Water-Food-Energy Nexus Requires Innovative Solutions

Hamed Ghoddusi (Stevens Institute of Technology)
Texas State University, 2016

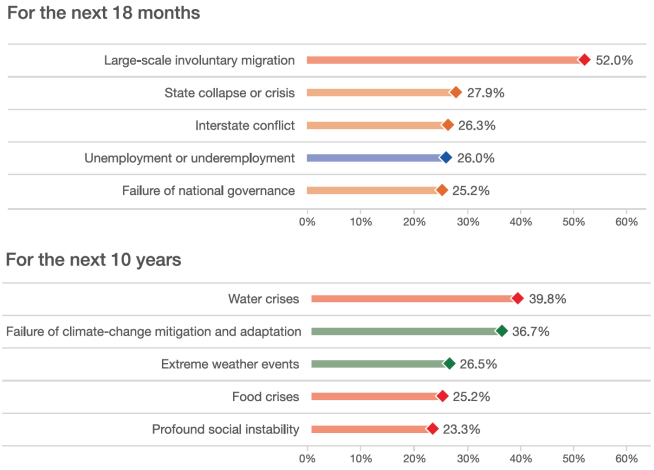
Agenda

- Why nexus?
- Global water crisis: drivers and trends
- Solutions and scenarios
- Knowledge gaps and future prospect
- Conclusion

Why Nexus?

- Agriculture sector as the largest consumer of fresh water: $> 70\%$
- Food sector as a large consumer of energy: $> 30\%$
- Water as input to the energy sector: hydropower, cooling, biofuels, ...
- Energy as a driver of water use: electrified irrigation
- Agriculture as an input to renewable energy: biofuels
- Carbon footprint of agriculture water
- ...

The Top Five Global Risks of Highest Concern

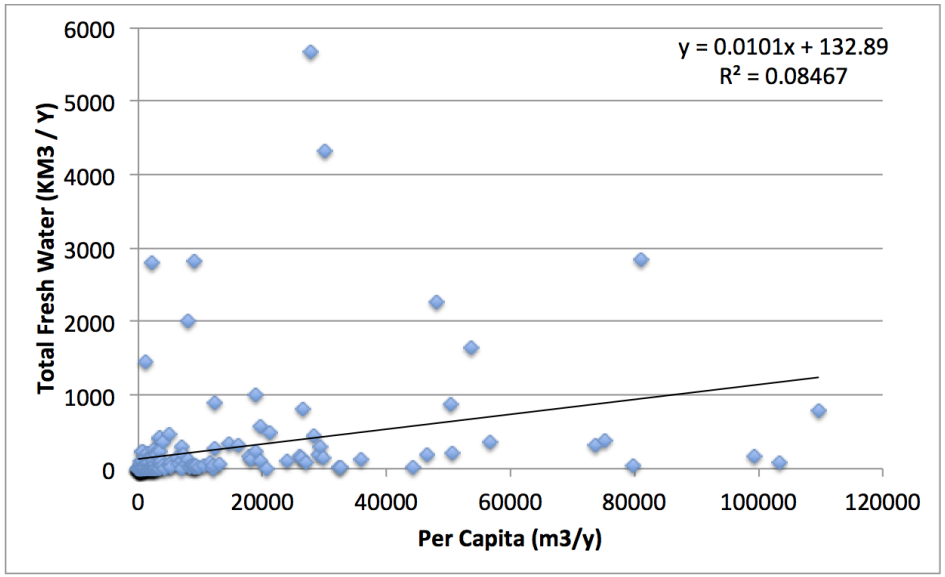


Source: World Economic Forum (2014)

Motivation: Global Water Resources

- Global versus local endowment of fresh water
  - Sufficient per capita renewable fresh water resources at the global level (6000 cubic meters)
  - Spatial mismatch: uneven distribution of water resources
  - Decreasing endowment and increasing unevenness over time

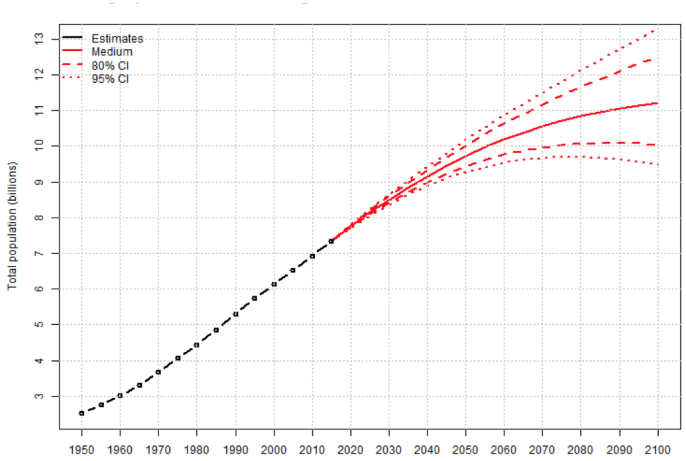
Water Availability and Population



Future Trends: Drivers of Change

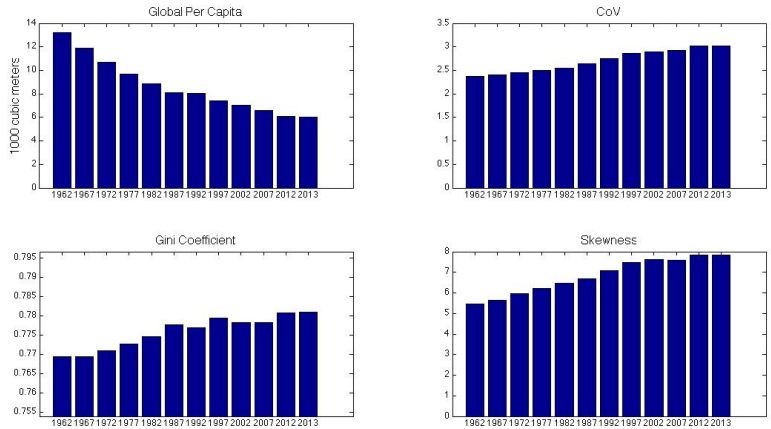
- Population growth
- Urbanization
- Economic growth ⇒ changes in diet pattern
- Climate change
  - Global distribution of water
  - Evapotranspiration
  - Temporal distribution of water
- Technological development
- Resource degradation

Population Prospects



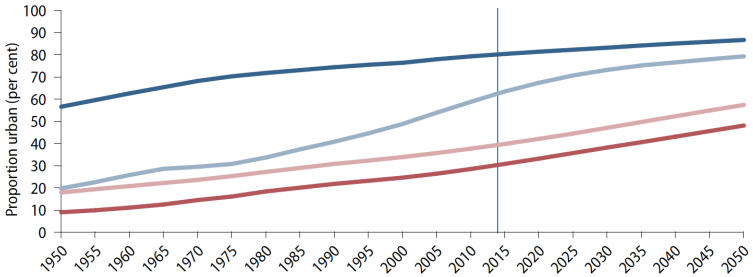
Source: UN (2015)

Cross Country Renewable Water Endowments Over Time



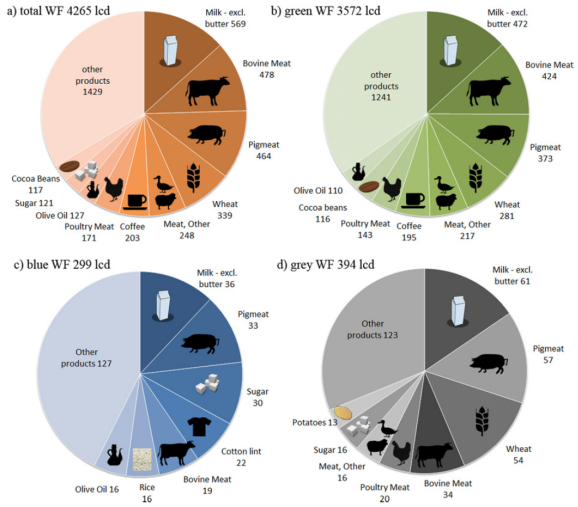
Raw Data Source: World Bank

Trend of Urbanization



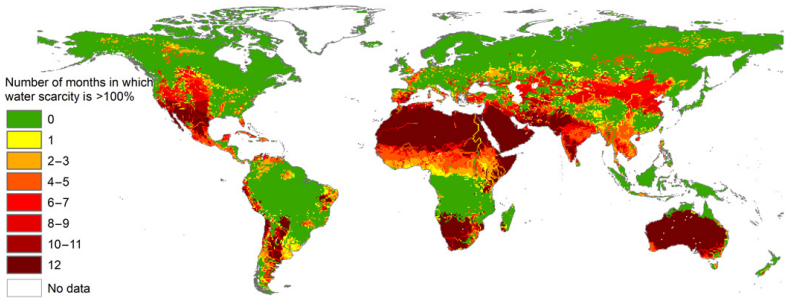
Source: UN (2014)

Diet and Water Footprint



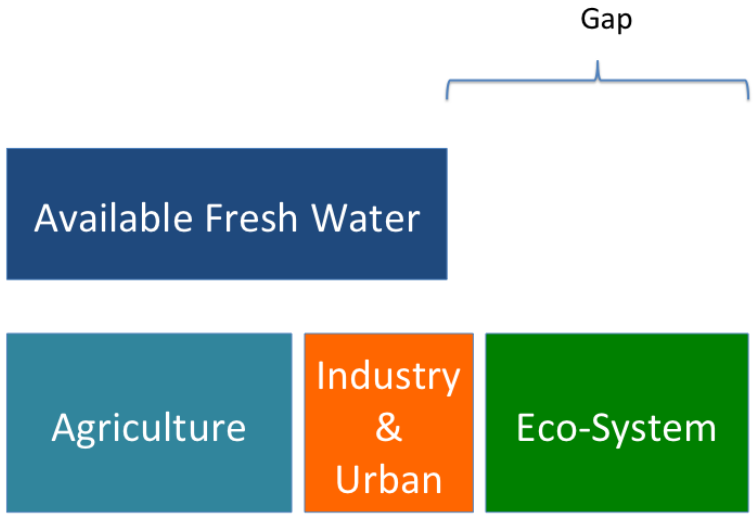
Source: Vanham et al (2013)

Intra-Year Water Shortage



Data Source: Mekonnen and Hoekstra (2016)

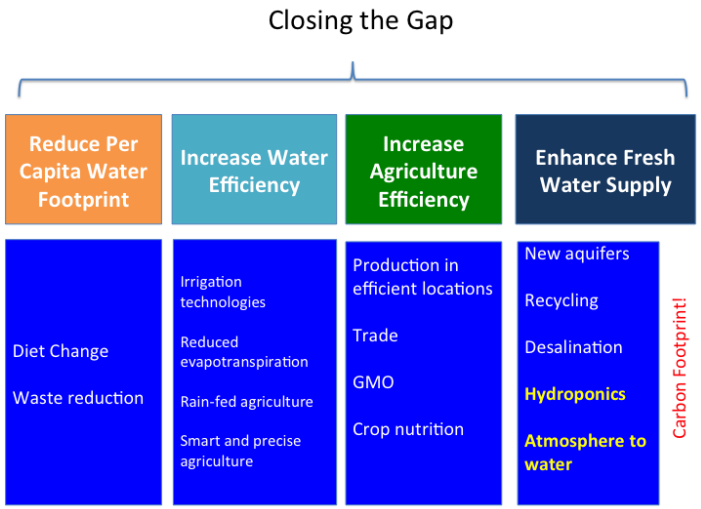
Summary: Increasing Gap between Demand and Supply



Grand Scenarios: Mix of Uncertain Factors

- Economy: rate of economic growth, investment flow to the food/water/energy sector
- Technology: pace of renewable energy technologies, acceptance of GMOs, efficient and smart agriculture technologies
- Life style: diet, urbanization
- Trade: local suitability solutions, globalized trade of *virtual water*

Strategies and Solutions to Bridge the Supply/Demand Gap

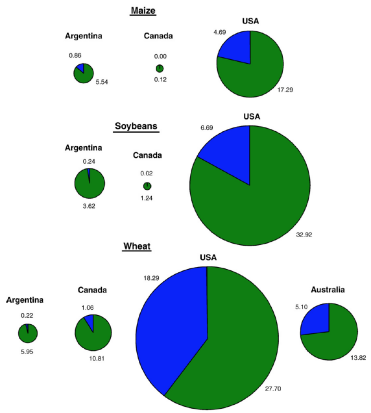


Recognize Different Types of Water Footprint

- Blue
- Green
- Grey

Possible futures extensions to the list: White water (e.g. desalination), Transparent water (humidity), etc

Green Water Crops



Data Source: Vanham et al (2013)

Limitations and Challenges

- Interactions with other key factors: energy, environment, global security, mass migration
  - Carbon and energy footprint of new methods
- Unknown and unintended consequences: GMOs, rebound effect
- Weak economics of the water sector
- Human aspects: behavioral factors
- Investment requirements
- Political barriers

Quantifying the Effect of Strategies and Scenarios

- Need for reliable large-scale global models covering local details
- Modeling challenges
  - Complexity: local and global impacts
  - Uncertainty
  - Economics: markets, prices, trade
  - Human behavior: computational social science (e.g. agent-based models), field experiments
- A great deal of opportunities for scientists in different disciplines to develop new models

EverGreen Project: Atmospheric Water Farming

A Viable Financial Model

- Economics of Atmospheric Water Farming
  - Energy: conventional energy price, availability of renewable energy (e.g. sunny days, wind blow)
  - Water: degree of humidity, dew point, annual precipitation, precipitation patterns
  - Agriculture productivity: soil quality, temperature, solar radiation, ...
  - Output: crop, vegetable, and flower prices
  - Other fixed and variable costs: labor price, land price, construction costs, cost of capital
- A global map of decision factors

Conclusion

- Concerns resulted in taking a nexus approach:
  - Food security
  - Climate change
  - Environmental degradation
  - Mass forced migration
- Limited space of action: $\Rightarrow$ need for major innovative solutions
- Modeling requirements
- EverGreen project