Managing water under climate variability:
Physical Options and Policy Instruments

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Purpose of the session

This session would discuss:

- The various physical options for water management both on the supply and demand side, in the face of climate variability
- Their scope and limitations
- Market instruments for affecting adoption of demand side solutions.
Content

- Introduction
- Key water management challenges
- Supply side options for water management
  - Scope and limitations
- Demand side options for water management
  - Physical options: scope and limitations
  - Market instruments for promoting water demand management in agriculture
- Summary and Conclusions
Introduction

- Semi arid and arid regions in India, which are naturally water-scarce, are facing three different sets of water problems
  - Over-appropriation of surface water
  - Groundwater depletion, natural quality problems
  - Scarcity of water for competitive and in-stream uses

- Magnitude of climate variability problems are larger there

- During years of low rainfall, with fewer rainy days, higher aridity, the stream flow reduces drastically

- Humid, sub-tropical regions also experience seasonal water shortage
Key water management challenges

- Making sufficient water available for irrigation at the regional level for agricultural growth—naturally water scarce regions
- Improving equity in access to water for irrigation and other uses—both water-scarce and water rich regions
- Improving sustainability of drinking water supply sources
- Making safe water available for drinking & domestic uses—in water rich regions as well as water scarce regions
- Maintaining flows in environmentally water-stressed regions
Standard instruments for dealing with water scarcity

- Supply augmentation
- Water rights in the form of well permits; volumetric use rights
- Indirect charges through energy pricing
- Direct regulation of drilling; pump sets
- Virtual water trade
- Mimicking of river flows
- Need local runoff; otherwise inter-regional water transfer
- Strong political system; institutional mechanisms needed
- Farmers are major vote banks in India
- Difficult to enforce in Indian context
- Many arid & semi arid areas are exporting virtual water
- Competition between agriculture and environment
Deciding on a management intervention

- There are three different types of benefits that the society could accrue from a management intervention.

- They are: economic benefits; ecological/environmental benefits; and social benefits.

- From societal point of view, a management decision would be sound, only if the aggregate of these benefits exceed the costs of proposed interventions.

- The aggregate benefits are a sum of the economic benefits and all the positive externalities on the society associated with the ecological/environmental and social benefits.
This could be quantified in terms of reduction in economic costs associated with any of the negative consequences:

- Damage to river ecology
- Long term decline in groundwater levels
- Intrusion of sea water in coastal aquifers
- Land subsidence
- Deterioration of natural quality of groundwater
- Loss of wetlands

The approaches to manage water should attempt: i] reducing the withdrawals that are the results of anthropogenic activities; and, ii] increasing the utilizable flows.
Various supply side approaches for water management

- Increasing the Inflows:
  - Local water harvesting and recharging of groundwater through:
    - Spreading basin method
    - Dug well recharging (ASR)
    - Check dams
    - Injection wells
    - Induced recharge
    - Percolation tanks with recharge tube wells
Supply side approaches

- Water transfers from water-rich regions for providing alternative sources of water supply
  - Groundwater banking in California CVP
  - Groundwater banking in MDB in Australia
  - North Gujarat receiving SSP waters
- Recycling and recharge
  - Waste stabilization ponds
  - Soil Aquifer Treatment (Israel)
Potential of local water harvesting and artificial recharge in India

- Naturally water rich regions which experience seasonal shortages can adopt water harvesting
  - North east hilly/mountainous region
  - Mountainous areas and midlands of Nepal, High rainfall areas of Sri Lanka
  - Western ghat and eastern ghat regions

- Water harvesting is unlikely to work in semi arid and arid regions due to:
  - Poor hydrological opportunities for harvesting and poor reliability of water supply
  - Poor economic viability
  - Adverse impacts due to high degree of water development
Physical approaches for demand management

- Agricultural water demand management
  - Technological interventions
    - Micro irrigation systems
  - Plastic mulching in arid areas
  - Cropping system change
  - Growing crops in regions with high water productivity due to climatic advantages
  - Improving reliability of irrigation
  - Water control
Potential impacts of micro-irrigation on water use

- Complex factors involved in assessing water saving from micro irrigation

- Water saving depends on three factors:
  - How much water could be saved using the technology at the field level
  - What farmers do with the saved water
  - What opportunities exist at the macro level for adoption of the technology
Opportunities for field level water saving

Field level water saving through MIS depends on:
- Agro-climate
- Type of MI technology
- Depth to groundwater table
- Crop type

Real water saving at field level would be significant in arid and semi arid basins, with deep groundwater table, with drip irrigation used for row crops.

Such areas include alluvial central Punjab, western Rajasthan and north & central Gujarat and deep water table areas of peninsular India.
Constraints and opportunities in adoption of micro irrigation systems

- Area under crops that are most amenable to MI systems in terms of water saving benefits and income benefits are low in semi arid & arid regions—7.8 M ha in India
- Area where it can lead to water saving is only 5.9 m. ha
- It can increase if we include surface irrigated area
- Lack of restrictions on groundwater pumping and zero marginal cost of using it reduces the economic incentives for well irrigators having smaller holdings in good aquifer basins
- In hard rock areas, well interference further reduces individual initiatives to save water in the aquifer
Constraints and Opportunities in adoption of micro irrigation systems

- Small operational holding of farmers increases the unit capital and operating cost of MI system.
- In the surface irrigated areas, intermediate storage systems are reqd. for use of MI-digie in Rajasthan.
- In areas where power supply limits water abstraction, farmers have least incentive to go for MI systems as it does not help them expand the area.
- In hard rock areas, farmers have high incentive to go for MI systems, as they could expand the area under the irrigated crops.
- Geographical spread of adoption of MIS is a testimony to this.
What is the likely impact of MI systems on aggregate water use at the regional level?

- Often MI adoption is associated with changes in cropping system towards from traditional crops to high valued orchards—north Gujarat, Nalgonda, Jalgaon etc.

- Hence water saving at the field level could be high.

- But, this can also lead to expansion in irrigated areas, particularly in situations where percentage irrigated area is less.

- In areas where MI system results in “saving in applied water” alone, aggregate impact would be greater depletion of water.

- In situations like Punjab, MI system adoption can lead to real water saving, but cropping system is not amenable.
What is the likely impact of cropping system changes at regional level?

- Many traditional crops and dairying in semi arid and arid regions have low water productivity.

- Replacement of traditional crops by high valued fruit crops can cut down water use even at the aggregate level due to:
  - Significant reductions in depleted water for a unit area.
  - Absence of sufficient cultivable area to use up all the saved water at the farm level.

- But, many farming systems are composite. Crop residues form inputs for dairying in many areas.

- **Dairying yields high water productivity in Punjab, when compliments rice-wheat system.**
How far can it work in semi arid and arid regions?

- Replacing low water-efficient rice-wheat system will disturb dairying
- Importing fodder would increase the farming risks if done at a large scale
- Large scale adoption of high valued fruit crops can lead to market crash, leading to major drops in water productivity itself
- Also, major regional level crop shifts can take place would be constrained by concerns of food security, stability of farm income and employment generation
- Improving the productivity of existing crops will have to get priority
Agro-climate impact on crop water productivity

- In many basins, major variations in agro-climate exist spatially
  - Krishna basin, Godavari basin, Indus basin, Narmada
- Climate can affect crop yields through solar radiation and sunlight
- It can also affect evapo-transpiration
- Soil conditions will have impact on crop yields
- Hence, agro climate can have big impact on water productivity
- In Narmada basin, wheat water productivity varied widely across 9 agro climatic sub-regions, changes during droughts
PART II

DRINKING WATER
Options for improving drinking water supplies in rural areas

- Creating small local surface storages in naturally water-rich regions (NE, Western Ghat, Eastern Ghat—management by local institutions)

- Regional water supply systems based on allocation from large reservoirs in naturally water-scarce regions—_institutions both at local and system level

- Decentralized water treatment systems in groundwater-rich regions (of eastern India) for local sources, and local institutions
  - Both household and community systems

- Groundwater based schemes are likely to be unsustainable in naturally water-scarce, hard rock regions
PART III: Use of market instruments for water demand management in agriculture
Using electricity prices as a tool for managing groundwater use in agriculture

- Consumption based pricing creates incentives among farmers to generate higher return from every unit of water.

- When confronted with marginal cost, and under higher tariff, they use electricity & water more efficiently; select crops and farming systems that are more water-efficient.

- Under higher (pro rata) tariff, they obtain higher returns from every unit of land also.

- They use less amount of groundwater per unit of land; improving sustainability of groundwater use.

- Returns from farming are elastic not to water/energy tariff; but quality of irrigation.
Different modes of pricing & expected outcomes under different energy use regimes

<table>
<thead>
<tr>
<th>Energy Supply Policy</th>
<th>Monitoring</th>
<th>Pricing Policy Option</th>
<th>Outcomes at farm level</th>
<th>Outcomes for Company</th>
</tr>
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<tbody>
<tr>
<td>Fixing Energy Quota of Each Farmer</td>
<td>Use is metered</td>
<td>Option 1: Pro rata tariff</td>
<td>Improved efficiency of energy/water use; water productive crops</td>
<td>Theft prevented; revenue loss reduced; Sustainable groundwater use possible</td>
</tr>
<tr>
<td>Fixing Energy Quota based on Connected Load &amp; Supply Hours</td>
<td>Use is metered</td>
<td>Option 2: Pro rata tariff</td>
<td>Improved efficiency of energy/water use by all</td>
<td>Theft prevented; revenue loss reduced</td>
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<tr>
<td></td>
<td>Do</td>
<td>Option 3: HP based Charges</td>
<td>Improved efficiency of energy/water use by large farmers only</td>
<td>Do</td>
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<tr>
<td>Unrestricted Energy Supply</td>
<td>Use is metered</td>
<td>Option 4: Pro rata tariff a must</td>
<td>Improved technical efficiency of energy/water use + High productivity gains due to improved reliability</td>
<td>No losses to the company</td>
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<td></td>
<td>Option 5: Fixed tariff based on reported connected load</td>
<td>Poor energy use efficiency; monopoly of large farmers</td>
<td>Theft high; revenue losses to the company</td>
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<tr>
<td>Fixing Supply Hours</td>
<td>Use is not metered</td>
<td></td>
<td></td>
<td>Unsustainable Groundwater Use</td>
</tr>
</tbody>
</table>
Summary

- The approaches for augmenting water resources in water-scarce areas include: groundwater recharge using local runoff; recharge using imported water; and, recharge using treated wastewater.

- In arid and semi-arid regions, the hydrological opportunities and economic viability of artificial recharge would be generally very low.

- Another major approach is MI system to raise crop water productivity.

- Field level real water saving through MI devices depends on the crop type, climate, soils and geo-hydrological environment.

- Water-saving at the aggregate level would depend on availability of extra land for cultivation; the availability of power supply vis-à-vis the amount of groundwater that can be abstracted.
Summary

- Scope for WP improvement at the regional level through crop shift would be determined by
  - Contribution of the existing cropping system to regional food security, the employment generation in rural areas
  - Presence of market infrastructure for high valued crops.

- But, in any case, the outcomes of water productivity improvement through crop shifts in terms of reduction in groundwater draft would also depend on the opportunities for farmers to expand the area

- In some regions, opportunities might exist for enhancing water productivity by taking climatic advantages

- Pro rata pricing of electricity could lead to efficient and sustainable use of groundwater and would also be socio-economically viable
Infiltration basin/spreading basin, Australia

Figure modified from Dillon 2004
Estimated & observed runoff in Dharoi sub basin (MCM) from 1951-1991
Will water harvesting and local recharging benefit naturally water-scarce regions?
Estimated unit cost of artificial recharge structures built under pilot scheme of CGWB

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Type of Recharge Structure (Life in years)</th>
<th>Expected Active Life of the System</th>
<th>Estimated Recharge Benefit (TCM)</th>
<th>Capital Cost of the Structure (in Lac Rs.)</th>
<th>Cost of the Structure per m³ of water (Rs/m³)</th>
<th>Annualized Cost* (Rs/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Percolation Tank</td>
<td>10</td>
<td>2.0-225.0</td>
<td>1.55-71.00</td>
<td>20.0-193.0</td>
<td>2.00-19.30</td>
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<tr>
<td>2</td>
<td>Check Dam</td>
<td>5</td>
<td>1.0-2100.0</td>
<td>1.50-1050.0</td>
<td>73.0-290.0</td>
<td>14.60-58.0</td>
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<tr>
<td>3</td>
<td>Recharge Trench/Shaft/</td>
<td>3</td>
<td>1.0-1550.0</td>
<td>1.00-15.00</td>
<td>2.50-80.0</td>
<td>0.83-26.33</td>
</tr>
<tr>
<td>4</td>
<td>Sub-surface Dyke</td>
<td>5</td>
<td>2.0-11.5</td>
<td>7.30-17.70</td>
<td>158-455.0</td>
<td>31.60-91.00</td>
</tr>
</tbody>
</table>
Effect of watershed interventions on reservoir inflows

Ghelo-Somnath Rainfall and Reservoir Inflows

- Total Rainfall, cm
- Total Runoff, cm

Year

- 1969
- 1971
- 1973
- 1975
- 1977
- 1979
- 1981
- 1983
- 1985
- 1987
- 1989
- 1991
- 1993
- 1995
- 1997
- 1999
- 2001
- 2003
- 2005
Impact of plastic mulching in western Rajasthan (Luni river basin)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Maize</th>
<th>Groundnut</th>
<th>Castor</th>
<th>Cotton</th>
<th>Cluster bean</th>
<th>Overall</th>
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<tbody>
<tr>
<td>Value</td>
<td>17.95</td>
<td>19.6</td>
<td>0.77</td>
<td>1.09</td>
<td>100.3</td>
<td>139.7</td>
</tr>
</tbody>
</table>
Changing water allocation: deficit irrigation

Figure 2: Water productivity vs irrigation dosage: serpentine furrow (Source: Kumar et al., 2012)

\[ y = 14.241e^{-0.04x} \]

\[ R^2 = 0.7922 \]
Farming system level water productivity in agriculture under different pricing regimes

<table>
<thead>
<tr>
<th>Name of the Regions</th>
<th>Name of the district</th>
<th>Electric Well Command</th>
<th>Diesel Well Command</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Flat Rate</td>
<td>Unit Pricing</td>
</tr>
<tr>
<td>North Gujarat</td>
<td>Banaskantha</td>
<td>6.20</td>
<td>7.90</td>
</tr>
<tr>
<td>Eastern UP</td>
<td>Varanasi and Mirzapur</td>
<td>10.95</td>
<td>11.18</td>
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<tr>
<td>South Bihar Plains</td>
<td>Patna</td>
<td>9.28</td>
<td>10.13</td>
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</tbody>
</table>
Net income from crop and milk production, three locations

<table>
<thead>
<tr>
<th>Type of Well Command</th>
<th>Type of farmer</th>
<th>Gross cropped area (Ha)</th>
<th>Net income from crops (Rs)</th>
<th>Net income from dairying (Rs/day)</th>
<th>Total Farm level Income (Rs)</th>
<th>Farm level net income (Rs/Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Well</td>
<td>Well owner</td>
<td>5.29</td>
<td>124587</td>
<td>7152.3</td>
<td>131739.6</td>
<td>24880</td>
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<td></td>
<td>Water buyer</td>
<td>2.21</td>
<td>54637</td>
<td>6165.0</td>
<td>60802.6</td>
<td>27570</td>
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<tr>
<td>Diesel Well</td>
<td>Well owner</td>
<td>5.66</td>
<td>74764</td>
<td>7429.5</td>
<td>82193.9</td>
<td>14528</td>
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<tr>
<td></td>
<td>Water buyer</td>
<td>3.79</td>
<td>62323</td>
<td>6260.6</td>
<td>68583.7</td>
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<td>Electric Well</td>
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<td></td>
<td>Metered</td>
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<td>311807</td>
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<td>Water buyer</td>
<td>1.70</td>
<td>61518</td>
<td>8130.9</td>
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<tr>
<td>Diesel Well</td>
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<td>2.49</td>
<td>140105</td>
<td>9958.1</td>
<td>150063.6</td>
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<tr>
<td></td>
<td>Water buyer</td>
<td>1.60</td>
<td>71810</td>
<td>12232.2</td>
<td>84042.5</td>
<td>197895</td>
</tr>
</tbody>
</table>
## Impact of pro-rata pricing on groundwater use

<table>
<thead>
<tr>
<th>Name of the Regions</th>
<th>Name of the district</th>
<th>Groundwater Pumpage by Electric Pump Owners</th>
<th>Groundwater Pumpage by Diesel pump</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unit Pricing</td>
<td>Flat Rate</td>
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<tr>
<td>North Gujarat</td>
<td>Banaskantha</td>
<td>303.88</td>
<td>443.88</td>
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<td>Eastern UP</td>
<td>Varanasi &amp; Mirzapur</td>
<td>175.38</td>
<td>183.93</td>
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<td>South Bihar</td>
<td>Patna</td>
<td>329.97</td>
<td>249.74</td>
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</tbody>
</table>
Water productivity in crops and milk production

- Paddy: 7.75 Rs/m³
- Wheat: 8.05 Rs/m³
- Milk Production: 13.06 Rs/m³
Water productivity in crops and dairying in north Gujarat

Net Water Productivity in Crops and Milk Production

Water Productivity (Rs/m³)

Cotton, Mustard, Tobacco, Castor, Potato, Wheat, Bajra Summer, Bajra Kharif, Buffalo, CB Cow
Vibrant dairy economy is a constraint to saving groundwater in north Gujarat

Milk Production and Aggregate Groundwater Use with WST

Proportion of Current Production of Milk

% Saving in Water Use

0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  Cur

Prod

Min
Rainfall and climate varies drastically within the Indus.
Irrigation and water productivity in wheat in different regions of Narmada basin
## Current scale of adoption of MI systems

<table>
<thead>
<tr>
<th>Name of States</th>
<th>Area under Drip</th>
<th>Sprinkler</th>
<th>Total Area (ha)</th>
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</thead>
<tbody>
<tr>
<td>Rajasthan</td>
<td>17002</td>
<td>706813</td>
<td>723815</td>
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<td>Maharashtra</td>
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<td>564023</td>
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<td>Karnataka</td>
<td>177326</td>
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<td>Tamil Nadu</td>
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<tr>
<td>Bihar</td>
<td>163</td>
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<td>369</td>
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<tr>
<td>Others</td>
<td>15000</td>
<td>30000</td>
<td>45000</td>
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<tr>
<td>India Total</td>
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