Adoption of farm-based irrigation water-saving techniques in the Guanzhong Plain, China


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Supplemental Information

Supplemental Appendix S.1: Irrigation techniques in the Guanzhong Plain

For the first stage, the delivery-to-the-field stage, the following community-based techniques are in use in the survey area. (i) **Earthen-lined canals.** The walls of these canals are made of earth and are highly permeable which leads to seepage, up to as much as 50% of total transport (Wang et al., 2002). (ii) **Cement-lined canals.** This kind of canal is less permeable than the earthen-lined canal which reduces seepage. Moreover, they have smoother surfaces resulting in faster flow velocity which also reduces seepage and evaporation. (iii) **Transportation pipelines.** This is a network of underground or surface pipes that are used to transfer irrigation water from the water source to the fields. The transportation pipelines are usually connected to a station that pumps water from an underground source or from a major canal. This technique is more efficient than cement-lined canals because evaporation and seepage are reduced to a minimum.

*Cement-lined canals* and *Transportation Pipelines* involve a once-only, but large fixed investment outlay, followed by small yearly maintenance costs. The costs are borne by the group of farmers who share the same canal. It is possible to obtain investment or maintenance subsidy from the local government. Although the investment is costly, there is a long-term water-saving potential. The choice of a community-based technique is a collective decision, although the village leaders usually have substantial influence.

For the second stage, the delivery-to-crop-root stage, the following, farm-based techniques are in use in the study area. (i) **Flood irrigation.** This technique lets the water flow over the fields. There are no barriers such as furrows or ridges that control the flow. It is popularly called ‘water-waste irrigation technique’, because a large proportion of the water is wasted due to seepage and evaporation. If the field is sufficiently flooded, the water will reach all the
plants. (ii) Border irrigation. This technique divides a plot into several strips by soil ridges (borders) (Wang et al., 2002). Water is released into the area between the borders which guide water flows down the field. Border irrigation is more efficient than flood irrigation in that water flows to the end of the field in a shorter period of time and thus reduces seepage and evaporation. Moreover, it is more precise than flood irrigation because it allows more accurate application of the appropriate doses. (iii) Furrow irrigation. This technique involves digging small, parallel ditches (furrows) into a plot through which the irrigation water flows to the crop beds. It is suitable for row crops that are usually grown on the ridges between the furrows. Water is infiltrated to the crop roots without wetting the entire surface. It is thus more efficient than flood irrigation. Border and furrow irrigation imply no fixed cost. However, there are labor costs related to constructing soil ridges or to digging ditches. (iv) Spray pipes are small, moveable plastic pipes that are used to transfer water from the water source at the field to spray the roots. This technique is more efficient than the previous ones because there is no seepage or evaporation during transportation from the field source to the roots. In addition, it allows better fine-tuning of the appropriate doses and requires less labor input. The direct financial outlay related to purchasing the plastic pipes is rather low.

At stage three, the uptake-by-the-crop stage, water absorption can be enhanced by adopting drought-resistant varieties or by using agronomy measures such as mulching and fertigation. (i) Mulching, implies that straw or plastic sheeting is placed over the soil surface to reduce evaporation and retain moisture. In the study area, wheat straw is the most common. It is left in the fields and used to cover corn which is grown after the wheat harvest. Plastic sheeting is commonly used in cotton, corn and vegetables cultivation. Straw mulching is cheaper but also less efficient than plastic sheeting. (ii) Use of drought-resistant varieties can significantly reduce vulnerability to droughts. These varieties have the ability to grow and produce satisfactory yields under drought conditions. The cost of drought resistant varieties is
slightly higher than the cost of traditional seeds. (iii) *Fertigation* is the integration of fertilization and irrigation. Soluble fertilizers and other chemicals are directly applied to irrigation water, resulting in a more efficient use of both water and fertilizers. Specifically, water enriched with fertilizers increases the soil structure which improves crop root growth, drought resistance and increases water storage capacity (Wang et al., 2002). Soluble fertilizers are more costly than traditional fertilizers and require know-how.

**Supplemental Appendix S.2: Water scarcity in the Guanzhong Plain**

The case study relates to the Guanzhong Plain which is located in the Yellow River basin in Shaanxi Province. It covers an area of 55,000 km² and has a population of 23.5 million. It accounts for 25% of Shaanxi’s total land area but is home to 65% of its population. The 1.5 million ha of arable land in the Plain accounts for 52% of the province’s total. Wheat and corn are the main crops. They account for 45% and 30% of the total sown area, respectively. Wheat and corn are produced consecutively. The growing period for wheat is October-June whereas corn is planted after the wheat harvest and grows in July-September. Each of the water-saving techniques can be used for each crop. Use of a water-saving technique is at farm level, not crop level.

The Guanzhong Plain is a typical Chinese water scarce region. In 2011, annual water availability per capita was 400 m³, which is only 20% of the national average and is far below the threshold of extreme water scarcity (SPBS, 2012). There are several reasons for the extreme scarcity. First, average annual precipitation is very low: 550mm. Secondly, the distribution of precipitation in the Plain is skewed. For example, as much as 80% of total rainfall in 2011 was concentrated in the summer (July-September) while winter (December-February) received only 3%. Moreover, the season that wheat requires most water (March-May) received only 15% of that year’s precipitation (SPBS, 2012). The probability of a
drought is also very high, at 70-80%. Thirdly, water pollution and land erosion decrease surface water availability. Of the 700 million tons of waste water generated each year, only 13% is treated before discharge. Because surface water is insufficient to meet increasing demand, underground water is abstracted at a large scale. 87 per cent of the Plain’s surface water and 85 percent of its renewable groundwater is withdrawn every year, which is far beyond the sustainable level of 25% (Yu et al., 2000). Since 1980s, the withdrawal has caused an average annual decline of the groundwater table by 2m (Li and Cao, 2003).

Irrigation plays an important role in Shaanxi and the Guanzhong Plain. The Plain has a well-structured irrigation canal system which transfers water from rivers and reservoirs to the fields. It irrigates an area of 0.78 million hectares of farmland accounting for 57 per cent of total irrigated land in Shaanxi Province. Irrigation is organized by irrigation districts. Each district has its own water source, canal system, and irrigation management bureau. Among the 11 largest irrigation districts (each covering an area of more than 20,000 ha) in Shaanxi, 10 are located in the Guanzhong Plain (Wang et al., 2006). Approximately 75% of grain production comes from irrigated land (50% of total arable land).

Similar to other regions in Northern China, industry and households in the Plain have been competing with agriculture for water. The percentage of water used in agriculture has decreased from 80% in 1980 to 55% in 2011 while water used by industry has increased from 10% to 20% and by household from 10% to 25% (SPDWR, 2012).
Supplemental Table S.1: Total effects for the structural equation model (SEM)

Table S.1 Standardized total effects for the WaterAwareness-Perception model

<table>
<thead>
<tr>
<th>Variables</th>
<th>WaterAwareness Coefficients</th>
<th>S.E.</th>
<th>Perception Coefficients</th>
<th>S.E.</th>
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</thead>
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<td>0.185</td>
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<td>Age</td>
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<td>Edu</td>
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<td>0.066</td>
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<tr>
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<tr>
<td>Network</td>
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<td>0.081*</td>
<td>0.044</td>
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<tr>
<td>Experience</td>
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<td>0.072</td>
<td>0.805***</td>
<td>0.046</td>
</tr>
</tbody>
</table>

Note: (1): *: p<.10, **: p<.05, ***: p<.01.

References: