Seminar

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Climate Change and Growth: Will There Be Enough Water?

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A. What do we know about likely impacts on water?

1. Higher temperatures and faster evaporation
2. Drought periods and flooding events more likely
3. Less groundwater recharge (big storms)
4. Less glaciers storage of water (melting glaciers)
5. Growth in population and income mean increases in water demand (Figure 1)

Figure 1

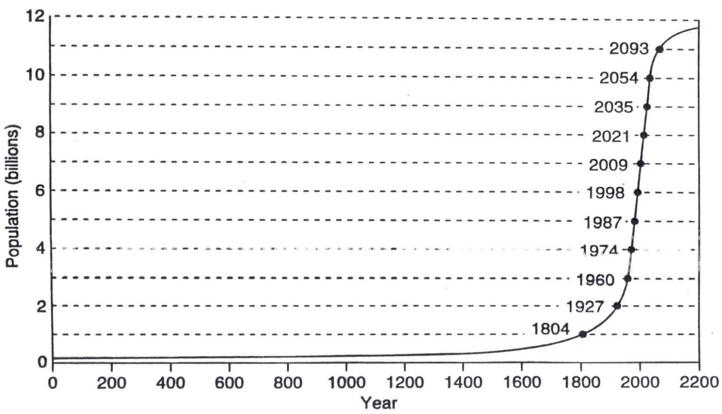


Fig .1 World population: actual and projected (*source:* Population Division of the United Nations Secretariat; graph adapted from one published in *The Independent* newspaper).

B. What problems does this raise

1. This raises growing concerns about water security for domestic uses, food production, energy production and environmental protection.
2. Major investments needed for flood protection and to stabilize water supply particular for larger cities.
   a. How will we plan these investments with the demise of "stationary" assumption regarding water availability (can't plan based on historic data)
3. How we reallocate water to its highest valued uses and encourage water conservation becomes critical.

C. Water requirement to obtain more Energy

1. For cooling
   a. Water used per unit of energy

Nuclear power	3,140 liters/mwh*
Coal	2,840 liters/mwh
Natural gas	2,270 liters/mwh

   b. Of total U.S. water withdraws 48% is for cooling (Table 1)

* megawatt hours

Table 1. U.S. Water Withdraws and Consumptive

	1995 Withdraws (mgd)*	2005 Withdraws (mgd)	2005 Withdraws (mgd)	Consumptive Use (%)
Public Supply	40,200	43,300	44,200	19
Domestic	3,390	3,590	3,830	n.a.
Irrigation	**134,000**	**137,000**	**128,000**	**61**
Livestock	5,490	1,760	2,140	58
Mining	3,770	3,500	n.a.	27
Thermoelectric Power	**190,000**	**195,500**	**201,100**	**2**
Agriculture	n.a.	3,700	8,780	n.a.
Industrial	27,100	19,780	18,190	13

*million gallons/day

n.a. = not available

Source: R.H. Abrams and N.D. Hall, "Framing Water Policy in a Carbon Affected and Carbon Constrained Environment", Natural Resources Journal, 2010, vol. 50, p.18.

C. Water requirement …continued

2. For extraction of Natural gas
   a. Coal bed Methane: pumping groundwater to release methane gas
   b. Shale held natural gas: water plus chemicals forced underground to extract the natural gas

C. Water requirement …continued

3. Oil from shale

   Green River Formation about 800 billion barrels of recoverable oil (western U.S.)

a. Three barrels of water are needed per barrel of shale oil produced

b. This puts stress on upper Colorado River basin where shale oil is located. (172.6 million m^3 of water required annually by 2040)

c. This competes directly with agriculture and environmental services

C. Water requirement …continued

4. Water for biofuels

- 15 liters of water per liter of ethanol. U.S. may need 542.5 million m^3 of water annually by 2022*.
- Biodiesel and cellulosic ethanol also will use large amounts of water

* U.S. Target for biofuels is 20% of transport energy by 2022.

C. Water requirement …continued

5. Tar sands use is uncertain in U.S. but extraction in western Canada has contaminated large quantities of water.

- Hot water is used to wash the oil from the sand
- Canada has between 300 and 600 billion barrels of oil in tar sands and production is increasing from 2 to 3 million barrels/day*
- About 25% of U.S. oil imports come from Canada

* A 50% increase

C. Water requirement …continued

6. Hydropower – changes the quantity and timing of water flows.
   a. This can cause shortage of irrigation water by storing water in summer to produce electricity in winter
   b. Kyrgyzstan vs. Uzbekistan (upstream vs. downstream or hydropower vs. irrigation)
   c. In Chile non-consumptive water rights of owners of hydropower dams trump consumptive water rights of downstream irrigators.

D. Irrigation water use will rise with population and income growth and climate change

1. Must be able to produce more with existing water (demand management).
2. Expand irrigation particularly in areas such as Sub-Saharan Africa that has very little water storage.
   - May need 20 to 25% increase in area irrigated between now and 2050.
3. Invest in and improve existing facilities
4. Develop crops varieties that are drought resistant and require less water.
   - Adapting long rooted perennial crops etc.

E. Where do we get additional water for domestic and environmental uses?

1. Irrigation is big consumptive water user: can we reallocate to other uses?
2. Increase storage for surface water?
3. Facilitate groundwater recharge by protecting recharge areas
4. Replace once - through cooling systems which account for 91% of cooling withdraws in U.S.
5. Develop effective demand management practices
   - Economic incentives reduce climate change adaption costs, in Western Europe, by $5 billion annually between 2010-50 for municipal and industrial water uses (Utilities Policy 18, 2010).

F. Impact of climate change on agriculture

1. Likely to be mixed effects on crop yields (Table

Table 2. Effect of climate change on cereal production, in million tons, 2020, 2050, and 2080

	2020		2050		2080	
Region	Low Impact	High Impact	Low Impact	High Impact	Low Impact	High Impact
Developed countries	60	-20	120	-65	85	-175
Developing countries	30	-30	55	-115	-10	-250
World	75	-40	140	-155	65	-420

Source: International Institute for Applied Systems Analysis (2009/2010) Biofuels and Climate change: Challenge to food security in the twenty first century. Options winter, pp18-9. Laxenburg, Austria

F. Impact … on Agriculture continued

2. Some relocation of production and crops grown
    - Cropping shifts away from drought prone areas
    - A number of rice producing areas will likely shift to other crops
3. Rise in uncertainty in yield and prices with some potentially large price increases
    - FAO reported that the food price index hit a historic high of 231 in Jan 2011.*

* Index was started in 1990

F. Impact … on Agriculture continued

4. Larger impacts from future droughts and floods
    - Prairie provinces in Canada lost $4.5 billion in GDP due to 2001-2 drought
    - The Mississippi River flood this year is the second largest in history
    - Red river of the North in 2011 set a second 61+ days above flood stage
5. Without trade some countries will likely face future food shortages

G. How might we respond with water policies?

1. Have to improve efficiency in water use particularly for irrigation
   a. Get serious about water pricing and water markets (demand management)
   b. Encourage water saving technology: drip and sprinkler irrigation
      - In Tamil Nadu, India drip irrigation increased water productivity by 50% to 200%*
      - Yet much of the water saved was used to irrigate more hectares

* Banana, grapes and coconut

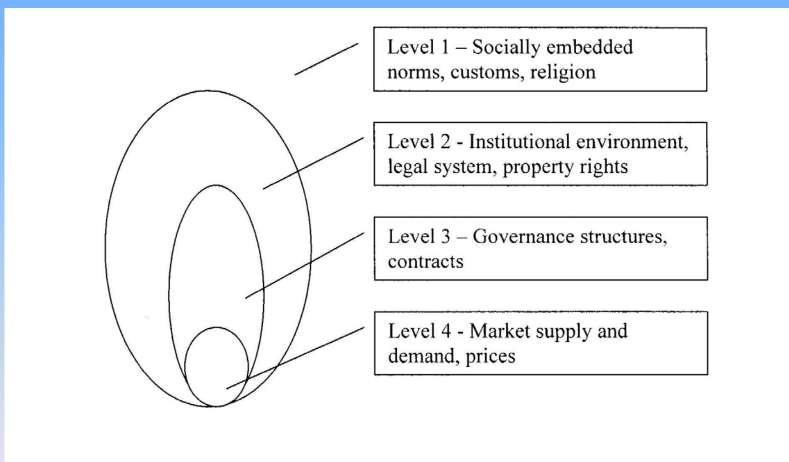
G. …Water Policies continued

2. Markets can help in reallocating water among sectors and within sectors.
   a. Water as an economic good (irrigation and commercial uses) Australia, Chile, US west etc.
      - Should water for domestic use be considered a basic right?
   b. Options markets
      - For drought management in cities etc.
      - Used in California

G. …Water Policies continued

3. Need to change water institutions including water laws for ownership of groundwater and surface water, for water markets and pricing to be effective (Figure 2)
   a. Need to reduce or eliminate open access to water use particularly for groundwater
   b. Establish enforceable water or water-use rights to make it possible to trade water.
   c. Key is enforceable rules for water pricing and markets that are accepted as "fair".

Figure 2. Levels of Institutional Analysis (developed from Williamson, 2000)



G. …Water Policies continued

4. Alternative pricing mechanism to improve water use

   a. Area-based charges for large scale irrigation (surface water)

   - Varied by hectare and crop
   - Varied by hectare and season (dry vs. wet season)
   - Varied by hectare and irrigatoin technology
   - Varied by time (hours) water is received

G. …Water Policies continued

b. Volumetric pricing for irrigation

- Fixed charge per m^3 pumped (water metered)
- Fixed charge per hour pumped (time metered)
- Two-part charge with a fixed charge plus volumetric charge: resolves conflict between full cost recovery and efficient pricing

  -- Pay fixed charge to cover fixed costs.

G. …Water Policies continued

c. Volumetric charges for domestic and industrial water

- Block charge: can vary charges by quantity delivered
- Should volumetric charge be increasing, decreasing or constant?
- What is the incentive provided by each?
- First block charge can be set low so it is affordable by low income families. Higher price for second block to cover costs. (increasing block) (Figure 3)
- Two block pricing provides you three tools to affect use

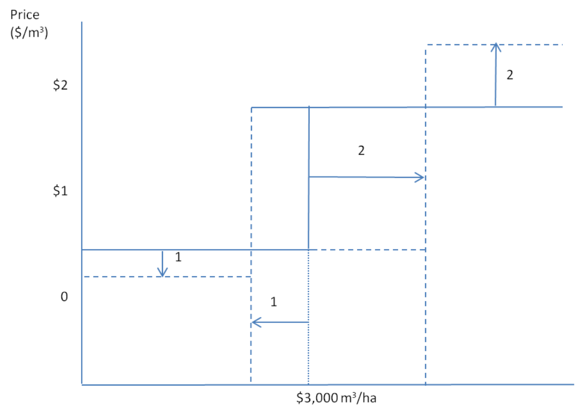


Figure 3. Pricing alternatives for donestic water use

G. …Water Policies continued

5. Where can we implement volumetric changes?
   a. We have the technology to closely meter water use
      - Spain and China use meters controlled by bank cards
      - Farmer have to pay before they can pump water
   b. In India the marginal cost of pumping with electricity is zero (political problem)
      - Farmer alter meters for electricity
      - Also it is good politics not to charge farmers for electricity
   c. For volumetric water pricing to work
      - Invest in meters
      - Develop an effective method of enforcing metering and payment of water charges

H. A default strategy has been to ration water

1. Some large cities in India deliver water only for a few hours per day (2 to 5 hours)
   - In many U.S. cities during droughts they ban activities such as car washing and lawn watering
2. For irrigation it creates a scarcity value for water
   - This has created informal water markets in some countries (Pakistan) usually among farmers on same canal
   - Formal water markets are more effective and can expand the market to the whole system
3. In the commercial sector it has caused some firms to recycle their water and others to develop their own water sources.
   - This can caused rapid declines in water tables (Bangkok)

I. Conclusion

1. Uncertainty regarding water supply will increase
2. Our increased energy use will require even more water which will compete with other water uses
3. With more frequent droughts we must make more efficient use of our water particularly for irrigation and in the energy sector
4. We will have a difficult time meeting the growing demands for environmental water uses

I. …Conclusion continued

5. More areas will face water storages resulting in food shortages and price increases
6. Because of increased scarcity the value of water will rise like oil.
   - Current price of oil $95 to 105/barrel
   - Current bottle water price $30 to 300/barrel
7. Pressure will build to construct additional water storage capacity for irrigation, flood control, and urban supplies

I. …Conclusion continued

8. We need to be serious about demand management in the agriculture and commercial sectors
9. Will we need to price water close to its scarcity value
10. In the final analysis we need to modernize our water infrastructure and management
11. Desalination will help in a few coastal urban settings. However, energy requirements will be high
    - 3 to 16 kwh to obtain 1,000 liters of desalinized water

J. Future research questions

1. How does “cheap” or under priced water bias our decisions concerning alternative energy sources?
2. Where will water constrain the development of alternative energy sources?
3. Do our current flood control and land use policies raise the cost of future floods?

J. Future research…continued

4. Do we have effective institutional arrangements to manage international rivers as water demands increase?
5. What information does the public sector need to provide to improve our water use decisions?
6. What are the potential cost savings from the sharing of water storage capacity among local communities?