Technological Advances in Water Management in Relation to Changing Climate

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Technological Advances in Water Management in Relation to Changing Climate

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Vice Chancellor, AAU, Anand.
India’s projected food supply and demand

Annual growth rate of projected supply and demand of food items in India to 2026

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Demand</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edible oilseeds</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Pulses</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Rice</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Wheat</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Demand calculation assumes GDP growth of 9 percent per year.
• Current yield gain for major cereals is 1.3% simple linear rate require a 1.3% compound annual rate of yield gain to meet demand from existing crop land.

• If yield increases are slower than demand, expansion of crop area, will be needed to maintain food security

• Associated GHG emissions from such land use change will accelerate GHG emission rates, which could provide strong positive feedback to rate of climate change
Annual Greenhouse Gas Emissions by Sector

- Power stations: 21.3%
- Waste disposal and treatment: 3.4%
- Transportation fuels: 14.0%
- Industrial processes: 16.8%
- Agricultural byproducts: 12.5%
- Fossil fuel retrieval, processing, and distribution: 11.3%
- Land use and biomass burning: 10.0%
- Residential, commercial, and other sources: 10.3%

Pie charts showing:
- Carbon Dioxide (72% of total) breakdown
- Methane (18% of total) breakdown
- Nitrous Oxide (9% of total) breakdown
<table>
<thead>
<tr>
<th>Different uses of water</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
<th>2015</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>32</td>
<td>42</td>
<td>56</td>
<td>73</td>
<td>102</td>
</tr>
<tr>
<td>Irrigation</td>
<td>437</td>
<td>541</td>
<td>688</td>
<td>910</td>
<td>1072</td>
</tr>
<tr>
<td>Industry</td>
<td>-</td>
<td>8</td>
<td>12</td>
<td>23</td>
<td>63</td>
</tr>
<tr>
<td>Energy</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>15</td>
<td>130</td>
</tr>
<tr>
<td>Others</td>
<td>33</td>
<td>41</td>
<td>52</td>
<td>72</td>
<td>80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>502</strong></td>
<td><strong>634</strong></td>
<td><strong>813</strong></td>
<td><strong>1093</strong></td>
<td><strong>1447</strong></td>
</tr>
</tbody>
</table>

*BCM: billion cubic metres*

**India overtakes China in 2030**

![Graph showing population growth in billions from 2000 to 2050 for India and China.](image)

*Source: UN Population Division: Medium variant*
Water requirements for food production (km³/year)

- Increases, over 2002 water requirements, needed to eradicate poverty by 2030 and 2050 respectively.
- Increase, over 2002 water requirements, needed to meet the 2015 hunger target.
Resulting in a potentially significant demand supply gap in the near future

Water Supply and Demand in India; 2010 - 2050
Cubic KM or Trilion Liters

River Basins in India, with water shortage, 2030
Percentage

2: EFR – Eastern Flowing Rivers; WFR – Western Flowing Rivers (non major rivers)

Source: Ministry of Water Resources, National Hydrology Institute
# Per Capita Water Availability in India

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (Million)</th>
<th>Per capita water availability M³/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951</td>
<td>361</td>
<td>5177</td>
</tr>
<tr>
<td>1955</td>
<td>395</td>
<td>4732</td>
</tr>
<tr>
<td>1991</td>
<td>846</td>
<td>2209</td>
</tr>
<tr>
<td>2001</td>
<td>1027</td>
<td>1820</td>
</tr>
<tr>
<td>2025</td>
<td>1394</td>
<td>1341</td>
</tr>
<tr>
<td>2050</td>
<td>1640</td>
<td>1140</td>
</tr>
</tbody>
</table>

(Source: Govt. Of India, Ministry of Water Resources(2009))

54% of India Faces High to Extremely High Water Stress
GROUND WATER STRESSED BLOCKS OF INDIA

- Over Exploited
- Critical
- Semi-critical

1: Andhra Pradesh, 2: Gujarat, 3: Karnataka, 4: Maharashtra, 5: Madhya Pradesh, 6: Rajasthan and 7: Tamil Nadu

Source: IWMI

Source: Central Ground Water Board, Chandigarh, 2009
# Agriculture’s Groundwater Crisis

## Falling Groundwater...

<table>
<thead>
<tr>
<th>Share of groundwater in irrigation</th>
<th>Share of groundwater in rural drinking water</th>
<th>Proportion of districts seeing unsustainable water extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>80%</td>
<td>35%</td>
</tr>
</tbody>
</table>

## ...is Threatening Dryland Agriculture

<table>
<thead>
<tr>
<th>Share of total cropped area</th>
<th>Share of land under food crops</th>
<th>Share of land under non-food crops</th>
<th>Share of agri subsidies*</th>
</tr>
</thead>
<tbody>
<tr>
<td>56%</td>
<td>48%</td>
<td>68%</td>
<td>6-8%</td>
</tr>
</tbody>
</table>

* Irrigation, fertiliser and fuels

Source: 12th Plan Approach paper
Crop response to the Global climate change depends upon the interaction of CO₂, temperature and water availability.

Potential Impacts of Climate Change:
- Air temperature
- Precipitation timing and quantity
- Sea level rise
- Runoff timing and quantity
Evidences of Climate Change

Physical evidence
1. Rise in atmospheric temp and CO₂ level
2. Depletion in rainfall
3. Shifting and shrinking of cooling period
4. Changing pattern of monsoon

Biological evidence
1. Early blossoming of trees
2. Appearance of grasses in Antartica
3. Changing cropping pattern

Kurukshetra, 2008
Changes in Precipitation

Annual precipitation trends: 1900 to 2000

More Rain

Less Rain

Trends in percentage per century:
-50% -40% -30% -20% -10% 0 +10% +20% +30% +40% +50%
- Rainfall will increase by 15–31%.
- 2°C rise in average temperature makes monsoon highly unpredictable.
- 4°C rise yields an extremely wet monsoon that currently occur once in 100 years will occur once in 10 years.
- More frequent droughts & floods.
- Decrease in rainy days & increase in intensity.
- With decrease in 6% of rainfall, net irrigation requirements increase by 29%.
- Impact on GWR due to changes in RF & ET Patterns.

**Increase in temperature**

- More water holding capacity in atmosphere
- Melting of glacier
- More evaporation
- Increase/decrease precipitation
- Imbalanced rainfall distribution

**Fresh water availability** (initially increase in availability but with time reduces drastically)
Floods and Droughts

- Frequency
- Magnitude
- Duration
Climate Change Impact on Recharge

- Spatial and temporal changes in temperature and precipitation may act to ultimately cause a shift in the water balance for an aquifer.

- For example, variations in the amount of precipitation, the timing of precipitation events, and the form of precipitation are all key factors in determining the amount and timing of recharge to aquifers.
Climate Change Impact on Recharge

- The occurrence of droughts or heavy precipitation can also be expected to impact water levels in aquifers.

- Droughts result in declining water levels not only because of reduction in rainfall, but also due to increased evaporation and a reduction in infiltration that may accompany the development of dry topsoils.

- Extreme precipitation events (e.g., heavy rainfall and storms) may lead to less recharge to groundwater because much of the precipitation is lost as runoff.
Mean sea-level-rise trends along the Indian coasts are about 1.30 mm/year

Future Projections globally indicate about 0.48 m rise by the turn of the century

<table>
<thead>
<tr>
<th>Station</th>
<th>No of years of data</th>
<th>Trends (mm/year)</th>
<th>GIA (Glacial Isostatic Adjustment) corrections</th>
<th>Net sea level rise (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumbai</td>
<td>113</td>
<td>0.77</td>
<td>-0.43</td>
<td>1.20</td>
</tr>
<tr>
<td>Kochi</td>
<td>54</td>
<td>1.31</td>
<td>-0.44</td>
<td>1.75</td>
</tr>
<tr>
<td>Vishakhapatnam</td>
<td>53</td>
<td>0.70</td>
<td>-0.39</td>
<td>1.09</td>
</tr>
<tr>
<td>Diamond Harbour (Kolkata)</td>
<td>55</td>
<td>5.22</td>
<td>-0.52</td>
<td>5.74</td>
</tr>
</tbody>
</table>

Unnikrishnan 2012
Sea level changes- past, present and future (Bindoff et al., 2007)
Consequences

- In the last hundred years, the sea level rose by 10–20 cm.
- In the next millennium, it will continue to rise; even greenhouse gas concentrations will stabilize due to lags in ocean warming & expansion and in the response of land ice.
- Projections of global sea-level rise from 1990 to 2100 is 0.48 m (IPCC, 2001a) which is 2-4 times the rate of rise over the 20th century.
- Present Greenland and Antarctic ice is sufficient to raise sea level by 70 m.
• Seawater intrusion into surface waters & coastal aquifers (i.e. contamination)
• Raises the interface between the saline and fresh water

Encroachment of tidal waters into estuaries and coastal river systems.

Groundwater salinization & higher water tables threaten many root crops, due to their low salt tolerance.
Multiple Stresses of a Changing Climate

- Increased Precipitation
- Increased Temperature
- Increased UV Radiation
- Increased Extreme Events
- Decreased Snowpack
- Decreased Soil Moisture
- Increased Carbon Dioxide
- Increased Run-off
- Increased Evaporation
- Land-use Change
- Loss of Biodiversity
- Invasive Species
- Air Pollution
- Acid Deposition
Mitigation of Climate Change Effect

**Advanced tools and techniques**
- Precision Farming: Minimum Input Maximum Output Approach
- Remote Sensing and GIS for Water Resources Management
- Water management: Micro-irrigation technologies
- Drought Relief and Rainwater Harvesting
- Reduction of Seepage and Leaks
- Water Education, Water Tariff Structures and Reuse of Grey Water
- Developing Climate-Ready Crops and Crop Diversification
- Improved Weather Forecasting and Crop Insurance Planning
Challenges before India

- Limited Natural Resources
- Increasing Population
- Deforestation
- Scarcity of Water
- Limited availability of Power
- Ensuring food security
- Climatic Change mitigation
Rain Water Management
Half moon shaped micro-catchment

Cup and Saucer shaped micro-catchment
Technology Transferred

Recharge shaft

Average recharge rate 5-6 l/s
New: Rs. 40000 to 50000
Abandoned well: Rs. 10000- 15000

Roof Harvesting Structures

RAINWATER HARVESTING THROUGH ROOFTOP

Inflow from rooftop
Flow toward filtration unit
Distillation tank
Filtration unit
Outlet chamber

Nearly Rs. 50000 for 500 m² rooftop
## Groundnut

<table>
<thead>
<tr>
<th></th>
<th>Pod yield Kg/ha</th>
<th>Net realisation Rs/ha</th>
<th>BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprinkler irrigation at 0.45 IW/CPE</td>
<td>1285</td>
<td>1182</td>
<td>1299</td>
</tr>
<tr>
<td>Sprinkler Irrigation at 0.60 IW/CPE</td>
<td>1462</td>
<td>1990</td>
<td>1563</td>
</tr>
<tr>
<td>Sprinkler Irrigation at 0.75 IW/CPE</td>
<td>1875</td>
<td>2493</td>
<td>1854</td>
</tr>
<tr>
<td>Surface Irrigation</td>
<td>1181</td>
<td>1448</td>
<td>1347</td>
</tr>
</tbody>
</table>


## Yield and Water Use under Drip and Sprinkler Irrigation Method

<table>
<thead>
<tr>
<th>Crop</th>
<th>Irrigation Method</th>
<th>Yield (kg/ha)</th>
<th>Water used (cm)</th>
<th>Gain over SIM (in %)</th>
<th>Water use efficiency (kg/ha/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yield</td>
<td>Water</td>
</tr>
<tr>
<td>Green gram</td>
<td>Sprinkler method</td>
<td>841</td>
<td>14.80</td>
<td>39.70</td>
<td>49.80</td>
</tr>
<tr>
<td></td>
<td>Surface method</td>
<td>602</td>
<td>29.50</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Black gram</td>
<td>Sprinkler method</td>
<td>1405</td>
<td>34.30</td>
<td>3.30</td>
<td>30.40</td>
</tr>
<tr>
<td>2.50cm/0.5 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface method</td>
<td>1360</td>
<td>49.30</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5.0cm/1.0 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>Sprinkler method</td>
<td>12167</td>
<td>55.70</td>
<td>-26.21</td>
<td>30.96</td>
</tr>
<tr>
<td>2.50cm/0.5 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface method</td>
<td>16489</td>
<td>80.70</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5.0cm/1.0 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundnut</td>
<td>Sprinkler method</td>
<td>1756</td>
<td>59.10</td>
<td>19.00</td>
<td>-6.70</td>
</tr>
<tr>
<td>3cm/0.6 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface method</td>
<td>1476</td>
<td>55.10</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5cm/0.6 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soyabean</td>
<td>Sprinkler method</td>
<td>1634</td>
<td>22.50</td>
<td>-2.00</td>
<td>29.02</td>
</tr>
<tr>
<td>5cm/1.0 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface method</td>
<td>1636</td>
<td>31.70</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5.0cm/1.0 ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compiled from Rajagopal (1998).
Rain Gun Irrigation Systems

- **Cost:** INR 15000 – 20000
- **Radius of Throw:** 50 - 100 feet
Focusable Research in sprinkler irrigation

- Strategies for achieving higher (> 80%) distribution uniformity (DU).
- Effect of discharge variations within the system on DU.
- Minimizing spray losses due to evaporation and wind drift.
- Evaluating optimum spacing arrangements of sprinkler heads viz., rectangular, square, and triangular.
- Optimizing the overlapping of wetted diameters under low and high wind situations.
- Fertigation through sprinkler system.
- Promoting use of plastic impact sprinklers.
Water saving over the conventional method of irrigation:

1. Vegetable crops: 12 - 40 % /ha
2. Fruit crops: 30 – 50 % /ha
3. Cotton, coconut & groundnut: 35 - 55 % /ha
4. Sugarcane: 40 % /ha

### Irrigation Efficiencies under Different Methods of Irrigation (Percent)

<table>
<thead>
<tr>
<th>Irrigation Efficiencies</th>
<th>Methods of Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
</tr>
<tr>
<td>Conveyance efficiency</td>
<td>40-50 (canal)</td>
</tr>
<tr>
<td></td>
<td>60-70 (well)</td>
</tr>
<tr>
<td>Application efficiency</td>
<td>60-70</td>
</tr>
<tr>
<td>Surface water moisture evaporation</td>
<td>30-40</td>
</tr>
<tr>
<td>Overall efficiency</td>
<td>30-35</td>
</tr>
</tbody>
</table>

Moisture availability for crops under different methods of Irrigation
Subsurface Drip Irrigation

- Irrigation requirements of maize reduced by 10% or more (Lamm et al., 1995) over surface drip
- Fertilizer use efficiency can be enhanced to 15% (Lamm et al., 1997b)
- Application of wastewater through SDI greatly reduce pathogen transfer to edible crops (Oron et al., 1995; Oron et al., 1991, Oron et al., 1992)
Subsurface Drip Irrigation

- Positions of placing the subsurface drip irrigation system
  - Shallow - 0.5-10cm deep
  - Medium – 10-25cm deep
  - Deep – deeper than 25 cm
  - Thinner wall thickness (0.15-0.6mm) dripper lines are used in SSD than on surface drip irrigation (0.6-1.2mm) system.
  - When irrigating with saline water, keep dripper lines shallower to prevent built-up of salts in the active root zone.
Porous Irrigation System

- 30 to 45 cm below surface
- Porous pipes
- 60 to 120 cm
1. Prevent evaporation component of ET
2. Water saving to 40% - 70% over drip irrigation
3. Improves quality and ensure early maturity
4. Save fertilizer (30%) and labour cost (10%).
5. Control diseases
6. High Water Use Efficiency over drip irrigation

Benefits Of Mulching

• Improves soil micro climate.
# Field Experimental Detail

<table>
<thead>
<tr>
<th>1</th>
<th>Main Plot</th>
<th>Irrigation regimes (IW/ET&lt;sub&gt;c&lt;/sub&gt;)</th>
<th>I&lt;sub&gt;1&lt;/sub&gt;</th>
<th>0.60 IW/ET&lt;sub&gt;c&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.80 IW/ET&lt;sub&gt;c&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&lt;sub&gt;3&lt;/sub&gt;</td>
<td>1.00 IW/ET&lt;sub&gt;c&lt;/sub&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>Sub Plot</th>
<th>Frequency of irrigation</th>
<th>F&lt;sub&gt;1&lt;/sub&gt;</th>
<th>Once in a 2 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>F&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Once in a 3 days</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F&lt;sub&gt;3&lt;/sub&gt;</td>
<td>Once in a 5 days</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3</th>
<th>Sub-Sub Plot</th>
<th>Mulching Material</th>
<th>M&lt;sub&gt;1&lt;/sub&gt;</th>
<th>Silver Black Plastic Mulch (20 micron)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Biodegradable Plastic Mulch (20 micron)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M&lt;sub&gt;3&lt;/sub&gt;</td>
<td>Wheat straw mulch</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>Control (No mulch)</td>
<td></td>
</tr>
</tbody>
</table>
Silver Black Plastic Mulch

1. Irrigation water saved by 15.43%, 11.47% and 19.78% over no mulch treatment at 0.6 IW/ET\textsubscript{c}, 0.8 IW/ET\textsubscript{c} and 1.0 IW/ET\textsubscript{c}
2. Highest seed cotton yield = 4661 kg/ha at 0.8 IW/ET\textsubscript{c} and 3 days irrigation frequency.
3. Lowest observed (1431 kg/ha) in no mulch at 1.0 IW/ET\textsubscript{c} and 5 days irrigation frequency.
4. Yielded net extra income of Rs. 81117/ha over no mulch treatment at 0.8 IW/ET\textsubscript{c} and 3 days irrigation frequency.
5. Payback period was 1.27 years.
6. Recorded good qualitative parameters at 0.8 IW/ET\textsubscript{c} and 3 days irrigation frequency.
Promoting Clean Energy use in agriculture for
- Pumping
- Farm and household lighting

Solar lanterns are a cleaner and safer renewable energy source for low income people in off grid areas.
Strategies to sustain crop yields in the arena of climate change

- Micro-irrigation and resource conservation technologies (RCTs), for economizing water is to be promoted.
- Improvements in irrigation efficiency are critical to ensure the availability of water for food production.
- Wastewater (18.4 million m³/day) needs to be utilized for irrigation after its proper treatment.
- Adoption of varieties with increased resistance to high temperature and drought.
Strategies to sustain crop yields in the arena of climate change

• Adoption of efficient technologies to ‘harvest’ every drop of rain water on field and off field
• Development of structures to provide more infiltration opportunity time for water recharge
• Modification of crop calendars, i.e., timing or location of cropping activities to eliminate losses due to climate change
• Developing thermo resilient, salt tolerant and water logging tolerant cultivars of our major crops
Strategies to sustain crop yields in the arena of climate change

- Need to revise IDF curves
- Research to attain higher yield production systems with reduction in GHG emissions per unit of production and protect water and soil quality — a process called ecological intensification is needed
- Integrated research to raise crop yield, nutrient and water use efficiency
The Way Forward: Our Priorities

- Controlled irrigation cum drainage structures needs to be developed.
- Develop climate smart villages by integrating hydrologists, crop specialists, and agro-meteorologists.
- Develop early warning and forecasting systems village wise.
- Water grid concept should be developed at micro level.
- Subsurface irrigations needs to be prioritized.
- Development of low energy irrigation systems.
- Micro level land use planning and capacity building of farmers.
The Way Forward: Our Priorities

• Afforestation on degraded forests, wastelands as well as river banks to facilitate soil conservation, recharging of ground water and preventing flooding of rivers and siltation of water reservoirs.
• Increase of irrigation efficiency from 35% to 50% in surface irrigation systems.
• Development of 80 Mega hectares of wastelands.
• Reduce cost of cultivation by improving mechanization.
• Strengthening market linkages and supply chains for agricultural products and technologies.
The Way Forward: Our Priorities

• Training farmers to enhance agricultural yields and revenues.
• Facilitating investments through public private partnerships for expanding capacity and improving management of grain silos and warehousing.
• Compelling farmers to adopt MIS in canal and ground water command areas.
• Prevention of water pollution by banning the discharge of untreated sewage and effluent in rivers.
• Encouraging Public Private Partnership, including civil society organizations and stakeholders in water resources development and conservation.
THANK YOU