Investing in Adaptation:
The Challenge of Responding to Water Scarcity in Irrigated Agriculture

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Agriculture’s Water Economy
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Outline

1. Characteristics of Water Important for Considering Adaptation Measures
2. Irrigated Agriculture and Water Scarcity: A Global View
3. Investing in Engineering and Technological Adaptation Measures
4. Investing in Policy and Institutional Adaptation Measures
5. Going Forward

References
1. Characteristics of Water Important for Considering Adaptation Measures

- Water is mobile, moving through the hydrological cycles
  - Exclusive property rights are relatively difficult and expensive to establish and enforce

- Water supplies are relatively variable and unpredictable
  - Due to these, coupled with variations in local demand, water-related problems are typically localized, and adaptation measures need to be adapted to local context

- Water is rarely completely “consumed” in human consumption or production activities
  - Interdependencies among water users are pervasive
  - Depending on the context, downstream users may be greatly affected by the return flows of upstream users
  - It is then difficult to derive water-related insights from what is observed on the field/farm for the overall effects at the basin level
  - With externalities, there is a need for public policy to complement individual activities and/or orient them toward more desirable outcomes from a social point of view
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2. Irrigated Agriculture and Water Scarcity: A Global View

Linking irrigated agriculture and water scarcity, and showing trends, is difficult due to

- special characteristics of water
- problem of defining water scarcity
- availability of data

Illustrations:

- Central role of water use in agriculture
- Country examples
- Link between agricultural and total water withdrawals
- Link between agricultural water withdrawals and area equipped for irrigation
- Water scarcity in terms of total and agricultural water withdrawals
- Trends in area equipped for irrigation
Global Trends in Agricultural and Total Water Withdrawals and Consumption

Source: Authors, based on Shiklomanov and Rodda (2003)
## Countries with the Largest Agricultural Water Withdrawals

<table>
<thead>
<tr>
<th>Country</th>
<th>Agricultural Water Withdrawals (billion cubic meters)</th>
<th>Total Water Withdrawals (billion cubic meters)</th>
<th>Agricultural Water Withdrawals as Percent of Total Water Withdrawals</th>
<th>Area Equipped for Irrigation (million hectares)</th>
<th>Area Equipped for Irrigation as Percent of Agricultural Area</th>
<th>Agricultural Water Withdrawals per Area Equipped for Irrigation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>688</td>
<td>761</td>
<td>90%</td>
<td>67</td>
<td>37%</td>
<td>1.0</td>
</tr>
<tr>
<td>China</td>
<td>358</td>
<td>554</td>
<td>65%</td>
<td>69</td>
<td>13%</td>
<td>0.5</td>
</tr>
<tr>
<td>United States</td>
<td>175</td>
<td>486</td>
<td>40%</td>
<td>26</td>
<td>6%</td>
<td>0.7</td>
</tr>
<tr>
<td>Pakistan</td>
<td>172</td>
<td>184</td>
<td>94%</td>
<td>20</td>
<td>75%</td>
<td>0.9</td>
</tr>
<tr>
<td>Indonesia</td>
<td>93</td>
<td>113</td>
<td>82%</td>
<td>7</td>
<td>12%</td>
<td>1.3</td>
</tr>
<tr>
<td>Iran</td>
<td>86</td>
<td>93</td>
<td>92%</td>
<td>10</td>
<td>19%</td>
<td>0.9</td>
</tr>
<tr>
<td>Vietnam</td>
<td>78</td>
<td>82</td>
<td>95%</td>
<td>5</td>
<td>42%</td>
<td>1.6</td>
</tr>
<tr>
<td>Philippines</td>
<td>67</td>
<td>82</td>
<td>82%</td>
<td>2</td>
<td>13%</td>
<td>3.4</td>
</tr>
<tr>
<td>Egypt</td>
<td>67</td>
<td>78</td>
<td>86%</td>
<td>4</td>
<td>100%</td>
<td>1.5</td>
</tr>
<tr>
<td>Mexico</td>
<td>62</td>
<td>80</td>
<td>77%</td>
<td>7</td>
<td>6%</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Source: FAO, 2016a; FAO, 2016b.
Agricultural Water Withdrawals and Total Water Withdrawals, by Country

Source: Authors’ calculations based on FAO, 2016a.
Agricultural Water Withdrawals and Area Equipped for Irrigation, by Country

**Linear Model**

\[ y = 0.7698x + 1.4494 \]

\[ R^2 = 0.8914 \]

**Log Model**

\[ y = 1.0113x - 0.3178 \]

\[ R^2 = 0.7999 \]

Source: Authors’ calculations based on FAO, 2016a.
Total Water Withdrawals as Percent of Total Renewable Water Resources

Agricultural Water Withdrawals as Percent of Total Renewable Water Resources

Source: Authors’ calculations based on FAO, 2016a.
Trends in Area Equipped for Irrigation 1962-2012, by Region

Source: Authors, based on FAO, 2016b.
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- **Most common** adaptation measures in irrigated agriculture
- Include **measures** such as
  - more capital-intensive irrigation technologies,
  - improved seens,
  - precision farming to optimize use of water and other inputs tailored to local conditions

- Usually **applied on-farm** and financed with **private investments**
- Often supported with **public subsidies and/or technical assistance**
- Typically effective at
  - increasing or at least maintaining **agricultural net revenues**
  - **also** at maintaining or increasing agricultural production
  - usually not at conserving agricultural water for reallocations to other uses and/or for coping with water scarcity

**Illustration:**
Conversion to more capital-intensive irrigation technologies as popular measure
Conversion to More Capital-Intensive Irrigation Technologies

• They increase the “efficiency” of irrigation water use on a field by reducing evaporation and losses from surface runoff or subsurface drainage.

• Because of less water withdrawn and applied to the field, they are assumed to maintain agricultural production and, at the same time, contribute to the objective of conserving water.

• With this in mind, they are often heavily subsidized.

However:

• In many instances, they have the counterproductive effect of increasing water consumption, and may even increase water withdrawals and water applications to the field—and thus contribute to a worsening of water scarcity.

Illustration:
Empirical studies from the United States on their effects on water scarcity
(i) Research on Effects on Water Scarcity when Return Flows Are Important: Need for Reduction in Consumption

- **Schematic illustrations**
  - Changes in return flows may affect downstream users (Hartman and Seastone, 1965)
  - If “saved” water is used to increase irrigated acreage, consumption may even increase (Huffaker and Whittlesey, 1995; Huffaker and Whittlesey, 2003)

- **Normative Models**
  - With reduced effective cost of consumption, farmers increase consumption and irrigated acreage; and these changes may decrease or increase water applications (Huffaker and Whittlesey, 2003)
  - Even if irrigated area is not expanded, consumption may increase (Scheierling et al. 2006)
  - At the basin level, water applications to irrigated lands may fall, but overall consumption increases (Ward and Pulido-Velazquez, 2008)
  - Consumption will increase at any non-zero marginal cost of water (Contor and Taylor, 2013)

- **Econometric Approaches**
  - For the average farm, subsidies may have reduced water application rates but also may have increased total water use, and led to an expansion in irrigated area (Wallander and Hand, 2011)
Research on Effects on Water Scarcity when Return Flows Are Not Important: Need for Reduction in Withdrawals

Studies (mostly on the Ogallala aquifer) showed that withdrawals may increase or decrease, depending on context.

- **Normative Models**
  - Even under simplifying assumption, the effect on withdrawals is ambiguous (Peterson and Ding, 2005)

- **Econometric Approaches**
  - Groundwater pumped and applications to fields increased (partly due to crop switches); also more area was irrigated (Pfeiffer and Lin, 2014)

Similar effects may be observed with other engineering and technological adaptation measures.

However, there are exceptions. They include, for example, when return flows are important:

- measures that decrease evaporation (e.g. conservation tillage)
- measures that decrease transpiration (e.g. varieties with shorter growing season length)
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- Increasing in importance
- Including measures such as
  - raising awareness
  - fostering innovations
  - applying economic instruments for balancing water supplies and demands

While supply side measures may continue to play a role, the emphasis is shifting to demand side measures.

Two Key Purposes:

(i) Essential to contribute to objective of conserving agricultural water for reallocations and/or coping with water scarcity

(ii) Need to promote and ensure the alignment of private adaptation investments with this objective
(i) Measures for Facilitating Reallocations

• **Price-based measures**
  - Often not advocated due to findings of price-inelastic demand for irrigation water; yet this does not imply that slightly higher prices could not result in significant reductions in water applications.
  - The real issue is that even significantly higher prices would **not** be very effective in reducing consumption—and not help when return flows are important.

• **Quantity-based measures/quotas**, e.g.
  - “Release sharing” in prior appropriation system in western U.S.
  - “Capacity sharing” in Australia

• **Reallocations with water markets** with exchangeable quotas
  - Increasingly used in countries with strong legal, institutional and regulatory arrangements.
  - Elsewhere:
    • Transfers of informal rights (e.g. farmer-to farmer)
    • Transfers by legal means (e.g. priorities at times of drought)
    • Transfers by administrative decision (compensation may be paid)
    • Transfers by stealth (compensation is usually not paid)
(ii) Measures for Promoting and Aligning Private Adaptation Investments

**Private adaptation investments** may

- not be provided at the desirable level (e.g., due to cost considerations)
- not be aligned with broader social objectives (e.g. water conservation)

**Public adaptation investments** need to provide incentives, coordination, regulation

- In the case of subsidies for irrigation technologies, for example,
  - objectives need to be clearly stated
  - context-specific assessments should be carried out to avoid counterproductive outcomes
  - regulations should be in place to guide farmers’ adjustments
  - farmers should be informed if reallocations are planned

- Care should be taken to not increase farmers’ water-related (and other) risk exposures

- Groundwater management needs to be improved to make any significant progress with water conservation efforts in irrigated agriculture.
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Going forward, it will be important to achieve progress on several fronts:

• Urgent progress needs to be made with policy and institutional adaptation measures.
• More research and development funding for fostering innovations should concentrate on policy and institutional arrangements.
• Many more ex-ante and ex-post assessments are needed to inform decision-makers in both the private and public sectors.
• Adaptation measures increasingly need to take into account, and be integrated within, the wider policy framework (e.g., in the agricultural and energy sectors).
• With increasing water scarcity and more pervasive interdependencies among water users, even relatively minor shortfalls in water supplies may create unpredictable economic, social and/or environmental crises that currently applied adaptation measures may not be able to address. Planning for such events has to attract increasing attention.
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