GTSP Technical Review (Theme 2): Bioenergy, Land-use, Climate Change, & Water

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• Introduction to Water: Modeling Supply & Demand
• Agriculture-Water Demand
• Energy-Water Demand
The GCAM Human Systems Overview

The Energy System

Energy Demand

- Energy Demand Technologies

Energy Markets

Energy Production Transformation & Use

Regional Resource Bases

Regional Energy Conversion Technologies

Energy Supply

GHG Emissions

The Economy

Regional Labor Force

Regional GDP

Regional Labor Productivity

Water

Agriculture and land use

Technology

Regional Land Categories and Characteristics

Demand
- Crops
- Livestock
- Forest products

Supply
- Crops
- Livestock
- Biocrops
- Forestry Products

Ag-Land Markets
- Land rent
- Crop prices
- Livestock prices
- Forest product prices
- Biomass prices

Land Use Change Emissions

Production
- Crops
- Livestock
- Forests products
- Biomass energy

Land Use
- Crops
- Livestock
- Managed Forests
- Unmanaged
Water in GCAM

Agriculture
- Agricultural Sector Demands
- Energy Sector Demands
- Industrial Sector Demands
- Household Sector Demands
- Commercial Sector Demands
- Ecosystem, Navigation, Inter-basin Transfers (prescribed)

Energy

Domestic

Supply
- Climate
- Surface Water
- Ground Water Recharge
- Water Supply
- Desalination
- Energy Demand

Water Markets

Water Allocation and Use

Proudly Operated by Battelle Since 1965
Global Water Demands

Global Water Withdrawal

- Domestic: 70%
- Industrial: 19%
- Agricultural: 11%


Water Supply → Extract → Water withdrawal → Return Flow

Water Consumption
- Evaporation
- Transpiration
- Incorporated into products or crops
- Significantly contaminated
- Made unavailable to other water users

Cubic km per year

Agriculture
Domestic use
Industry

Present Water Demand & Supply:

- **Domestic water need**
  
  [100 liters/person/day] OR [40 m³/person/yr]

- **Other water needs (agricultural, industrial, and energy)**
  
  [800 m³/person/yr]

- **Total water need**
  
  [840 m³/person/yr]

Water scarcity  
< 1000 m³/person/yr

Water stress  
< 1700 m³/person/yr

Water sufficiency  
> 1700 m³/person/yr
WATER SUPPLY

Model & Results

Precipitation: 110,000 km³
Evapotranspiration: 65,200 km³
Runoff + GW Recharge: 44,800 km³

Modeling Water Supply

- Complexity level?
- Temporal scale?
- Spatial scale?

1) Empirical models
2) Water-balance models
3) Conceptual lumped-parameter models
4) Process-based distributed-parameter models

Global Monthly Water-Balance Model:

- Climate
  - Precipitation
  - Temperature
  - Potential Evapotranspiration

- Macro-scale Hydrology
  - Runoff
  - Storage
  - Evapotranspiration

- Water Management Models (consumption/allocation)
  - Most suitable
    - Storage effect
    - Seasonality
Water Supply Model

MODEL INPUTS
- Temperature
- Precipitation
- Maximum Soil Moisture Capacity

MODEL OUTPUTS
- Potential Evapotranspiration (PET)
- Actual Evapotranspiration (AET)
- Storage
- Runoff

MONTHLY WATER BALANCE MODEL
Simulated Runoff

This Study

WBM
Fekete et al. (2000)
Comparison to Statistics at the Country Scale

- FAO
- UNESCO
- WRI
Climatic Future Projections

- 16 permutations of four GCMs (HadCM3, CSIRO2, CGCM2, PCM) with four SRES scenarios (A1FI, A2, B1, B2)
- Community Earth Systems Model (CESM) + Regional Climate Model (WRF)

Table of climate grids and derived data-sets

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<th>space</th>
<th>time</th>
<th>variety</th>
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Climatic Research Unit (CRU)
University of East Anglia
Domestic, Energy, & Agricultural Uses

WATER DEMANDS

PRELIMINARY RESULTS

1. DOMESTIC WATER USE DEMAND
Domestic Water Use Data

**GDP** (from World bank)

![GDP vs. Water Use](image1)

**Population** (from World bank)

![Population vs. Water Use](image2)

**Water Price**


Average Revenue W&WW (US$/m3 water sold) Vs. Total Water Consumption (/person/day)


<table>
<thead>
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<td>India</td>
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Water Use Per Capita (Liters/person/day)

- **WU= 348.97P^{-0.457}**
  - $R^2 = 0.403$
  - GDPC>$16,000$

- **WU= 160.46P^{-0.229}**
  - $R^2 = 0.1227$
  - $1,000<$GDPC<$16,000$

- **WU= 48.436P^{0.504}**
  - $R^2 = 0.3833$
  - GDPC<$1,000$

Where:
- **WU** = Water Use
- **P** = Population
- **GDPC** = Gross Domestic Per Capita
Domestic Water Use Model

\[
WUc \left( \frac{m^3}{\text{capita/yr}} \right) = 2.93 \cdot GDPC^{0.4}_{(2005\text{US$}/\text{Capita})} \cdot Price^{-0.3}_{(2005\text{US$})}
\]

- **Scaling coefficient**
- Elasticity = 0.4
  - i.e., double per capita income → \( WUc \uparrow \) by 40%
- Elasticity = -0.3
  - i.e., double Price → \( WUc \downarrow \) by 30%

**Country-scale**

**GCAM-scale**
HOW BIG WILL GLOBAL DOMESTIC WATER DEMANDS GROW IN THE FUTURE?

Projecting to the future…
From GCAM Output

Exogenous Information

Domestic Water Withdrawal Per Capita

Total Domestic Water Withdrawal

GDP

Population

Price

Consumption to Withdrawal Ratio

From GCAM Output

\[ WUc (m^3/capita/yr) = 2.93 \cdot GDPC^{0.4} (2005/US$/Capita) \cdot Price^{-0.3} (2005/US$) \]
Effects of Price, End-Use Technology, Supply Efficiency

- **Income per Capita**
- **Water end-use Technological Changes**
  - 0.5% Annually
  - Source: Vob et al., 2009
- **Water Price**
  - Doubles in 90 yrs
- **Water Supply Efficiency**
  - Source: (Shiklomanov, 1999)
Key Findings:

- Domestic water use will increase by **4 folds** by 2095 due to population and income per capita growth
- Total domestic water consumption in 2095
  - Doubling **water price** ➔ ↓20%
  - Investing in **water end-use technology** ➔ ↓29%
  - Investing in **supply efficiency** ➔ ↓21%

Future Efforts:

- Integrating water supply and demand in GCAM
- Allocating water to sectors by solving water markets (prices)
AGRICULTURAL WATER DEMAND

Next…