Water Scarcity and Food Security

Challenges in Water-Food-Energy Nexus

Mukand S. BABEL
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
   o Facts and figures
   o Water and food issues
   o Water and energy issues
   o Energy and food issues
   o Exacerbation by climate change

2. Case studies
   o Climate change and rice production
   o 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.”

**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.

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
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.

Aggregated global gap between existing accessible, reliable supply\(^1\) and 2030 water withdrawals, assuming no efficiency gains

### Compound annual growth rate (CAGR)

- **2%\(^2\)**

### Existing accessible, reliable, sustainable supply\(^1\)

- **Billion m\(^3\), 154 basins/regions

### Basins with deficits

- **6,900**

### Basins with surplus

- **2,800**

### Basins with deficits

- **2030 withdrawals\(^3\)**

### Surface water

- **4,200**

### Groundwater

- **700**

### Relevant supply quantity is much lower that the absolute renewable water availability in nature

### Agriculture

- **3,100**

### Industry

- **4,500**

### Municipal & Domestic

- **6,900**

### Existing withdrawals\(^2\)

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 gains 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.
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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of people</td>
<td>15.0</td>
<td>11.2</td>
<td>11.5</td>
<td>10.8</td>
</tr>
<tr>
<td>undernourished (millions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion</td>
<td>26</td>
<td>18</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>of undernourished in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total population</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 have pushed 44 million people into extreme poverty and hunger since June 2010.

That's twice the population of Australia.

Family spending on food:
- USA (7%)
- Guatemala (36%)
- Kenya (45%)
- Azerbaijan (49%)

Source: US Department of Agriculture

Key:
- Blue: % of income spent on food
- Black: % of income remaining for other bills

A poor family in a poor country spends as much as 70% of its income on food.

What happens when food prices go up?
- Food (70% of total income)
- Everything else (30%)

Food (85% of total income)
- Everything else (15%)

School, Medicine, Clothing, Rent...
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

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Bio-ethanol production (million litres)</th>
<th>Share of global bio-ethanol production (%)</th>
<th>Energy share in gasoline type fuel use (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>21478</td>
<td>38394</td>
<td>52444</td>
</tr>
<tr>
<td>Brazil</td>
<td>17396</td>
<td>22110</td>
<td>40511</td>
</tr>
<tr>
<td>China</td>
<td>5564</td>
<td>6686</td>
<td>10210</td>
</tr>
<tr>
<td>EU27</td>
<td>2049</td>
<td>4402</td>
<td>11883</td>
</tr>
<tr>
<td>India</td>
<td>1411</td>
<td>1909</td>
<td>3574</td>
</tr>
<tr>
<td>Canada</td>
<td>762</td>
<td>1383</td>
<td>2730</td>
</tr>
<tr>
<td>Columbia</td>
<td>272</td>
<td>497</td>
<td>796</td>
</tr>
<tr>
<td><strong>Thailand</strong></td>
<td><strong>285</strong></td>
<td><strong>408</strong></td>
<td><strong>1790</strong></td>
</tr>
<tr>
<td>Other countries*</td>
<td>1066</td>
<td>1266</td>
<td>2922</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>50,283</strong></td>
<td><strong>77,055</strong></td>
<td><strong>126,860</strong></td>
</tr>
</tbody>
</table>

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

Source: OECD/FAO (2008); \(^a\) estimated value
### Global Bio-Diesel Projections

<table>
<thead>
<tr>
<th>Country</th>
<th>Biodiesel production (million litres)</th>
<th>Share of global biodiesel production (%)</th>
<th>Energy share in diesel type fuel use (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU27</td>
<td>5095</td>
<td>6580</td>
<td>13271</td>
</tr>
<tr>
<td>United States</td>
<td>1429</td>
<td>2017</td>
<td>1731</td>
</tr>
<tr>
<td>Australia</td>
<td>199</td>
<td>911</td>
<td>994</td>
</tr>
<tr>
<td>Indonesia</td>
<td>241</td>
<td>753</td>
<td>2984</td>
</tr>
<tr>
<td>Brazil</td>
<td>158</td>
<td>760</td>
<td>2519</td>
</tr>
<tr>
<td>Malaysia</td>
<td>148</td>
<td>443</td>
<td>1137</td>
</tr>
<tr>
<td>India</td>
<td>277</td>
<td>317</td>
<td>385</td>
</tr>
<tr>
<td>Columbia</td>
<td>10</td>
<td>218</td>
<td>388</td>
</tr>
<tr>
<td>Canada</td>
<td>46</td>
<td>207</td>
<td>660</td>
</tr>
<tr>
<td><strong>Thailand</strong></td>
<td>0</td>
<td>48</td>
<td>75</td>
</tr>
<tr>
<td>Other countries*</td>
<td>7</td>
<td>19</td>
<td>213</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7,610</td>
<td>12,273</td>
<td>24,357</td>
</tr>
</tbody>
</table>

Source: OECD/FAO (2008); \(^a\) estimated value

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

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

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.

### Virtual water content of selected products

<table>
<thead>
<tr>
<th>Plant-based product</th>
<th>Water requirement</th>
<th>Animal-based product</th>
<th>Water requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1,150</td>
<td>Beef</td>
<td>15,977</td>
</tr>
<tr>
<td>Rice</td>
<td>2,656</td>
<td>Pork</td>
<td>5,906</td>
</tr>
<tr>
<td>Maize</td>
<td>450</td>
<td>Poultry</td>
<td>2,828</td>
</tr>
<tr>
<td>Potato</td>
<td>160</td>
<td>Eggs</td>
<td>4,657</td>
</tr>
<tr>
<td>Soybean</td>
<td>2,300</td>
<td>Milk</td>
<td>865</td>
</tr>
</tbody>
</table>

Figures in global averages, liter of water per kg of product, Hoekstra 2003
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)*
Challenges for irrigated agriculture:
• improve equity
• reduce environmental damage
• increase ecosystem services
• enhance water and land productivity in existing and new irrigated systems

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
both challenges must be addressed together

Vicious Cycles
Water consumed to produce 1 MWh of electricity:\textsuperscript{16}

Wind turbines. \hspace{2cm} 0 m\textsuperscript{3}/MWh
Solar \hspace{2cm} 0 m\textsuperscript{3}/MWh
Natural gas \hspace{2cm} 0.2 m\textsuperscript{3}/MWh
Coal \hspace{2cm} 0.7-3.0 m\textsuperscript{3}/MWh
Nuclear \hspace{2cm} 0.9-3.3 m\textsuperscript{3}/MWh
Oil/petroleum \hspace{2cm} 0.1-6.5 m\textsuperscript{3}/MWh
Hydropower (from evaporation) \hspace{2cm} 17.0 m\textsuperscript{3}/MWh
First generation biofuels* \hspace{2cm} 32.3-360.0 m\textsuperscript{3}/MWh

\textit{* 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)

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

Source: IWMI 2007

Groundwater withdrawal (cubic kilometers per year)

### Electricity consumption in Indian Agriculture

<table>
<thead>
<tr>
<th>Electricity consumption</th>
<th>1980-81</th>
<th>1999-2000</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total electricity consumption (MkWh)</td>
<td>81 400</td>
<td>332 474</td>
<td>308</td>
</tr>
<tr>
<td>Electricity consumption in the agricultural sector</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (MkWh)</td>
<td>14 489</td>
<td>98 800</td>
<td>582</td>
</tr>
<tr>
<td>(17.8)</td>
<td>(29.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per tube well (kWh)</td>
<td>3 346</td>
<td>8 100</td>
<td>142</td>
</tr>
<tr>
<td>Per 1000 ha of GCA (kWh)</td>
<td>80</td>
<td>520</td>
<td>550</td>
</tr>
<tr>
<td>Per Rs 1000 of agricultural output</td>
<td>31</td>
<td>116⁸</td>
<td>274</td>
</tr>
</tbody>
</table>

**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

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
Bio-fuel as an alternative

- 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 evapotranspiration (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.
Bio-fuel and food security

Excuse me, I’m going to need this to run my car.

No, but I can offer you a gallon of ethanol!
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
• 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
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
- Low soil fertility, poor physical endowment of the region
- Highly uneven distribution of rainfall
- Average yield of rice lower than the country average yield
Major rice varieties and their yields

Source: Office of Agriculture Economics, 2007
Research methodology

**Study Area**
(Ubon Ratchathani, Khon Kaen, RoiEt)

- **Data Collection**
  - Soil Data from LDD
  - Weather Data from TMD
  - Crop Data from RRC’s

- CERES-Rice v 4.0

- Calibration and validation of model

- Possible adaptation measures

- Calibrated model

- Forecasted rice yield under climate change scenario

- Evaluated agro adaptation measures

- Results and recommendations

**Future Scenarios**
- 2020-29
- 2050-59
- 2080-89

**Global Resolution**
- 280km X 280km

**Downscaled ECHAM output**
- 25km X 25 km

**IPC SRES A2 Scenario**
- Baseline Data: 1980-89

**Objective 1**
- GCM (ECHAM4)

**Objective 2**
- RCM (PRECIS)

**Parameters**
- Tmax
- Tmin
- Rainfall
- Solar Radiation

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**Parameters**
- Tmax
- Tmin
- Rainfall
- Solar Radiation
Observed & simulated weather (1980-89)

- **Rainfall in mm**
  - **Month**: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
  - **Observed**
  - **Simulated**

- **Tmax (°C)**
  - **Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec**
  - **Observed**
  - **Simulated**

- **Tmin (°C)**
  - **Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec**
  - **Observed**
  - **Simulated**
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

![Graph showing rainfall trends over months for different periods (1980-89, 2020-29, 2050-59, 2080-89). The graph includes lines for wettest, mean, and driest months, with rainfall in mm on the y-axis and month on the x-axis.

Bar charts for each period showing rainfall for wettest, mean, and driest months.

- **Rainfall (mm)**
  - 1980-89
  - 2020-29
  - 2050-59
  - 2080-89

- **Legend**:
  - Dry Season
  - Total
  - Wet Season

- **Graph Details**:
  - Y-axis: Rainfall in mm
  - X-axis: Month (0 to 12)
  - Lines represent different periods:
    - 1980-89
    - 2020-29
    - 2050-59
    - 2080-89
  - Bars for each period:
    - Wettest
    - Mean
    - Driest
Calibration: KDML105 at Ubon Ratchathani

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

Grain Yield

<table>
<thead>
<tr>
<th></th>
<th>Simulated</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Rainfed with late seeding</td>
<td>2500</td>
<td>2500</td>
</tr>
</tbody>
</table>

Harvest Index

<table>
<thead>
<tr>
<th></th>
<th>Simulated</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed</td>
<td>0.400</td>
<td>0.350</td>
</tr>
<tr>
<td>Rainfed with late seeding</td>
<td>0.350</td>
<td>0.300</td>
</tr>
</tbody>
</table>

Number of seeds per m²

<table>
<thead>
<tr>
<th></th>
<th>Simulated</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed</td>
<td>12000</td>
<td>12000</td>
</tr>
<tr>
<td>Rainfed with late seeding</td>
<td>11500</td>
<td>11500</td>
</tr>
</tbody>
</table>

Anthesis Day

<table>
<thead>
<tr>
<th></th>
<th>Simulated</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfed</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>Rainfed with late seeding</td>
<td>60</td>
<td>50</td>
</tr>
</tbody>
</table>

Anthesis day - day after planting
Yield results for experiments

**KDML105 at RoiEt**

- **No fertilizer**: Simulated yield is around 1200 kg/ha, Observed yield is around 1500 kg/ha.
- **Fertilizer 16-16-8 @ 157kg/ha**: Simulated yield is around 1800 kg/ha, Observed yield is around 2000 kg/ha.

**RD6 at RoiEt**

- **Fertilizer 16-16-8 @ 356kg/ha**: Simulated yield is around 2500 kg/ha, Observed yield is around 2800 kg/ha.
- **No Fertilizer**: Simulated yield is around 2000 kg/ha, Observed yield is around 2100 kg/ha.
- **Fertilizer 16-16-8 @ 157 kg/ha**: Simulated yield is around 2300 kg/ha, Observed yield is around 2400 kg/ha.
Comparison of baseline year (1980-89) yield

- 5.15%
### Effect of climate on yield components

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

- **RD6 at RoiEt**
  - **Mean**
  - **Max**
  - **Min**

- **KDML105 at RoiEt**
  - **Mean**
  - **Max**
  - **Min**

- **KDML 105 at Ubon**
  - **Mean**
  - **Max**
  - **Min**

- **KDML 105 at Khon Kaen**
  - **Mean**
  - **Max**
  - **Min**
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

RD6 at RoiEt

 KDML105 at RoiEt

Change in Yield (%)
Effect of different N rates

RD6 at RoiEt

KDML105 at RoiEt
Effect of Change in N Application Time

**RoiEt**

- +10 days
- +5 days
- -5 days
- -10 days

**Khon Kaen**

- +10 days
- +5 days
- -5 days
- -10 days

**Ubon**

- +10 days
- +5 days
- -5 days
- -10 days
Effect of Using Hybrid Cultivars

**RoiEt**

- **Yield (kg/ha)**
- **1997-06**
- **2020-29**
- **2050-59**
- **2080-89**

**Khon Kaen**

- **Yield (kg/ha)**
- **1997-06**
- **2020-29**
- **2050-59**
- **2080-89**

**Ubon**

- **Yield (kg/ha)**
- **1997-06**
- **2020-29**
- **2050-59**
- **2080-89**
Conclusions

- Simulated and observed weather
  - in good agreement in terms of seasonal pattern
- Temperature and CO\textsubscript{2} under future scenarios and rainfall pattern will change
  - Increase in temperature will effect rice yield negatively
  - Increase in CO\textsubscript{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
Impact of Bio-fuel Production on Hydrology

A case study of Khlong Phlo Watershed, Thailand
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°57’-13°10’N
101°35’-101°45’E

Area 202.8 km²
Rainfall 1,734 mm
Temperature 27 to 31°C
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
Step 1: Water footprint of crops (WF$_{CP}$)

- Climatic Parameters
  - Effective Rainfall
  - Reference crop ET
- Crop Coefficient
  - Crop ET
  - Irrigation required
  - Pollutant emission
  - Agreed water quality

Green WF$_{CP}$
Blue WF$_{CP}$
Grey WF$_{CP}$

Step 2: Water footprint of biofuel (WF$_{B}$)

- Biofuel conversion rate
  - Green WF$_{CP}$
  - Blue WF$_{CP}$
  - Grey WF$_{CP}$

Green WF$_{B}$
Blue WF$_{B}$
Grey WF$_{B}$

Step 3: Water footprint of biofuel energy (WF$_{BE}$)

- Energy of bio-fuel
  - Green WF$_{B}$
  - Blue WF$_{B}$
  - Grey WF$_{B}$

Green WF$_{BE}$
Blue WF$_{BE}$
Grey WF$_{BE}$
<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green WF</td>
<td>Min (Evapotranspiration, Effective rain)</td>
</tr>
<tr>
<td>Blue WF</td>
<td>Irrigation requirement</td>
</tr>
<tr>
<td>Grey WF</td>
<td>Max (Pollutant released/Permissible limit)</td>
</tr>
<tr>
<td>$WF_{CP}$</td>
<td>Water use for crop production / crop yield</td>
</tr>
<tr>
<td>$WF_B$</td>
<td>$WF_{CP}$ / biofuel conversion rate</td>
</tr>
<tr>
<td>$WF_{BE}$</td>
<td>$WF_B$ / energy per liter biofuel</td>
</tr>
<tr>
<td>Energy /L biofuel</td>
<td>HHV x density</td>
</tr>
</tbody>
</table>
Methodology: SWAT, Preprocessing phase

Impact on water balance and water quality

DEM

Drainage

Sub-watersheds

Land use

Soil

Hydrological Response Units
Methodology: SWAT, Preprocessing phase

Impact on water balance and water quality

Meteorological data
- Rainfall
- Temperature
- Humidity
- Wind
- Solar Radiation

Model evaluation

Land use change scenarios

Management data
- Tillage Practice
- Crop Calendar
- Fertilizer application
- Irrigation Schedules

Hydrological Response Units

Model calibration and validation

Scenarios simulation

Evaluation
  - Water balance
  - Water quality
## Bio-fuel target of Thailand by the year 2022

<table>
<thead>
<tr>
<th>Bio-fuel</th>
<th>Year 2008</th>
<th>Year 2009-2011</th>
<th>Year 2012-2016</th>
<th>Year 2017-2022</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mLd</td>
<td>mLd</td>
<td>mLd</td>
<td>mLd</td>
</tr>
<tr>
<td>Bio-diesel</td>
<td>1.22</td>
<td>3.00</td>
<td>3.64</td>
<td>4.50</td>
</tr>
<tr>
<td>Bio-ethanol</td>
<td>0.88</td>
<td>3.00</td>
<td>6.20</td>
<td>9.00</td>
</tr>
<tr>
<td>Total</td>
<td>2.10</td>
<td>6.00</td>
<td>9.84</td>
<td>13.50</td>
</tr>
</tbody>
</table>

Source: [http://www.dede.go.th](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

<table>
<thead>
<tr>
<th>Code</th>
<th>Land Use</th>
<th>Area (km²)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Rice</td>
<td>1.82</td>
<td>0.90</td>
</tr>
<tr>
<td>8</td>
<td>Cashew Nut</td>
<td>4.84</td>
<td>2.39</td>
</tr>
<tr>
<td>9</td>
<td>Cassava</td>
<td>9.88</td>
<td>4.87</td>
</tr>
<tr>
<td>21</td>
<td>Evergreen Forest</td>
<td>66.36</td>
<td>32.73</td>
</tr>
<tr>
<td>27</td>
<td>Deciduous Forest</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>41</td>
<td>Institutional Land</td>
<td>0.51</td>
<td>0.25</td>
</tr>
<tr>
<td>43</td>
<td>Water bodies</td>
<td>0.89</td>
<td>0.44</td>
</tr>
<tr>
<td>47</td>
<td>Residential</td>
<td>0.28</td>
<td>0.14</td>
</tr>
<tr>
<td>57</td>
<td>Wet Land</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>64</td>
<td>Orchard</td>
<td>27.96</td>
<td>13.79</td>
</tr>
<tr>
<td>67</td>
<td>Oil Palm</td>
<td>1.12</td>
<td>0.55</td>
</tr>
<tr>
<td>70</td>
<td>Rubber</td>
<td>85.12</td>
<td>41.98</td>
</tr>
<tr>
<td>82</td>
<td>Range grass</td>
<td>1.83</td>
<td>0.90</td>
</tr>
<tr>
<td>89</td>
<td>Sugarcane</td>
<td>2.11</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td><strong>202.80</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>
**Land use change scenarios**

### A. Oil Palm expansion (Biodiesel)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Oil palm Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Orchard to oil Palm</td>
<td>&lt;1 to 17%</td>
</tr>
<tr>
<td>A2</td>
<td>Rubber to oil Palm</td>
<td>&lt;1 to 43%</td>
</tr>
<tr>
<td>A3</td>
<td>Orchard + rubber to oil palm</td>
<td>&lt;1 to 59%</td>
</tr>
<tr>
<td>A4</td>
<td>Forest to oil palm</td>
<td>&lt;1 to 33%</td>
</tr>
<tr>
<td>A5</td>
<td>Orchard, Rubber and Forest to oil palm</td>
<td>&lt;1 to 91%</td>
</tr>
</tbody>
</table>

### B. Cassava expansion (Bio-ethanol)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Cassava Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Orchard to cassava</td>
<td>5 to 21%</td>
</tr>
<tr>
<td>B2</td>
<td>Rubber to cassava</td>
<td>5 to 47%</td>
</tr>
<tr>
<td>B3</td>
<td>Orchard + rubber to cassava</td>
<td>5 to 63%</td>
</tr>
<tr>
<td>B4</td>
<td>Forest to cassava</td>
<td>5 to 38%</td>
</tr>
<tr>
<td>B5</td>
<td>Orchard, Rubber and Forest to cassava</td>
<td>5 to 96%</td>
</tr>
</tbody>
</table>

### C. Sugarcane expansion (Bio-ethanol)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Sugarcane Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Orchard to sugarcane (Sc)</td>
<td>Sc1 to 17%</td>
</tr>
<tr>
<td>C2</td>
<td>Rubber to sugarcane (Sc)</td>
<td>Sc1 to 43%</td>
</tr>
<tr>
<td>C3</td>
<td>Orchard + rubber to sugarcane (Sc)</td>
<td>Sc1 to 59%</td>
</tr>
<tr>
<td>C4</td>
<td>Forest to sugarcane (Sc)</td>
<td>Sc1 to 34%</td>
</tr>
<tr>
<td>C5</td>
<td>Orchard, Rubber and Forest to sugarcane (Sc)</td>
<td>Sc1 to 92%</td>
</tr>
</tbody>
</table>
Results: Water footprints of Bio-energy

![Bar chart showing water footprints for Oil Palm, Cassava, and Sugarcane.]

- **Oil Palm**
  - Grey WF: 20 m³/GJ of energy
  - Blue WF: 10 m³/GJ of energy
  - Green WF: 90 m³/GJ of energy

- **Cassava**
  - Grey WF: 5 m³/GJ of energy
  - Blue WF: 15 m³/GJ of energy
  - Green WF: 60 m³/GJ of energy

- **Sugarcane**
  - Grey WF: 10 m³/GJ of energy
  - Blue WF: 30 m³/GJ of energy
  - Green WF: 90 m³/GJ of energy
Results: Effects on water balance

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

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

**Scenario A1**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario A2**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario A3**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario A4**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario A5**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario B1**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario B2**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario B3**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario B4**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)

**Scenario B5**
- NO3-N loss: (value)
- Total P loss: (value)
- Sediment loss: (value)
## Results

Less water use per energy production but higher environmental impact

<table>
<thead>
<tr>
<th>Crops</th>
<th>Water use per GJ bioenergy</th>
<th>Water Quality Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>183 m$^3$/GJ</td>
<td>Nitrate loss rise 52%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phosphorus loss rise 29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sediment loss rise 15%</td>
</tr>
<tr>
<td></td>
<td>108 m$^3$/GJ</td>
<td>Nitrate loss rise 45%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phosphorus loss rise 165%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sediment loss rise 92%</td>
</tr>
<tr>
<td></td>
<td>143 m$^3$/GJ</td>
<td>Nitrate loss rise 29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phosphorus loss rise 125%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sediment loss rise 68%</td>
</tr>
</tbody>
</table>
Results

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

Blue water (base case) = 20 mm

90% of land use change would increase blue water by more than 20 times = about 80% of the current annual water yield
Results

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

Grey water (base case) = 37 mm
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 affect 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
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.
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
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 toward 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 Diplomas 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.ac.th/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 (DO-AWELP) in collaboration with UNESCO-IHE, The Netherlands
- Hydroinformatics and Water Management (HWM) in collaboration with The University of Nice, Sophia Antipolis, France

Distance-based Program

WEM also offers e-learning programs on:

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

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.

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 limited arable land, where possible combined with increased input of food. Research estimates that in the coming decades about 80-90% of the required increase will need to be realized on existing cultivated land, and about 10-20% on newly reclaimed land. For sustainable rural development, socioeconomic and environmental aspects play crucial roles. It is also imperative that the modernization of existing water management systems, including management transfers, entails a continued process. Increased vulnerability of agriculture is due to flooding caused partly by the impact of climate change, land subsidence and the subsiding water level 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 practices. This Doubled Degree Master programme focuses on these issues.

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 an integrated rural development management science 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/she will be required to take one of the internationally recognized language tests before confirmation of admission.

TARGET GROUP

The target group for the programme are young professionals working at ministries, authorities, river boards, and water users associations, universities, research institutes, civil society organizations, and consultants dealing with or interested in the fields of planning, water resources, agriculture, environment, public sector, 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 for admissions, and selected participants will receive an admission letter from both institutes. The UNESCO-IHE admission letter is needed to apply for an NRP scholarship.

www.unesco-ihe.org/awm
email: msbabel@ait.asia
DOUBLE DEGREE MASTER PROGRAMME IN URBAN WATER ENGINEERING AND MANAGEMENT

**Overview**

The world is increasingly urbanised with 50% of the world's population living in urban areas. By 2050, in Asia 34% will live in cities compared to 3% in 2000. This enormous growth of urban areas poses several challenges, such as delivery of essential urban 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 forecasted that coping with them requires a substantial increase of highly trained and qualified human resources.

**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, as two renowned institutes for international postgraduate 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 January, they move to Delft where they join students in UNESCO-IHE’s Municipal Water and Wastewater Programme for five modules and the international field trip. Students then either move back to Bangkok or continue in Delft for their additional coursework and individual thesis research work.

**Subjects at AIT (August - December)**

- Water Resources Management
- Urban Drainage and Wastewater Collection
- Water Sector and Utility Management
- Integrated Water Resources Management

**Subjects at UNESCO-IHE (January - May)**

- Integrated Wastewater Concepts
- Environmental Economics
- Water Transport and Distribution
- International Water Supply and Wastewater Technology

At AIT or UNESCO-IHE (June onwards)

- Thesis Supervision/Committee
- Thesis Proposal & Work

For more information, visit [www.unesco-ihe.org/uwem](http://www.unesco-ihe.org/uwem) or [www.ait.asia/double-degree-uwem](http://www.ait.asia/double-degree-uwem)

Email: msbabel@ait.asia
Diploma in Integrated Water Resources Management (IWRM)

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 (UNDESA).

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

email: wvlc@ait.asia