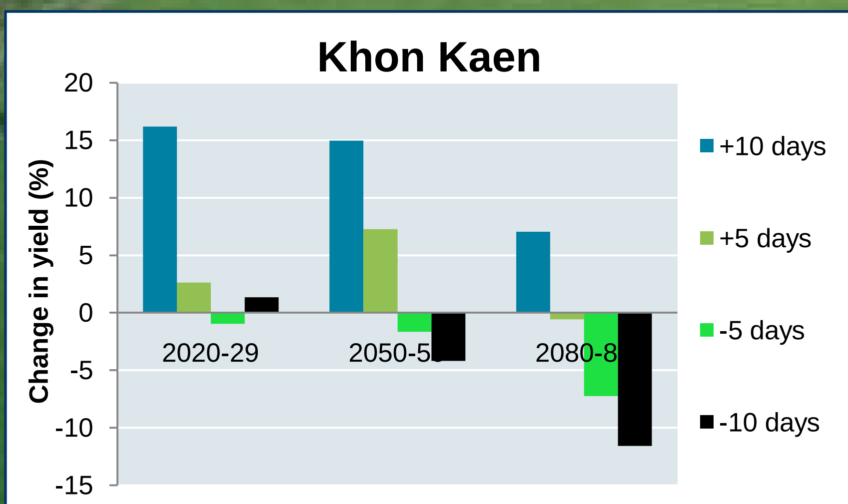
Effect of different N rates

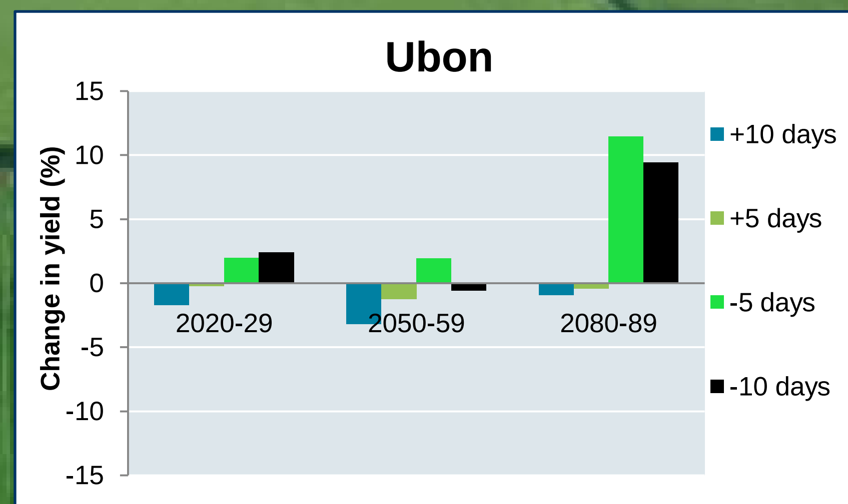




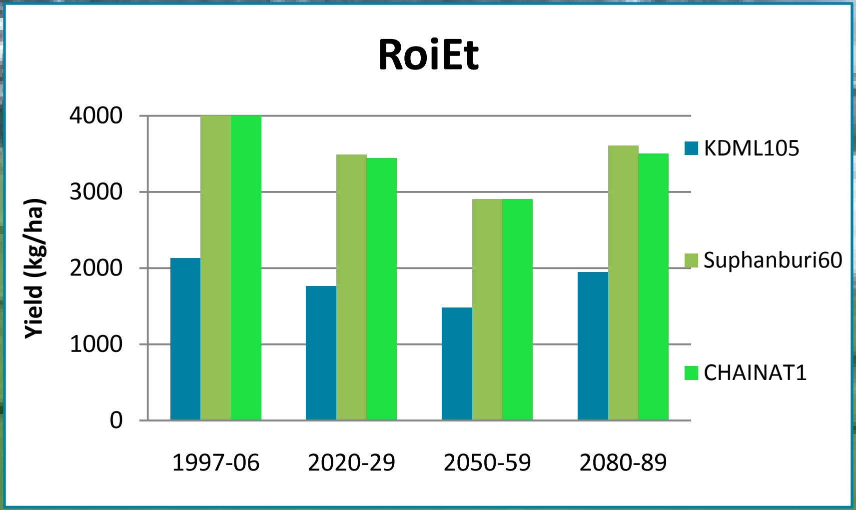
Effect of Change in N Application Time

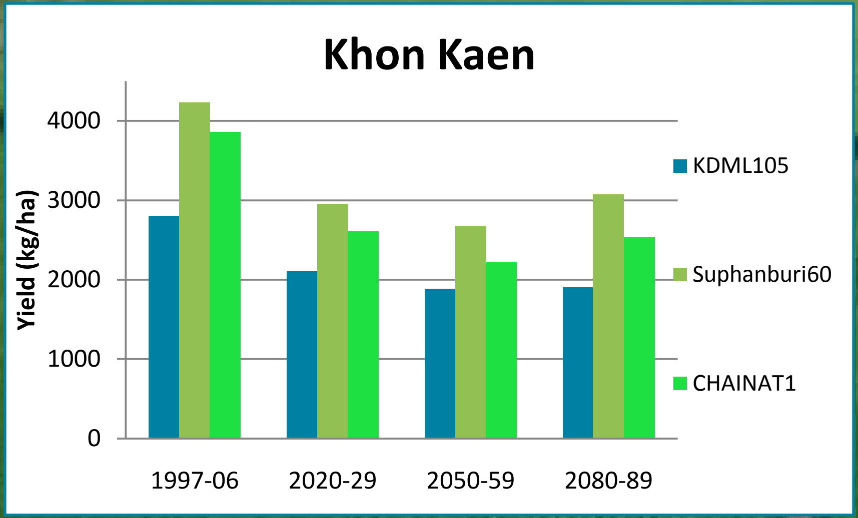


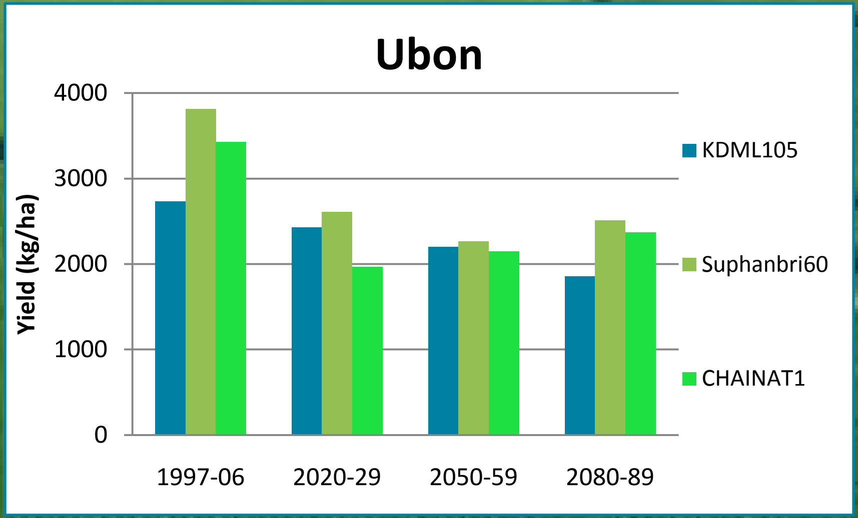




Effect of Using Hybrid Cultivars







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.

Impact of Bio-fuel Production on Hydrology

A case study of Khlong Phlo Watershed, Thailand

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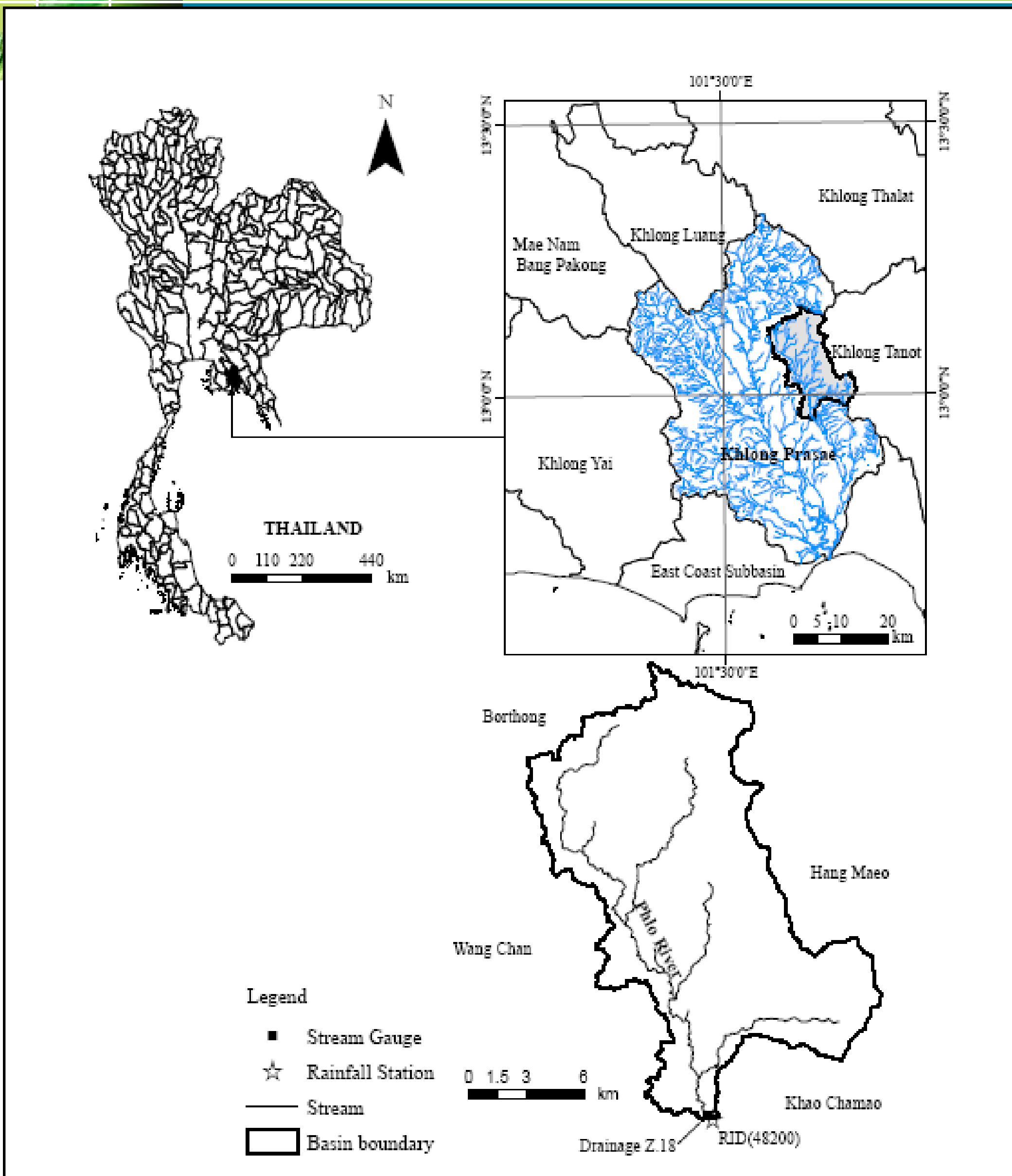
Objectives

- To estimate water footprints of bio-fuel and bio-fuel energy
- To evaluate impact on annual water balance due to land use change for bio-fuel production
- To quantify impact on the water quality of the watershed due to land use change for bio-fuel production

Study area

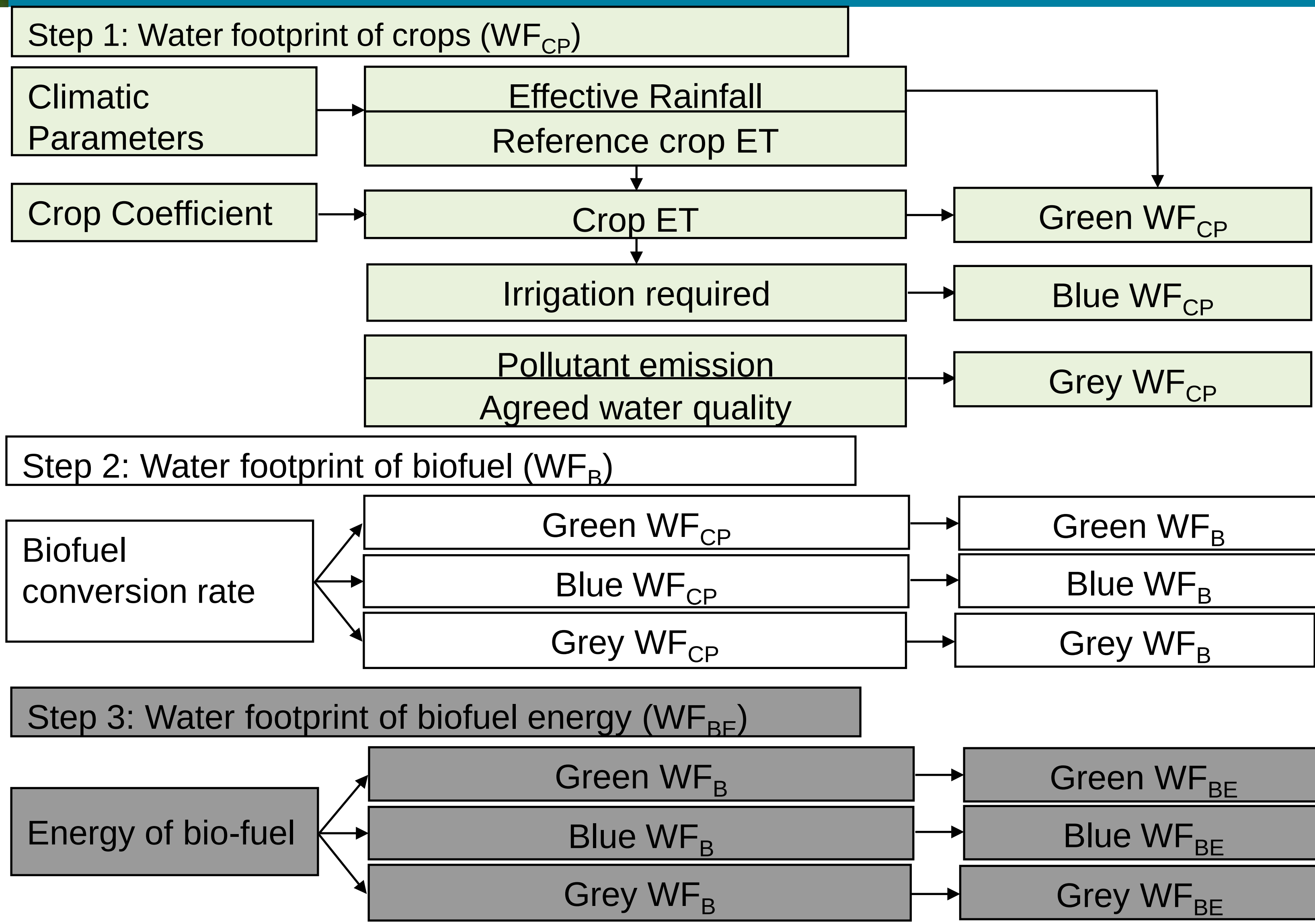


Location:	Khlong Prasae
	Rayong
	$12^{0}57'$-$13^{0}10'$N
	$101^{0}35'$-$101^{0}45'$E

Area	202.8 km2
Rainfall	1,734 mm
Temperature	27 to 31^{0}
Humidity	69 to 83%
Elevation	13 to 723 amsl
Land use	Agriculture (66%) Forest (33%)
Major Soils	S – Cl – L S – L

S – Cl – L = Sandy – Clay – Loam
S – L = Sandy Loam

Water footprint: Methodology

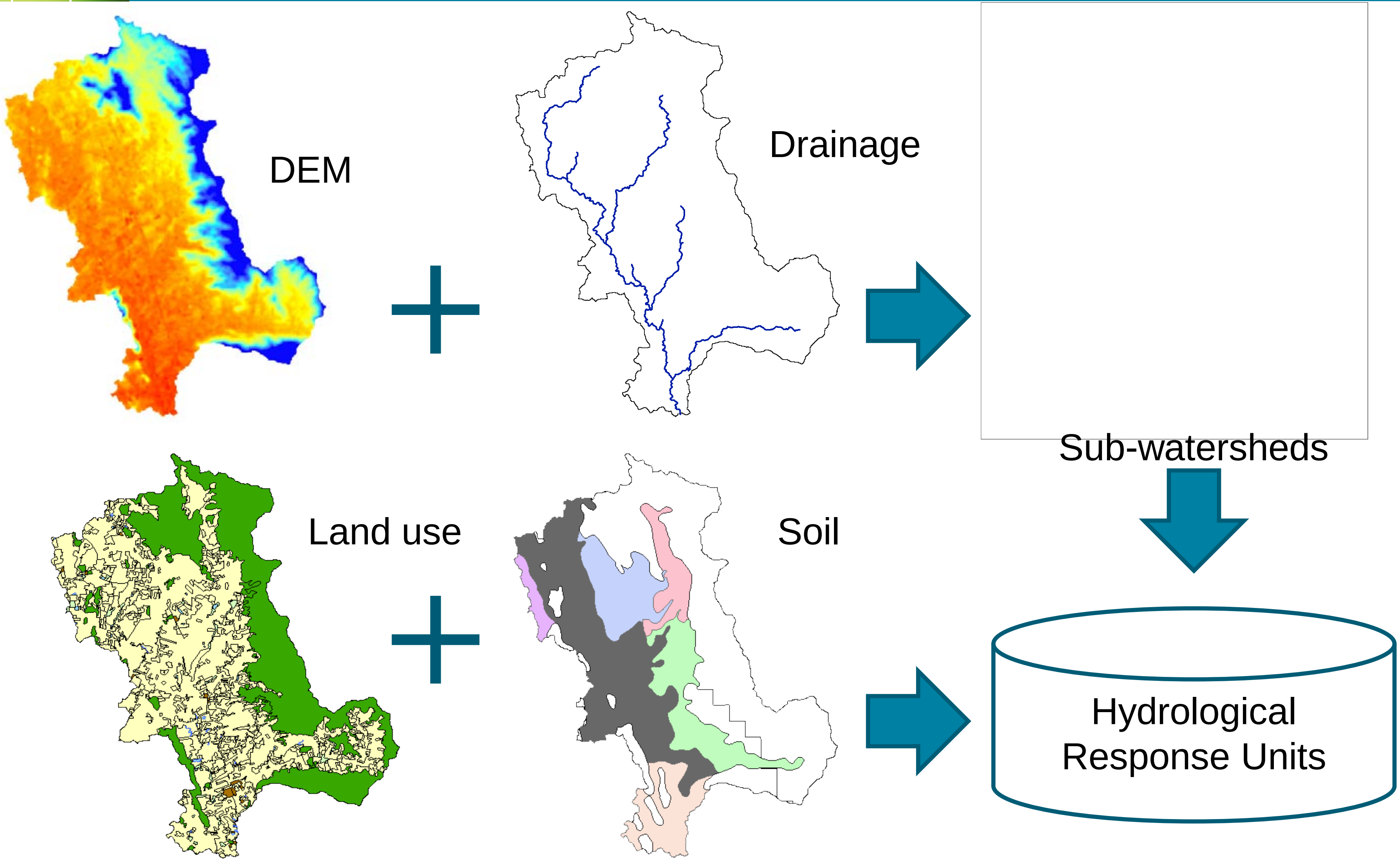


Formulae used for water footprint (WF)

Green WF	Min (Evapotranspiration, Effective rain)
Blue WF	Irrigation requirement
Grey WF	Max (Pollutant released/Permissible limit)
WF_{CP}	Water use for crop production / crop yield
WF_{B}	WF_{CP}/ biofuel conversion rate
WF_{BE}	WF_{B}/ energy per liter biofuel
Energy /L biofuel	HHV x density

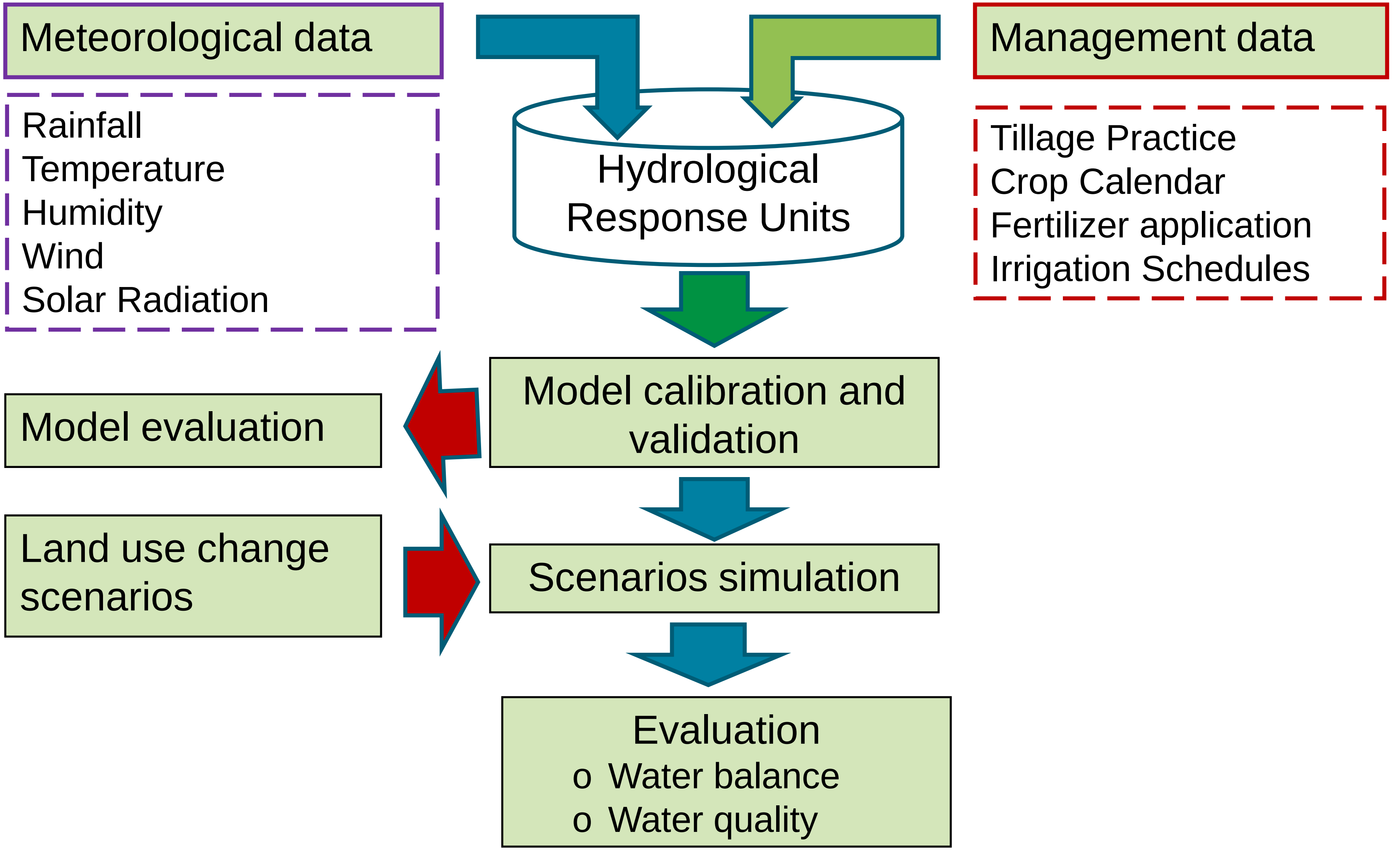
Methodology : SWAT, Preprocessing phase

Impact on water balance and water quality



Methodology : SWAT, Preprocessing phase

Impact on water balance and water quality



Thailand's bio-fuel policy

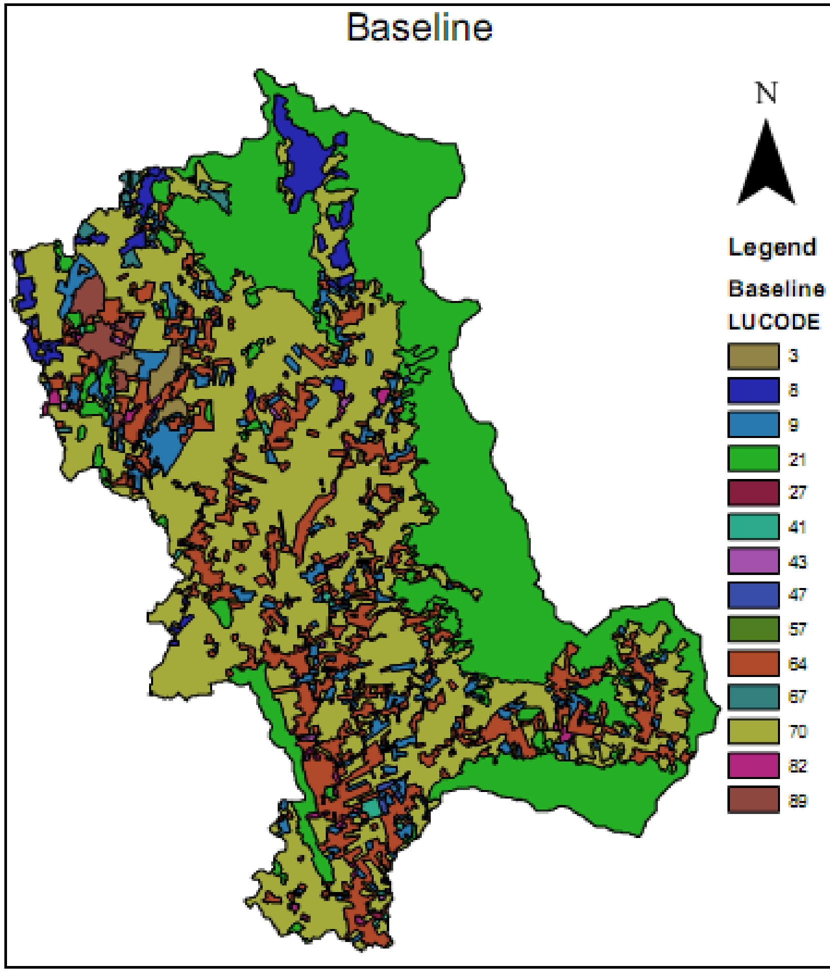
Bio-fuel target of Thailand by the year 2022

Bio-fuel	**Year 2008**	**Year 2009-2011**	**Year 2012-2016**	**Year 2017-2022**
	mLd	**mLd**	**mLd**	**mLd**
Bio-diesel	1.22	3.00	3.64	4.50
Bio-ethanol	0.88	3.00	6.20	9.00
Total	2.10	6.00	9.84	13.50

Source: http://www.dede.go.th Note: mLd = million liters per day

- Bio-diesel
  - expand the oil palm coverage to 1 million ha by 2012
  - orchard replacement already happening
- Bio-ethanol
  - No land expansion but increase sugarcane and cassava yield

Land use: Baseline year 2006



Code	Land Use	Area km^2	Percent
3	Rice	1.82	0.90
8	Cashew Nut	4.84	2.39
9	Cassava	9.88	4.87
21	Evergreen Forest	66.36	32.73
27	Deciduous Forest	0.05	0.03
41	Institutional Land	0.51	0.25
43	Water bodies	0.89	0.44
47	Residential	0.28	0.14
57	Wet Land	0.01	0.01
64	Orchard	27.96	13.79
67	Oil Palm	1.12	0.55
70	Rubber	85.12	41.98
82	Range grass	1.83	0.90
89	Sugarcane	2.11	1.04
Total		202.80	100.00

Land use change scenarios

A. Oil Palm expansion (Biodiesel)

Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5
-Orchard to oil Palm	- Rubber to oil Palm	- Orchard + rubber to oil palm	- Forest to oil palm	- Orchard, Rubber and Forest to oil palm
- Oil palm <1 to 17%	- Oil palm <1 to 43%	- Oil palm < 1 to 59%	- Oil palm <1 to 33%	- Oil palm <1 to 91%

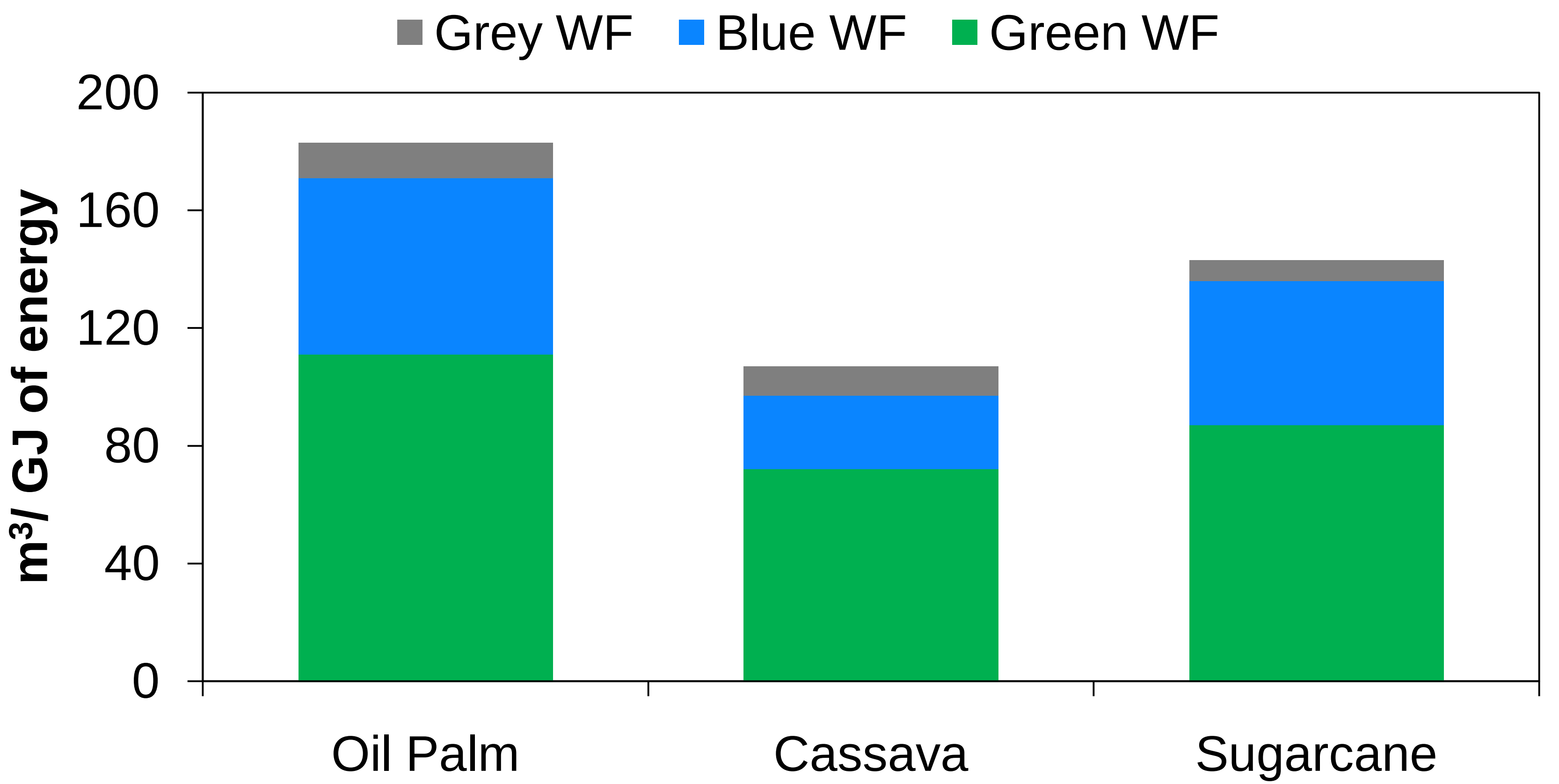
B. Cassava expansion (Bio-ethanol)

Scenario B1	Scenario B2	Scenario B3	Scenario B4	Scenario B5
-Orchard to cassava	- Rubber to cassava	- Orchard + rubber to cassava	- Forest to cassava	- Orchard, Rubber and Forest to cassava
- Cassava 5 to 21%	- Cassava 5 to 47%	- Cassava 5 to 63%	- Cassava 5 to 38%	- Cassava 5 to 96%

C. Sugarcane expansion (Bio-ethanol)

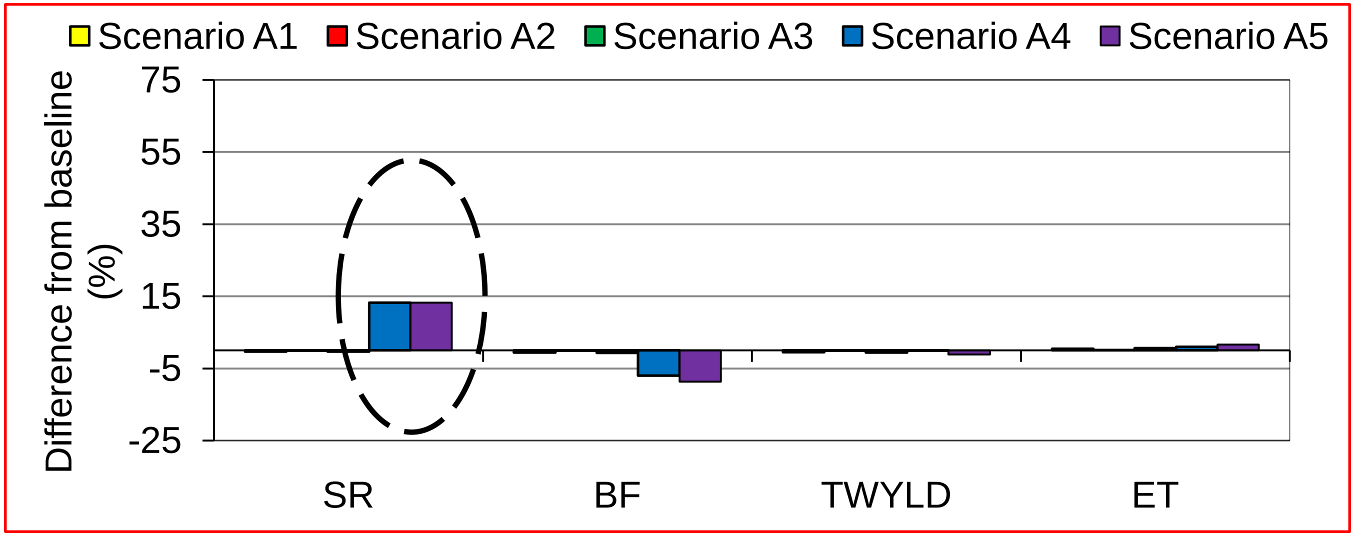
Scenario C1	Scenario C2	Scenario C3	Scenario C4	Scenario C5
-Orchard to sugarcane (Sc)	- Rubber to sugarcane (Sc)	- Orchard + rubber to sugarcane (Sc)	- Forest to sugarcane (Sc)	- Orchard, Rubber and Forest to sugarcane (Sc)
- Sc1 to 17%	- Sc 1 to 43%	- Sc 1 to 59%	- Sc1 to 34%	- Sc 1 to 92%

Results : Water footprints of Bio-energy

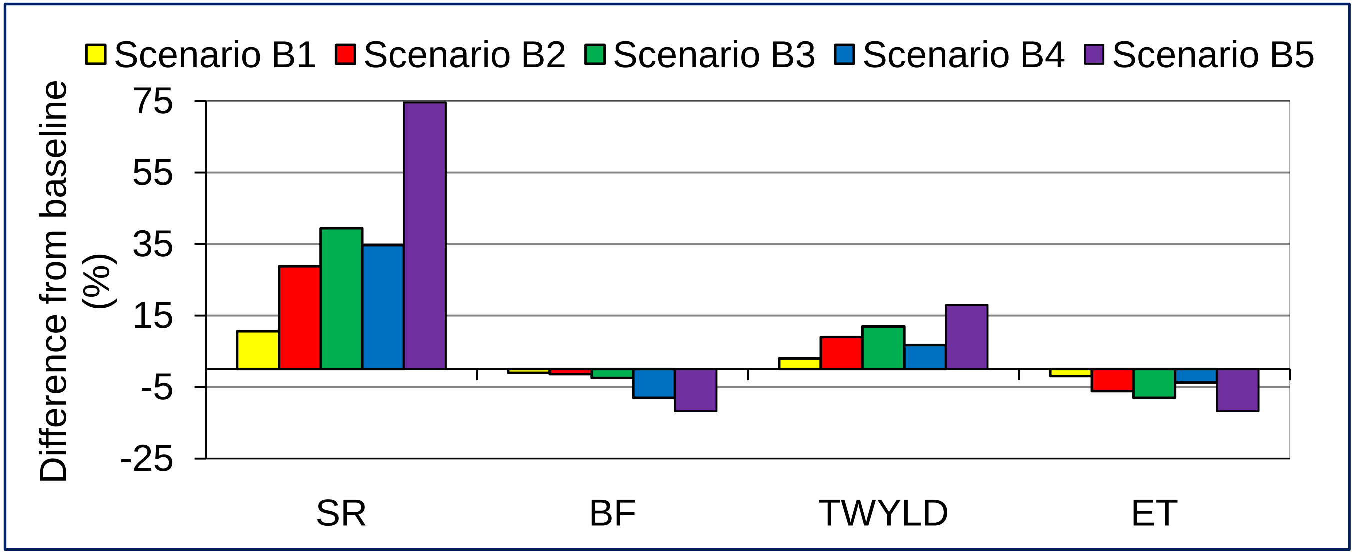


Results : Effects on water balance

Differences in annual water balance from land use change scenarios to baseline



Oil Palm

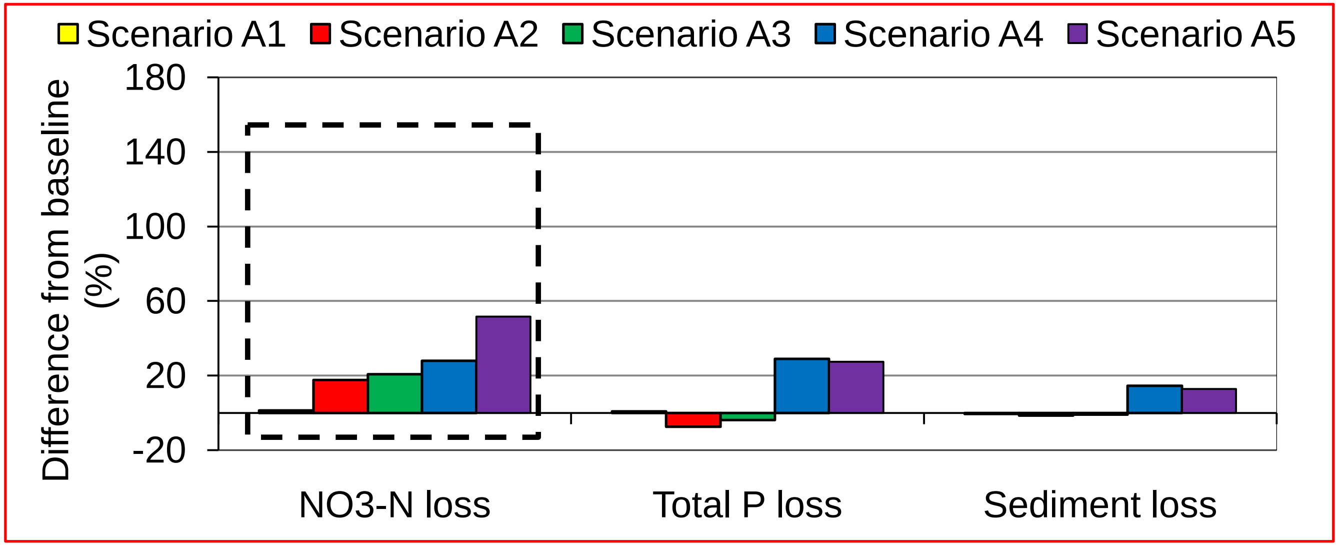


Cassava

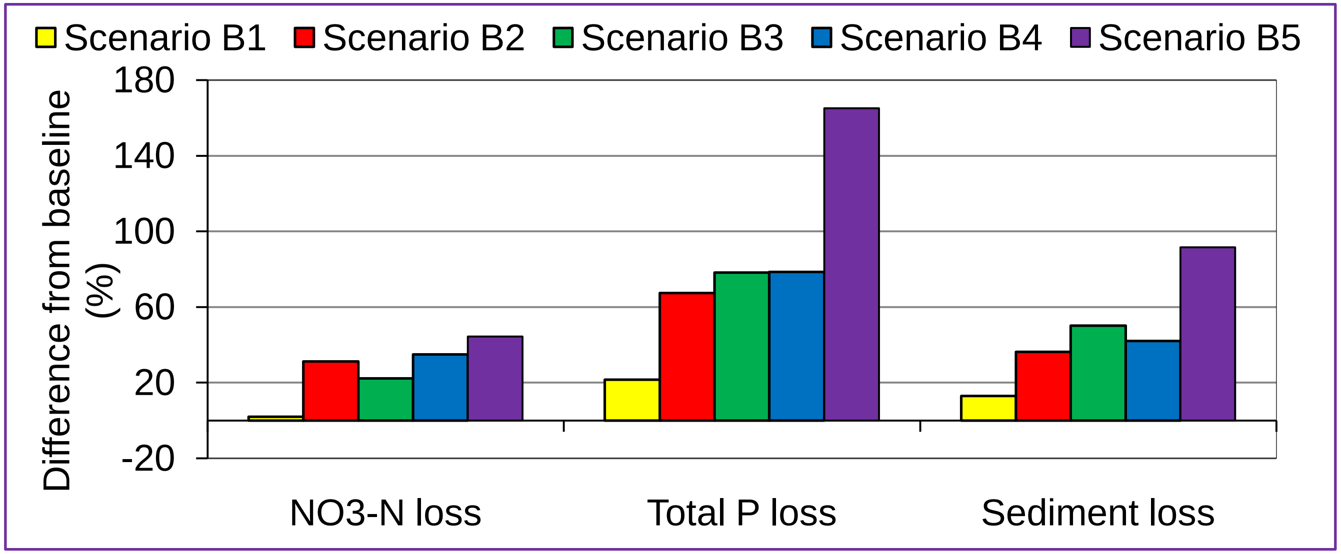
Note: SR = Surface runoff, BF= Baseflow, TWYLD = Total water yield and ET = Evapotranspiration

Results : Effects on water quality

Differences in NPS pollutants from land use change scenarios to baseline



Oil Palm



Cassava

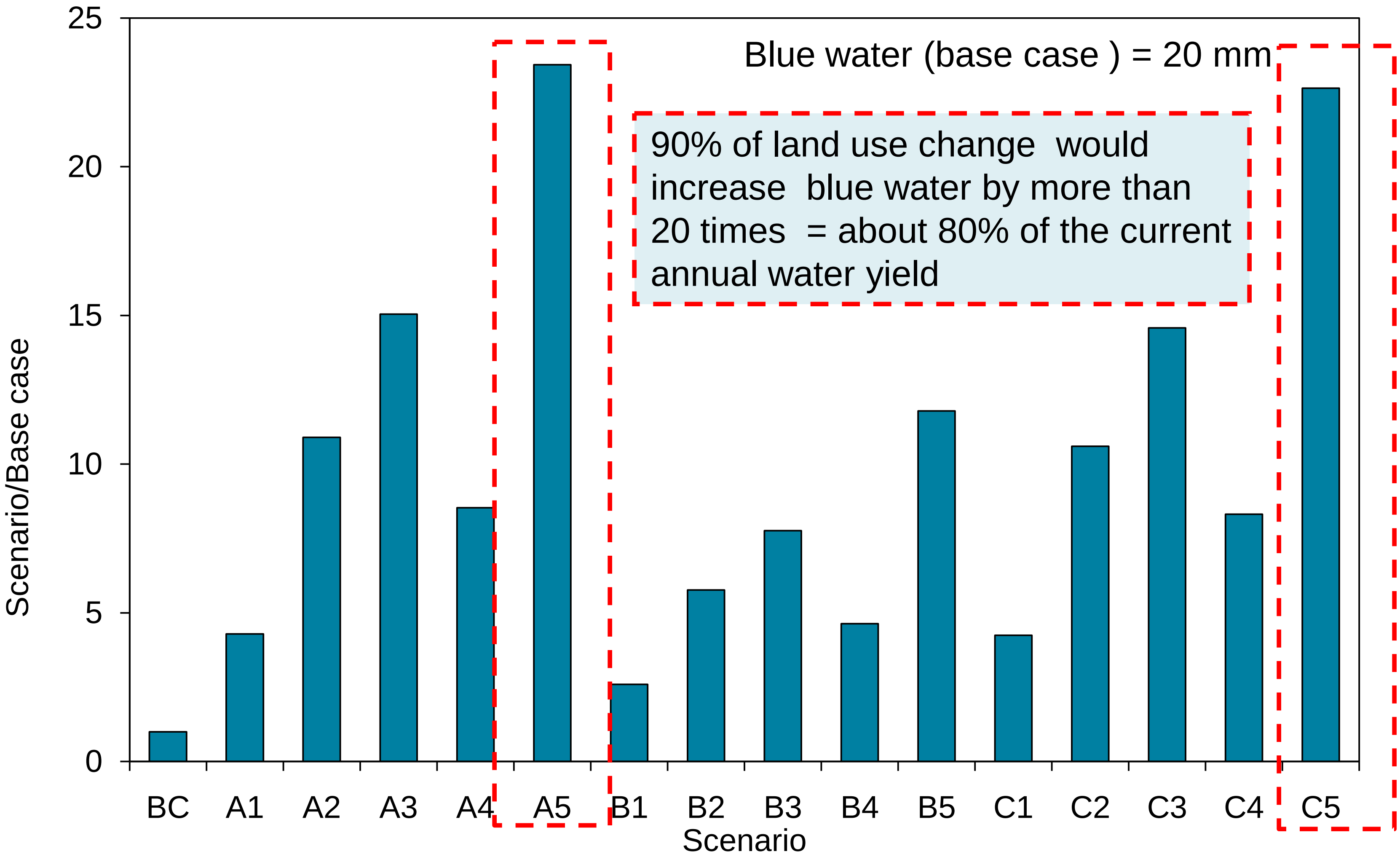
Results

Less water use per energy production but higher environmental impact

Crops	Water use per GJ bioenergy	Water Quality Impact
	183 m³/GJ	Nitrate loss rise 52% Phosphorus loss rise 29% Sediment loss rise15%
	108 m³/GJ	Nitrate loss rise 45% Phosphorus loss rise165% Sediment loss rise 92%
	143 m³/GJ	Nitrate loss rise 29% Phosphorus loss rise125% Sediment loss rise 68%

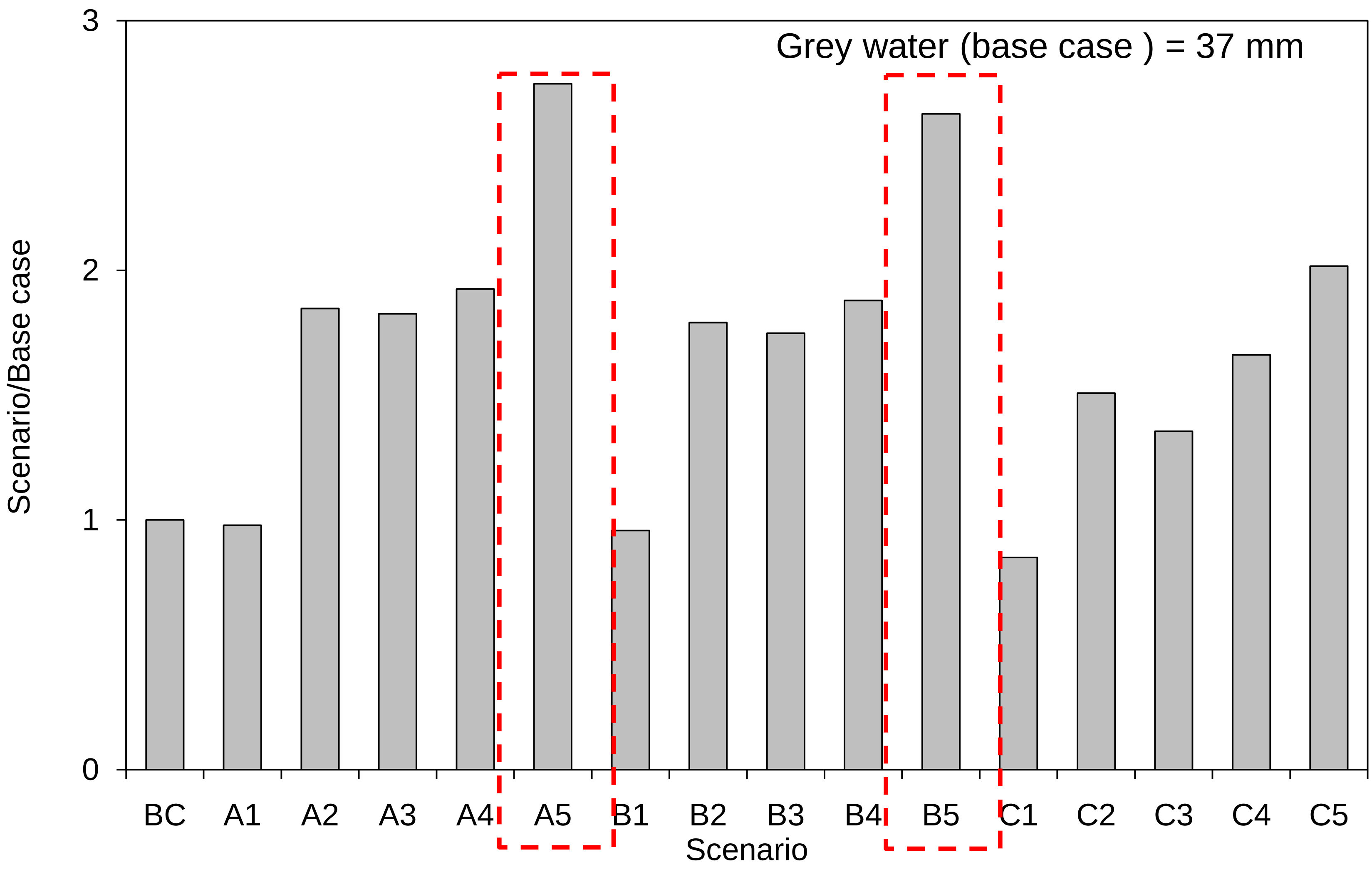
Results

Increase in biofuel crops increases the blue water = Increased irrigation withdrawals



Results

Increase in biofuel crops increases the grey water = adds more stress to freshwater



Summary

- Biodiesel no impact on water balance
  - Forest conversion will affect the water balance
- Bio-ethanol production will affect the water balance
- Biodiesel production will also effect the water quality due to increased nitrate loading
  - Conversion of orchard showed less water quality impact
- Bio-ethanol production will have impact on water quality
- Bio-fuel production will have negative impact on the environment
- Land use management plans like combined expansion and assessing threshold areas for expansion of bio-fuel crops may be implemented to safeguard against or mitigate any potential adverse consequences on water resources.

Final Reflections

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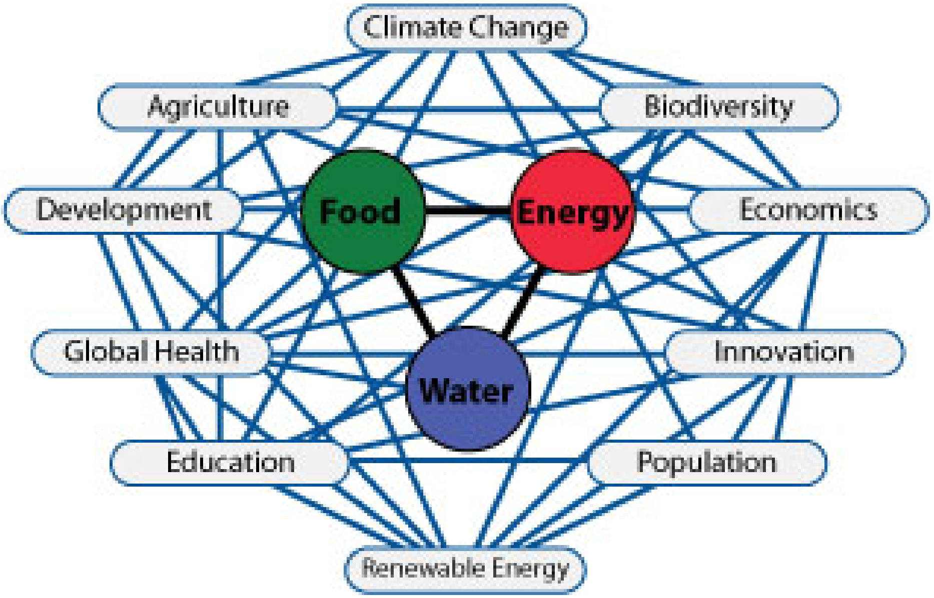
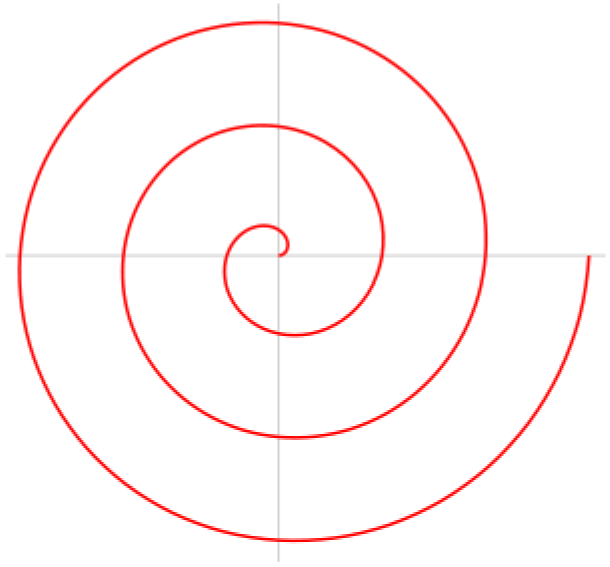
Food security and the 3-dimension nexus

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…

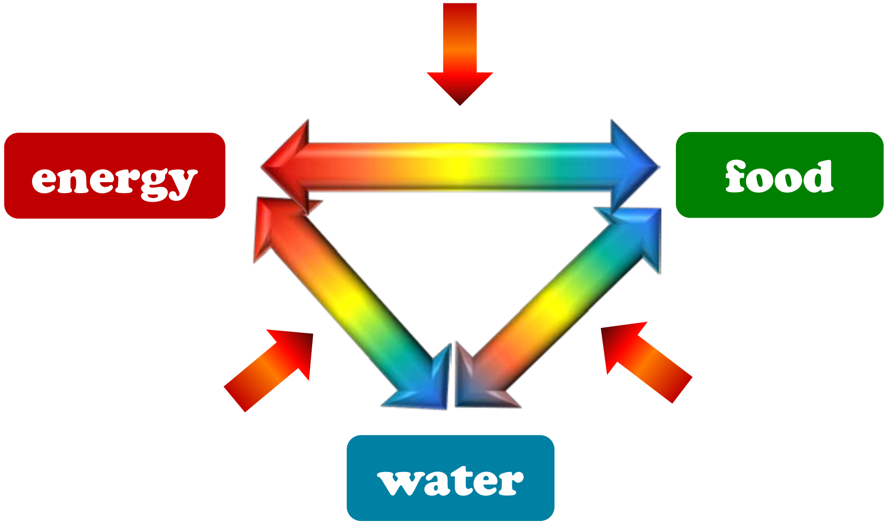




generating a mutually reinforcing spiral of insecurity

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.

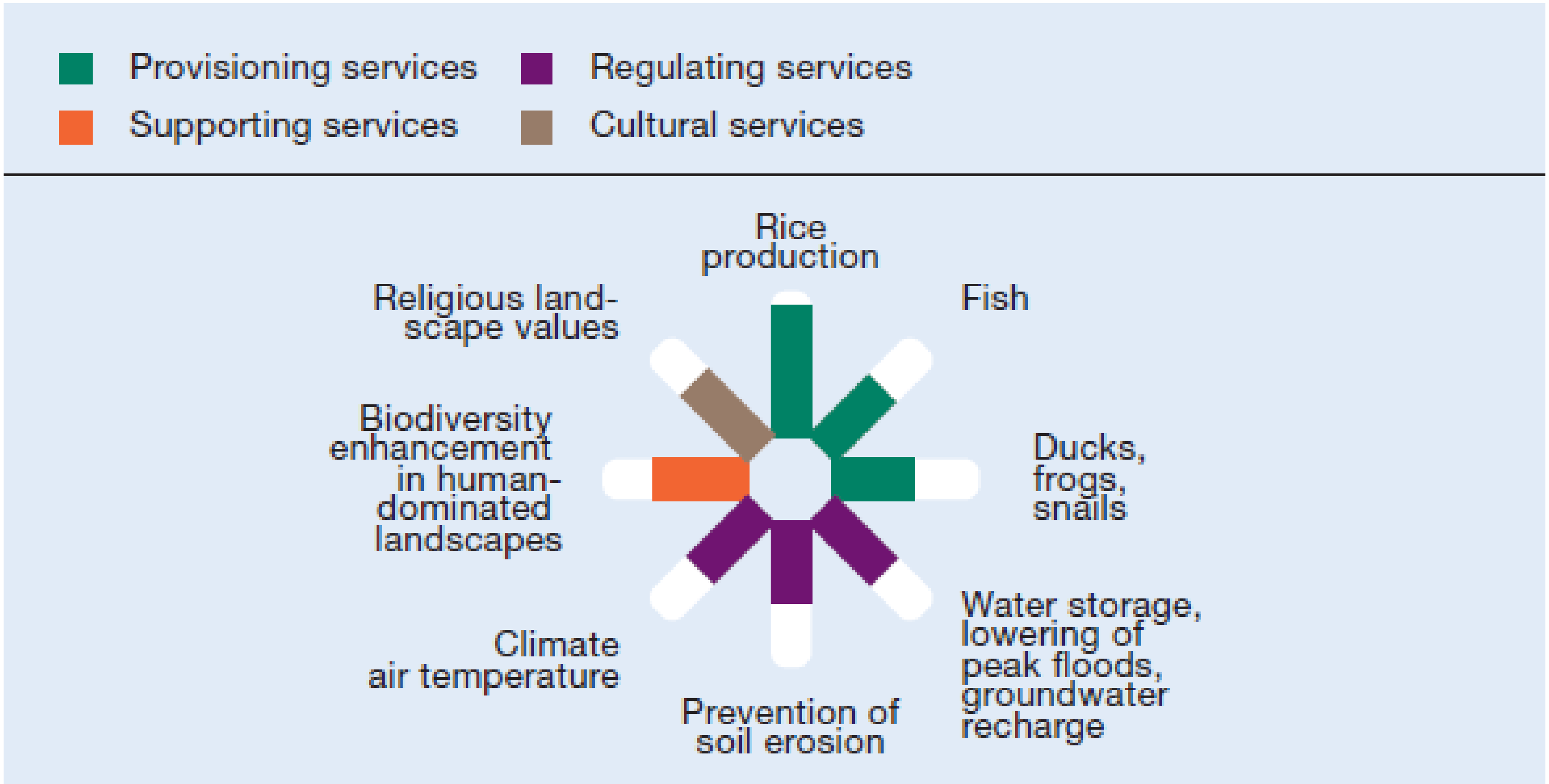
- **Increase the productivity** of water
  - A 35% increase in water productivity could reduce additional crop water consumption from 80% to 20%
- **Upgrade rainfed systems** — a little water can go a long way
- **Small Scale Irrigation** – is this the Future?
  - Private and informal irrigation is important 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

Multifunctionality in rice fields



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

Asian Institute of Technology

AIT
Asian Institute of Technology
SCHOOL OF ENGINEERING AND TECHNOLOGY

Why Water Engineering and Management ?

Today's major challenges for water engineers and managers include securing water for people and for food production, protecting vital ecosystems, and dealing with climate variability and change and uncertainty of water in space and time. The Water Engineering and Management (WEM) imparts education and training towards an understanding of the complexity of water cycle, utilization, and management. It offers a balanced curriculum covering both engineering and management aspects of water resources. Students acquire knowledge and hands-on practice in tools and techniques to come up with viable and sustainable water management for water, food, energy, and environmental security. Students conduct research on country-specific water related problems, and have opportunities to join research and internship programs with industries and partners.

Academic Programs

Masters and Doctoral Degree Program

WEM offers academic programs leading to Masters Degree, Doctoral Degree, Professional Masters Degree, and Diploma and Certificates covering five focal areas: *Agricultural Water, Coastal Water, Urban Water, Water Resources, and Extreme Events and Risk Management.* For further details, please visit www.set.ait.asia/wem/

Double Degree Masters Program

The following Double Degree Masters programs are offered with renowned institutions under which students are awarded two Masters degrees: one from AIT and one from AIT's partner institution.

- Urban Water Engineering and Management (UWEM) in collaboration with UNESCO-IHE, The Netherlands and Environmental Engineering and Management field of study at AIT
- Agricultural Water Management for Enhanced Land and Water Productivity (DD-AWELWP) in collaboration with UNESCO-IHE, The Netherlands
- Hydroinformatics and Water Management (HWM) in collaboration with The University of Nice, Sophia Antipolise, France

Distance-based Program

WEM also offers e-learning programs on:

- Integrated Water Resources Management (IWRM) in collaboration with UNU-INWEH, Canada
- Service Oriented Management of Irrigation Systems (SOMIS) in collaboration with UNESCO-IHE, The Netherlands

Courses Offered

Required courses

- Watershed Hydrology
- Water Resources Systems
- Hydrodynamics
- Concepts in Water Modeling

Elective courses

- Irrigation and Drainage Engineering
- Irrigation and Drainage Systems Management
- Coastal and Estuarine Processes
- Coastal Zone Management
- Water Supply and Sanitation
- Urban Drainage Management
- Climate Change and Water Resources
- River Engineering and Modeling
- Groundwater Development and Management
- Integrated Water Resources Management
- Land and Water Conservation and Management
- Modeling of Water Resources Systems
- Floods and Droughts
- Flood Modeling and Management
- EIA and GIS Applications in Water Resources
- Research Design and Experimental Methods

Outreach Activities

WEM also conducts customized training programs, short courses, seminars, and workshops by inviting experts and practitioners from the region and across the globe.

AIT Asian Institute of Technology
GOLDEN JUBILEE
PARTNERING ASIA'S FUTURE

For more information on WEM academic matters, please contact Dr. Mukand S. Babel, WEM Coordinator at msbabel@ait.asia

http://www.set.ait.ac.th/wem

email: msbabel@ait.asia

DOUBLE DEGREE MASTER PROGRAMME

AGRICULTURAL WATER MANAGEMENT FOR ENHANCED LAND AND WATER PRODUCTIVITY

CONTEXT

The population growth - particularly high in emerging and developing countries - means that these countries have an additional challenge to meet the Millennium Development Goal of food security by increasing production in their own territory, where possible combined with increased import of food. Researches estimate that in the coming decades about 80-90% of the required increase will need to be realised on existing cultivated land, and about 10-20% on newly reclaimed land. For sustainable rural development, socio-economic and environmental aspects play crucial roles. It is also imperative that the modernisation of existing water management systems, including management transfers, remains a continued process. Increased vulnerability of agriculture is due to flooding caused partly by the impacts of climate change, land subsidence and the escalating value of land because of the requirement of higher yields per hectare. This necessitates the agricultural water management in such areas to be integrated with flood management and flood protection provisions. This Double Degree Master programme focuses on these issues.

The Agricultural Water Management for Enhanced Land and Water Productivity programme is jointly offered by the Asian Institute of Technology (AIT) and UNESCO-IHE Institute for Water Education (UNESCO-IHE). The AWELWP programme is a double degree programme.
Students who successfully complete this programme will be awarded two Master degrees: one from UNESCO-IHE and one from AIT. The degree students receive from UNESCO-IHE is the MSc degree in Water Science and Engineering, with a specialisation in Hydraulic Engineering - Agricultural Water Management for Enhanced Land and Water Productivity. AIT will award a degree in Water Engineering and Management.

PARTICIPANT'S PROFILE

Candidates with a bachelor's degree preferably in Civil, Agricultural, or Environmental Engineering or related fields are eligible to apply. In principle, candidates should have a minimum of three years of practical or research experience in water management (irrigation, drainage) or on integrated rural development/management since graduation. All applications are, however, considered on their individual merits. Since instruction and examinations are given in English, it is essential that participants have a good working knowledge of the English language. If there is any doubt about a candidate's proficiency in English, he or she will be required to take one of the internationally recognised language tests before confirmation of admittance.

TARGET GROUP

The target group for this programme are young professionals working at ministries, authorities, river basin and water users associations, universities, research institutes, civil society organisations, and consultants dealing with or interested in the fields of planning, water resources, agriculture, environment, public works, or related fields.

ADMISSION PROCEDURE

Interested persons apply for admission with AIT, which can be done either online, or through regular post. More information on the application procedure (including the necessary forms) can be found on their website: www.ait.ac.th/admissions. AIT will coordinate with UNESCO-IHE on admissions, and selected participants will receive an admission letter from both Institutes.
The UNESCO-IHE admission letter is needed to apply for an NFP scholarship.

AIT Asian Institute of Technology

UNESCO-IHE Institute for Water Education

www.unesco-ihe.org/awm

email: msbabel@ait.asia

The Urban Water Engineering and Management programme is jointly offered by the Asian Institute of Technology (AIT) and UNESCO-IHE Institute for Water Education (UNESCO-IHE).
The UWEM programme is a double degree programme.

Students who successfully complete this programme will be awarded two Master degrees: one from UNESCO-IHE and one from AIT. The degree students receive from UNESCO-IHE is the degree in Municipal Water and Infrastructure, with a specialisation in Urban Water Engineering and Management. AIT will award a degree in Urban Water Engineering and Management.

AIT Asian Institute of Technology

UNESCO-IHE Institute for Water Education

The Urban Water Engineering and Management programme is one of the few programmes worldwide that addresses the need for Master level professionals capable of delivering both water and wastewater services within the context of the urban water cycle, covering both technical and management aspects. As such, it is attractive to professionals from both the government sector and the water industry, particularly from developing and transitional countries.

DOUBLE DEGREE MASTER PROGRAMME IN URBAN WATER ENGINEERING AND MANAGEMENT

Context

The world is increasingly urbanised with 50% of the world's population living in urban areas. By 2030 in Asia 54% will live in cities compared to 39% in 2005. This enormous growth of urban areas poses several challenges, such as delivery of essential water and sanitation services and the management of the urban water cycle.
This is also recognised by the Millennium Development Goals and Targets established at the UN Millennium Summit in 2000.
These challenges are further complicated due to climate change, and it is foreseen that coping with them requires a substantial increase of highly trained and qualified human resources.

Target group

The target group for this programme are professionals from urban water and wastewater authorities, urban development ministries/ authorities, water and environment ministries, private companies, academia, NGOs and city and municipal authorities dealing with or interested in water and sanitation services and managing the urban water cycle.

Programme structure and contents

The Urban Water Engineering and Management Programme offers students the possibility to study in Bangkok, Thailand, and in Delft, the Netherlands, at two renowned institutes for international post-graduate education: AIT and UNESCO-IHE.

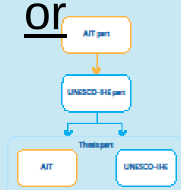
The coursework part of the programme starts at AIT in Bangkok in August, where students follow a number of courses until the second half of December. In early January, they move to Delft where they join students in UNESCO- IHE's Municipal Water and Infrastructure programme for five modules and the international field trip. Students then either move back to Bangkok or remain in Delft for their additional coursework and individual thesis research work.

Subjects at AIT (*August – December*)
- Watershed Hydrology
- Drinking Water Treatment
- Wastewater Treatment
- Integrated Water Resource Management

Subjects at UNESCO-IHE (*January – May*)
- Integrated Infrastructure Concepts
- Urban Drainage and Wastewater Collection
- Water Sector and Utility Management
- Integrated Asset Management Systems
- Water Transport and Distribution
- International Fieldtrip & Fieldwork

At AIT or UNESCO-IHE (*June onwards*)
- Elective Subjects/Groupwork
- Thesis Proposal & Work

or



www.unesco-ihe.org/uwem

www.ait.asia/double-degree-uwem

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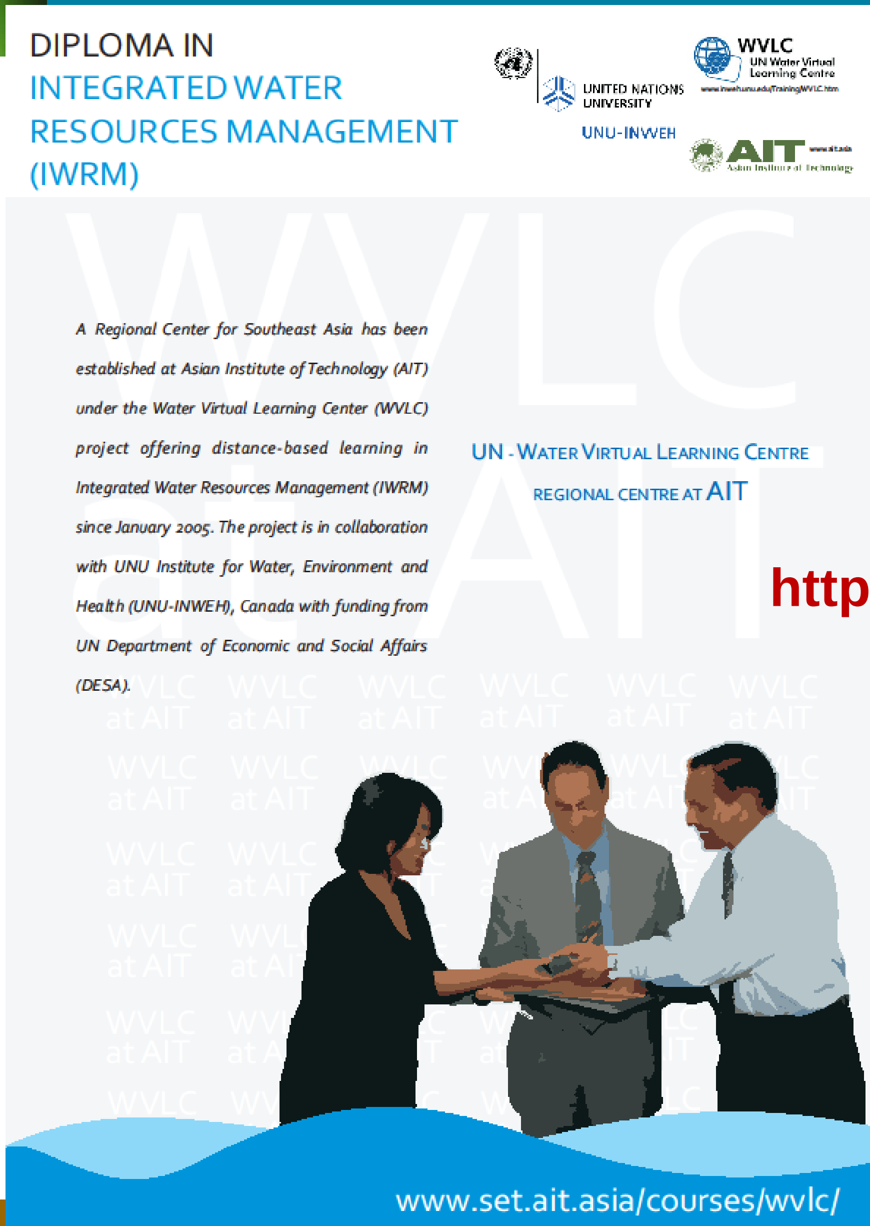

DIPLOMA IN
INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)

UNITED NATIONS UNIVERSITY

UNU-INWEH

WVLC UN Water Virtual Learning Centre

www.inweh.unu.edu/Training/WVLC.htm

AIT Asian Institute of Technology www.ait.asia

WVLC at AIT

A Regional Center for Southeast Asia has been established at Asian Institute of Technology (AIT) under the Water Virtual Learning Center (WVLC) project offering distance-based learning in Integrated Water Resources Management (IWRM) since January 2005. The project is in collaboration with UNU Institute for Water, Environment and Health (UNU-INWEH), Canada with funding from UN Department of Economic and Social Affairs (DESA).

UN - WATER VIRTUAL LEARNING CENTRE
REGIONAL CENTRE AT AIT

www.set.ait.asia/courses/wvlc/

http://www.set.ait.ac.th/courses/wvlc

email: wvlc@ait.asia