Climate Change: Impacts on Fresh Water and Adaptation of South Asian Agriculture

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Water for a food-secure world
www.iwmi.org
Breaching the Boundary

Planetary Boundaries

<table>
<thead>
<tr>
<th>Earth-system Process</th>
<th>Parameter</th>
<th>Prop. boundary</th>
<th>Current status</th>
<th>Pre-industrial value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>CO₂' ppmv</td>
<td>350</td>
<td>387</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>Rad. Forcing w/m²</td>
<td>1.0</td>
<td>1.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Rate of biodiversity loss</td>
<td>Extinct. rate, per m species</td>
<td>10</td>
<td>&gt;100</td>
<td>0.1-1</td>
</tr>
<tr>
<td>N cycle</td>
<td>N₂ removed, m t/y</td>
<td>35</td>
<td>121</td>
<td>0</td>
</tr>
<tr>
<td>Fresh Water use</td>
<td>Consu. km³/y</td>
<td>4,000</td>
<td>2,600</td>
<td>415</td>
</tr>
</tbody>
</table>

Source: Rockstrom, 2009

Water for a food-secure world

www.iwmi.org
South Asia: Home for 40% of World’s Poor

- > 1.6 billion people, 23% of world population
- Still has high growth rate of population
- Tremendous progress in last 4 decades
  - Food consumption increased from 1900 kcals to > 2500 kcals
  - Average GDP growth >7%
  - Little food imports now
- Yet, 1/4th of the world’s hungry; 40% of the world’s malnourished children and women
- Lagging in MDGs
- Agriculture important for livelihood security of > 50% population
- Projected to be very vulnerable to climatic risks

Source: IFPRI, 2009
Climatic stresses are common in South Asia
High CV of rainfall in Pakistan; northwest and south India

- Drought: >26 droughts in last 130 years
- Frost: common in northern regions
- Heat: frequent episodes at many places
- Frequent floods and cyclones in several regions

(Source: Erickson et al., 2011)
Vulnerability of agriculture to climate change: South Asia a major hotspot

(Source: Erickson et al., 2011)
Climate is likely to change faster in future

Minimum temperature changes, 2000 to 2030, 2050, and 2080, CNR GCM

Both the color and elevation convey the same information. As the colors increase from yellow to red and the height of the map increases, temperature increases. The future values are from the CNR GCM using the A1B SRES scenario. (Courtesy: Nelson, IFPRI)
Climate is likely to change faster in future
Precipitation changes, 2000 to 2030, 2050, and 2080, CNR GCM

Both the color and elevation convey the same information. As the colors increase from yellow to red and the height of the map increases, precipitation increases from 0 mm per month to 300 mm per month. The future values are from the CNR GCM using the A1B SRES scenario. (Courtesy: Nelson, IFPRI)
Trends in sub-divisional rainfall data for different seasons (1901-2003).

Different levels of significance are shaded with colors.

Source: IMD, 2010
Spatial changes in precipitation over the last 100 years
What are the projected changes in river water availability on a regional scale?

River basins of Mahi, Pennar, Sabarmati and Tapi are likely to experience constant water scarcity and shortage.

River basins of the Cauvery, Ganga, Narmada and Krishna are likely to experience seasonal or regular water stressed conditions.

Source: India’s Initial National Communication, 2002
Simulated effects of de-glaciations on Himalayan river flows over ten decades

Gwyn Rees et al., 2005
## Retreat of Glaciers in Himalaya and Karakoram

<table>
<thead>
<tr>
<th>Mountain Range</th>
<th>Name of Glacier</th>
<th>Periods</th>
<th>Year</th>
<th>Total Retreat, m</th>
<th>Average Retreat (m/ year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Himalaya</td>
<td>Milam</td>
<td>1849-1957</td>
<td>108</td>
<td>1350</td>
<td>12.5</td>
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<tr>
<td></td>
<td>Pindari</td>
<td>1845-1966</td>
<td>121</td>
<td>2840</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td>Gangotri</td>
<td>1934-1976</td>
<td>41</td>
<td>600</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1962-2000</td>
<td>38</td>
<td>1341</td>
<td>35.4</td>
</tr>
<tr>
<td></td>
<td>Zemu</td>
<td>1975-1990</td>
<td>15</td>
<td>297</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>Sonapani</td>
<td>1906-1963</td>
<td>57</td>
<td>905</td>
<td>15.9</td>
</tr>
<tr>
<td>Karakoram</td>
<td>Siachin</td>
<td>1929-1958</td>
<td>29</td>
<td>914</td>
<td>31.5</td>
</tr>
<tr>
<td></td>
<td>Yengutsa</td>
<td>1892-1925</td>
<td>33</td>
<td>4134</td>
<td>125.3</td>
</tr>
</tbody>
</table>
Retreat of the Gangotri glacier snout during the last 220 years (from 1780 AD to 2001) (ICIMOD, 2007)
Water Resources in the Ganges Basin

- Gangotri glacier in Gomukh
- 1.09 m km² (79-I, 13-N, 4-C, 4-B)
- Tehri Dam, Farakka Barrage

Values in (BCM)

Water for a food-secure world
Average contribution from melting of snow and ice in glaciated areas simulated for some sub-basins where WEAP-Ganga's setting is very good to good.

<table>
<thead>
<tr>
<th>N°</th>
<th>Sub-basin</th>
<th>Average proportion of annual streamflows from glaciated areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>For years 1982 to 2002</td>
</tr>
<tr>
<td>44</td>
<td>Busti</td>
<td>44%</td>
</tr>
<tr>
<td>46</td>
<td>Rabuwa Bazar</td>
<td>45%</td>
</tr>
<tr>
<td>51</td>
<td>Chatara Kothu</td>
<td>24%</td>
</tr>
</tbody>
</table>
Analysis of current situation: contribution from glaciers

Average streamflows simulated for period 1982 - 2002

Figure 16: Average contribution of glaciers to annual and seasonal streamflows in the Ganges basin down to Farakka.

Water for a food-secure world
Scenario Analysis: Increase in Temperature

• According to the IPCC: temperature +3.8 °C at the end of the century in the Tibetan region.
• Same order by ICIMOD.
• ⇒ considered 3 scenarios for 20 years:
  — +1°C after 20-years, i.e., a rate of +0.05°C/year,
  — +2°C after 20-years, i.e., a rate of +0.10°C/year,
  — +3°C after 20-years, i.e., a rate of +0.15°C/year.
• Compared to the reference scenario = period 1982 to 2002.
Scenario Analysis: Increase in Temperature

Haridwar

Devghats

Risks of floods

Farakka

0. Outline
1. WEAP
2. Input data
3. Setting WEAP
4. Current situation
   Scenarios
Scenario analysis: increase in temperature

**Additional annual flow**

- **Additional annual flow:**

<table>
<thead>
<tr>
<th>Ganges</th>
<th>km³/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tehri dam</td>
<td>Haridwar</td>
</tr>
<tr>
<td>+1°C over 20 years</td>
<td>+0.6 (+8%)</td>
</tr>
<tr>
<td>+2°C over 20 years</td>
<td>+1.2 (+17%)</td>
</tr>
<tr>
<td>+3°C over 20 years</td>
<td>+1.9 (+26%)</td>
</tr>
</tbody>
</table>

Water for a food-secure world
Analysis current situation: contribution from glaciers

Indus heavily depend on contribution from glaciers
Scenario analysis: increase in temperature

0. Outline
1. WEAP
2. Input data
3. Setting WEAP
4. Current situation

Scenarios

Risks of floods

Tarbela dam

Danyour Bridge

Sukkur
Scenario analysis: increase in temperature

- Additional annual flow in Indus

<table>
<thead>
<tr>
<th></th>
<th>Inflow to Tarbela dam</th>
<th>Flow at Sukkur barrage</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1°C over 20 years</td>
<td>+6.6 (+9%)</td>
<td>+8.1 (+10%)</td>
</tr>
<tr>
<td>+2°C over 20 years</td>
<td>+15.2 (+21%)</td>
<td>Indus (+22%)</td>
</tr>
<tr>
<td>+3°C over 20 years</td>
<td>+22.6 (+31%)</td>
<td>+28.5 (+34%)</td>
</tr>
</tbody>
</table>

- Additional flow mainly during the high flow season ⇒ how to use it?
- Tricky as high discharge.
- Maybe extra flows in April, May & June + September & October?
The extra water from the glaciated areas in the short to medium term presents a set of potential opportunities and some threats.

Potential threats in the form of floods in the upper catchments, which generally have not witnessed these kind of phenomenon.
Flash flood hotspots in South Asia: 2010 scenario

(Source: Giriraj et al., 2012; unpublished)
Flood disaster trend in Asia in the last 48 years
Sea Level Rise in Pussur & Sibsa River System

Projection of SLR from 1990-2100, based on IPCC temperature projections for three different emission scenarios (Rahmstorf, 2009)

Rahmstorf (2009) prediction for Global SLR is 124 cm, A1B in 2100 over 2000

Temperature ranges and associated sea-level ranges by the year 2100 for different IPCC emission scenarios

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1.4–2.9</td>
<td>2.0</td>
<td>81–131</td>
<td>104</td>
</tr>
<tr>
<td>A1T</td>
<td>1.9–3.8</td>
<td>2.6</td>
<td>97–158</td>
<td>124</td>
</tr>
<tr>
<td>B2</td>
<td>2.0–3.8</td>
<td>2.7</td>
<td>89–145</td>
<td>114</td>
</tr>
<tr>
<td>A1B</td>
<td>2.3–4.3</td>
<td>3.1</td>
<td>97–156</td>
<td>124</td>
</tr>
<tr>
<td>A2</td>
<td>2.9–5.3</td>
<td>3.9</td>
<td>98–155</td>
<td>124</td>
</tr>
<tr>
<td>A1FI</td>
<td>3.4–6.1</td>
<td>4.6</td>
<td>113–179</td>
<td>143</td>
</tr>
</tbody>
</table>
Projected flooding: Extended footprint & Deeper flooding

50 year return period flood maps for present day (left) and 2080s (right)

2005-like event in 2080s - larger flood area, deeper flood waters
Simulation of External Driver of Change

Minimum Trans-boundary flow

South-West Regional Model

Sea level Rise (A1B-2030,2050)
Effects of External drivers on Salinity intrusion and Fresh water availability

- 2 PPT Salinity line moves 10-15 km upwards
- 800 Sqkm more area is likely to be affected

- 2 PPT Salinity line moves 12-18 km upwards
- 1050 Sqkm more area is likely to be affected

Map showing maximum river salinity in February 2011 and 2050, with projections for A1B Scenario.
Impact of climate change on crop yields in South Asia

Source: Knox et al., 2011
Climate change impacts on crop yields in India:

Wheat
Projected impacts of climate change on agriculture in South Asia

- Increase in CO$_2$ (550 ppm) increases yields of most C3 crops by 10-20%.

- A 1°C increase in temperature may reduce yields of some crops by 0-7%. Much higher losses at higher temperatures.

- Productivity of most crops to remain unaffected/ marginally decrease by 2030 but decrease by 10-50% by 2100.

- Increased droughts, floods, and heat events will increase production variability
There is a large untapped potential of currently available agricultural technologies.
Simple agronomic adaptation options can help increase yields - wheat
Farms of the future

- Use of climate analogues for germplasm characterization, conservation and evaluation
- Partners: Bioversity, NBPGR, India; Gene Bank of Nepal
Farms of the Future:
Farmer exchanges at analogue sites

• Social, cultural, economic and political barriers and opportunities for adaptation
Back-casting is then conducted to develop step-by-step plans which build on locally available strengths and resources to reach community identified goals and visions.

Farmer exchanges facilitate shared examination of challenges, opportunities and strategies for reaching locally defined goals and visions.

Socially and culturally appropriate exchange locations are chosen from climate analogue locations through a participatory process.
Linking knowledge to action-Climate smart villages/farms: Key agricultural activities for managing risks

**CLIMATE SMART VILLAGE / FARM**

**Weather smart**
- Seasonal weather forecasts
- ICT based agro-advisories
- Index based insurance
- Climate analogues

**Water smart**
- Aquifer recharge
- Rainwater harvesting
- Community management of water
- Laser leveling
- On-farm water management

**Carbon smart**
- Agroforestry
- Conservation tillage
- Land use systems
- Livestock management

**Nitrogen smart**
- Site specific nutrient management
- Precision fertilizers
- Catch cropping/legumes

**Energy smart**
- Biofuels
- Fuel efficient engines
- Residue management
- Minimum tillage

**Knowledge smart**
- Farmer-farmer learning
- Farmer networks on adaptation technologies
- Seed and fodder banks
- Market info
- Off-farm risk management-kitchen garden
Policy innovations induced by droughts in India

Drought Events

- 1877
- 1965
- 1972
- 1979
- 1987
- 2002
- 2009

Major Policy Interventions

- Famine Codes
- Green Revolution and FCI
- Employment Generation Programmes
- Contingency Crop Plan
- Watershed Approach
- Improved weather forecasts and their applications
- Scarcity relief
- Drought relief
- Drought management
- Water management
- Knowledge management

Each round represents:
- Death of one million people
- Around fifty million people affected

Source: ADPC/MOA
Realise the potential of rainfed agriculture through small but ‘critical’ irrigation:

Employ appropriate measures of rainwater/ streamwater harvesting
Provide access to groundwater sustainably and smartly, mediate groundwater-energy nexus:

Access to GROUNDWATER is the best insurance against an uncertain monsoon.
Undertake **Big** and **Bold** interventions now to tackle the **perpetual** uncertainty:

- **Interlink surplus and deficit basins**
- **Managed Aquifer Recharge**
- **Underground Taming of Floods**
Response-4

Improved and enhanced protection through use of Science, ICT, Safety nets:

Reach the ‘unreached’, protect the ‘vulnerable’ and enhance the system resilience

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Greater focus on climate risk management

- Forecasting From satellite to cell phone
- Risk insurance Rapid payments so assets are protected
- Technologies and practices That cope with extremes
Assisting farmers to cope with current climatic risks

- Providing value-added weather services
  - Weak weather infrastructure; data protocols, storage, access and dissemination

- Promoting insurance for climatic risk management
  - Scientific and economically validated schemes; weather derivatives; awareness

- Facilitating community partnership in food, forage, and seed banks
  - Technical know-how; capital costs; reduced acceptance if successive years are risk free

- Compensating farmers for environmental services
  - Technical know-how; costs of production go up

- Sharing experiences across similar regions
  - Validation in emerging scenarios of development and climate risks
Conclusion: Adapting South Asian Agriculture to Climate Change and Declining Resources: Four Key action points

1. Invest in management of land and water resources, and input delivery and market linkage mechanisms, to fully exploit the benefits of available technologies.

2. Manage current climatic risks for poverty alleviation and for equitable development.

3. Exploit large mitigation co-benefits of adaptation options.

4. Address issues of poverty, governance, institutions and human capital which limit agriculture growth even today.
Thank You for being a wonderful audience!!

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