The Hitchhiker’s Guide to Global Water Issues

Philippe Van Cappellen
Ecohydrology

HUMAN DIMENSION

HYDROLOGY  ECOLOGY
Water Use (Water Footprint)

Global
- agriculture: 22%
- industry: 8%
- domestic use: 70%

Canada
- agriculture: 11%
- industry: 9%
- domestic use: 80%

Source: United Nations Environment Programme (UNEP)
Withdrawal versus Consumption

**water withdrawal** = water diverted or withdrawn from a surface water or groundwater source.

**water consumption** = water permanently withdrawn from its source – i.e., the water is not returned to the immediate water environment.

Global Water Withdrawal and Consumption

Top 20 water consumers per capita

Water use at the end of the 1990s

Withdrawal
Consumption

Asia
North America
Europe
Africa
Australia and Oceania


UNEP
You may think that every drop of rain that falls from the sky, or every glass of water that you drink, is brand new. But in fact, it has always been here and is a constant part of The Water Cycle.

The sun evaporates water from the oceans into water vapor. This invisible vapor rises into the atmosphere, where it is cooled.

The water vapor condenses into clouds.

The rain or snow then falls back to Earth as precipitation (rain and snow).

Some of the water infiltrates into the ground, replenishing groundwater.
Renewable Freshwater Resources (RFWR)

- Water is a “circulating” resource.

- **Water flows** (or fluxes), not stocks, are the most relevant measures of freshwater availability.
RFWR: Global Supply and Demand

Water withdrawals (in 1000 km$^3$/year):

- agriculture: 2.8
- industry: 0.9
- domestic: 0.4

\[ \text{4.1} \]

Compare to total river flow: 45 (x 1000 km$^3$/year)

→ Current demand << renewable freshwater resources

→ globally, there is enough water to cover human demand (given adequate water management)
But ...

- Not all freshwater resources are (easily) accessible.

- There is a large geographic variability in precipitation and runoff.

- Human consumption competes with water requirements of natural ecosystems.

- Supply and demand analysis must account for water quality.
Extreme Case: Aral Sea

Aral Sea, Kazakhstan

Landsat MSS
May 29, 1973

1973
Environmental Flows

*Indicators: usable habitat, vegetative cover, biodiversity, trophic status, food web structure, assimilative capacity, nutrient recycling, ...
Integrated Water Management = *Watershed*

- Water balance
- Water quality
- Ecosystem health

Source: NASA
Integrated Water Management: Implementation

**Human pressures on the watershed**
- land-use changes
- population growth
- increased water abstraction
- release pollutants
- invasive species
- magnified extreme events
- ...

**Changed ecosystem structure and function**
- decreased biodiversity
- decreased resilience
- increased disease
- changed community structure
- eutrophication
- ...

**Decreased ecosystem services**
- flood control
- water quality
- air quality
- fish and wildlife
- ecological barriers
- recreation
- ...

**Societal response**
- improved environmental management
- decreased pressures

**Negative economic, environmental and health impacts**

“Anthropogenic” Nutrients (N, P, K, S)

Projected human N input

Total human N input

Fertilizers and industrial uses

Range of N fixation in natural terrestrial ecosystems

Milenium Ecosystem Assessment (2005)
(Harmful) Algal Blooms

Qindao, July 2013

The seas off China have been hit by their largest ever growth of algae, ocean officials said, with vast waves of green growth washing onto the shores of the Yellow Sea.

Picture: AFP/GETTY IMAGES
Great Lakes (Summer 2012)
ALGAL BLOOM ADVISORY

A harmful algal bloom has been detected at this location. Users are encouraged to avoid ingesting water and avoid surface scum.
Ecosystem Services
Ecosystem Services

“Healthy” ecosystems

Provide ecosystem services

- food and biomass production
- drinking water supply
- habitat and biodiversity
- storage, filtering and transformation
- recreation
- support for man-made structures, protection
- regulation of climate (e.g., carbon sequestration)
- ...

Decrease exposure to environmental hazards

Strengthen economic and social development

Improve human health and well-being, contributes to sustainable development
“... For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$ 16-54 trillion ($10^{12}$) per year, with an average of 33 trillion per year. Because of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$ 18 trillion per year....”
Economic Valuation: Grand River Watershed

- 6,800 km², larger than PEI
- Approx. 11,000 km rivers and streams
- Highly regulated
- Extensive agriculture (>70% total area)
- ~1 M people
- Rapid population growth (1.4 M by 2031)
- Rapid urbanization (>80% population)
- 50 municipal drinking water systems
- 70% water supply = groundwater

Lake Erie
Grand River Watershed: Ecosystem Services

Air quality
Climate regulation
Flood control
Flow regulation
Water supply
Soil retention
Nutrient recycling
Waste treatment
Pollination
Pest and disease control
Habitat
Food production
Raw materials
Genetic resources
Medicinal resources
Education, culture, recreation

Water purification
Water supply for agriculture
Carbon sequestration
Nutrient recycling
Flow regulation
... $$$$$ ...

- 5 ecosystem services\(^1\): $200 million per year

- Waterloo Region (Canada’s Technology Triangle): GDP (2009): $19.5 billion per year\(^2\)

- Pre-European settlement\(^1\): $900 million per year

\(^1\)Conservative estimates (Tariq Aziz)
You Are Richer Than You Think

• Natural processes in watersheds provide a wide range of ecosystem services.

• Financial values can be placed on certain ecosystem services.

• Economic valuation of ecosystem services helps raise public awareness about water and water-dependent resources, and can inform sustainable regional development.
The Cost of Water

Opportunity costs

Ecological costs

Administrative and support costs

Operation and maintenance costs

Investment costs

Environmental costs

Financial costs

Full cost

The Price of Water

Annual water withdrawal in m³ per capita

Price in US$ per m³

Source: OECD
Water Stress: Global Issues – Now

- Hydro-environmental limits are being reached in many of the major grain producing areas (Mediterranean, Punjab, Northern China, Western United States, NE Brazil, ...)

- Depletion groundwater resources, salinization aquifers and surface waters, accumulation pollutants, environmental degradation downstream ecosystems, including coastal areas (e.g., algal blooms)

Source FAO, UNEP, UNESCO-IHP
Water Stress: Global Issues – The Future ...?

- World population and per capita water demand continue to rise.

- Climate change will intensify competition for water and exacerbate regional differences.

- In many areas, existing water management and supply systems will not be able to cope with the growing demand.

- The number of people affected by water stress is projected to double by ≈2080.
Water-Related Conflicts

- 145 countries share river basins; 33 countries rely for ≥ 95 % of their freshwater supply on a source located outside their national boundaries; there are 273 major transboundary groundwater aquifers.

- Water crosses not only national, but also economic, policy, trade, social, cultural, environmental and knowledge boundaries.

- In water disputes political power is often asymmetrically distributed.

(World Water Week, Stockholm, August 16-22, 2009)
Ecohydrological Engineering

- Protect key ecosystems
- Minimize human impact
- Steer/enhance natural remediation and flow regulation*
- Reuse water (blue, green, gray water)
- Diversify sources
- Replace natural/local sources (transport water, desalination)

*Riparian buffer zones, aquifer recharge, marshes, constructed wetlands

Ecological solutions

Engineering solutions
Linear Nutrient Flows (N, P, K, S)

Rural → Urban → Natural

fertilizers → food

wastewater discharge, storm overflow, urban emissions (e.g., NOx) → accumulation
Nutrient (Re)cycling

Rural ↔ Urban → Natural

fertilizers → food → accumulation → biosolids, compost...

wastewater discharge, storm overflow, urban emissions (e.g., NOx)
Take-Home Messages

- **Water** is our most precious natural resource.
- It is a **renewable** resource.
- Globally, **water stress** is on the rise, because of increasing consumption and deteriorating water quality.
- The key challenges for **integrated water management** are (1) to balance the water needs of humans and those of natural ecosystems, and (2) to simultaneously anticipate changes in anthropogenic pressures (especially population growth and climate change).
- Economic valuation of **ecosystem services** can help raise public awareness about water and water-dependent resources, and inform sustainable regional development.
- **Ecohydrological engineering** solutions incorporate hydrological and ecosystem processes and principles into sustainable development strategies.
Water footprint

75L

120L

10L
THANK YOU FOR YOUR ATTENTION

http://uwaterloo.ca/ecohydrology/