Managed water resource systems: the human dimension of the global water cycle

Richard Harding
Global Water Use

Hejazi et al 2013
**Global Water Resources**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual land precipitation</td>
<td>$1.15 \times 10^3$ KM$^3$</td>
</tr>
<tr>
<td>Total annual runoff</td>
<td>$4.9 \times 10^3$ KM$^3$</td>
</tr>
<tr>
<td>Total capacity of reservoirs</td>
<td>$7.4 \times 10^3$ KM$^3$</td>
</tr>
<tr>
<td>Annual water use for irrigation</td>
<td>$\approx 1.5 \times 10^3$ KM$^3$</td>
</tr>
<tr>
<td>Unsustainable groundwater extraction</td>
<td>$0.23 \times 10^3$ KM$^3$ yr$^{-1}$</td>
</tr>
<tr>
<td>Total global land area</td>
<td>$1.49 \times 10^3$ KM$^2$</td>
</tr>
<tr>
<td>Total irrigated area (Year 2000)</td>
<td>$2.6 \times 10^3$ KM$^2$</td>
</tr>
</tbody>
</table>

Global land

- **Precipitation**
  - Mean: $872$ mm yr$^{-1}$

**Evaporation**

- Mean: $499$ mm yr$^{-1}$
- Range: $415$-$586$ mm yr$^{-1}$

**Runoff**

- Mean: $375$ mm yr$^{-1}$
- Range: $290$-$457$ mm yr$^{-1}$

$\Delta$Soil = $16$ mm, $\Delta$Snow = $33$ mm
Percentage Irrigated area
### India: Water: sources and use

#### Renewable freshwater resources

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (long-term average 1 170 mm/yr)</td>
<td>$3.8 \times 10^3$ km³ yr⁻¹</td>
</tr>
<tr>
<td>Internal renewable water resources (long-term average)</td>
<td>$1.4 \times 10^3$ km³ yr⁻¹</td>
</tr>
<tr>
<td><strong>Total actual renewable water resources</strong></td>
<td>$1.9 \times 10^3$ km³ yr⁻¹</td>
</tr>
<tr>
<td>Total dam capacity 2005</td>
<td>224 km³</td>
</tr>
</tbody>
</table>

#### Water withdrawal

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total water withdrawal 2010</strong></td>
<td>761 km³ yr⁻¹</td>
</tr>
<tr>
<td>- irrigation + livestock 2010</td>
<td>688 km³ yr⁻¹</td>
</tr>
<tr>
<td>- municipalities 2010</td>
<td>56 km³ yr⁻¹</td>
</tr>
<tr>
<td>- industry 2010</td>
<td>17 km³ yr⁻¹</td>
</tr>
<tr>
<td>per inhabitant 2010</td>
<td>630 m³/yr</td>
</tr>
</tbody>
</table>

**Surface water and groundwater withdraw as % of total actual renewable water resources 2010** 40 %

Non-renewable extraction (Wada et al 2011) 68 km³ yr⁻¹

![Water withdrawal by source](image-url)
Water Scarcity 20th and 21st C

Figure 1: Water stress, calculated as the ratio between water withdrawals and availability, for the late 20th and 21st centuries (see Flörke and Eisner 2011).
Human Impact on river discharge

Haddeland et al. 2014

H08
LPJml
MPI-HM
PCR-GLOBWB
VIC
WaterGap
WBMplus

1971–2000
WaterMIP: Land Surface Hydrology Model/ Global Hydrology Model Intercomparison

Global hydrology models
- WBMplus
- MacPDM
- PCR-GLOBWB
- GWAVA
- WaterGap
- H07
- MPI-HM
- VIC
- LPJml
- Jules
- Orchidee
- HTERSS

River basin Models
- HBV
- WATBAL
- Bilan
- FRIER

Vegetation models

WATCH
Water and Global Change
Mean annual water fluxes (mm year$^{-1}$)

![Graph showing various water fluxes comparing runoff and evapotranspiration across different regions and models. The graph includes data points for Amazon, Ganges-Brahm, Chang Jiang, Danube, and others, with different models represented by distinct symbols and colors.](image)
Estimating water resources

Scenarios and policy

Climate (rainfall – evaporation)

Demand (agriculture, domestic, industry)

Catchment characteristics (geology, topography, land use, groundwater)

Human interventions (dams, extractions, irrigation ...)

River flows, groundwater etc
Demand and allocation into Climate models?

Figure 1. A fully coupled framework for inclusion of water resources management in a typical LSS grid.

Nazami and Wheater 2014
Human impacts - interactions

- Land/atmosphere Interactions
- Sea level
- River flows
- Land cover (incl. irrigation)
- Groundwater
- Water security
- Food security

Interactions:
- Land/atmosphere Interactions to Sea level
- Sea level to River flows
- River flows to Land cover (incl. irrigation)
- Land cover (incl. irrigation) to Groundwater
- Groundwater to Water security
- Water security to Food security
Quantifying the Human Impact on the World’s freshwater

- Water supply – *uncertainties in P-E*
- Demand – *linked to supply*
- Management – *seasonality and extremes, ground water extraction, basin transfers*
- Land cover? – *irrigation, rainfed agriculture and deforestation etc*

- Coupled models?
- Scale – regional vs global?
- Data issues
- Complexity
- Role of calibration
- Scenarios
Crosscut: Modelling Human Impacts on freshwater 2: activities

Progress so far:

Hague July 2014 – proposed

Informal committee: Richard Harding, Howard Wheater, Taikan Oki, Ruby Leung, Jan Polcher, Eric Wood, Ali Nazemi ....

Pasadena Dec 2014 – draft plan

- Ongoing review (web based? – what are we doing? - where are the global data gaps?
- Modelling Workshops – with GLASS - RHPs - link to local operational models
- Inter-comparison? - land MiP
- Sessions at International meeting