Identifying and Reducing Threats to Sustainable Agriculture in Iran

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The river basin perspective

The Zayandeh Rud (fig. 1) has been the basis for the importance of the heartland of central Iran. For centuries it has provided water for irrigation and enabled the growth and prosperity of the ancient cultural capital of Esfahan. As demand for water grows, however, with urban and industrial growth and the development of modern irrigation systems, there is intense pressure on the limited water resources of the basin.

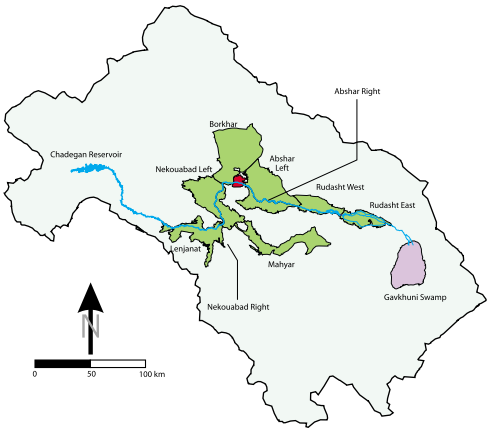
Traditional irrigation systems and tail-end areas may no longer receive their expected share of water, and what is received is frequently of poor quality due to upstream use. At the end of the basin, water is almost as saline as seawater. Soil salinity is spreading in the lower parts of the basin, groundwater resources are being depleted in all parts of the basin, urban demand is growing, and there is no scope for any additional reservoir storage.

To help cope with these issues, IWMI and Iranian organizations are working together in a series of studies that look at water resources for agriculture from the basin perspective, enabling the development of an integrated approach to the management of water and soil salinity to help sustain agricultural productivity.

The Iran-IWMI collaboration

The Iran-IWMI Collaborative Research project, established in 1998, aims to address the role of water management for sustaining agricultural productivity. Through an integrated program that looks at basin-level water management, management of irrigation systems and farm-level water management practices. The project aims to find solutions to three main elements of water management problems: alleviating soil salinity, minimizing the negative impacts of return flows to the Zayandeh Rud, and attempting to reduce the gap between actual and

Figure 1: Overview of the Zayandeh Rud basin and its irrigated areas.



potential yields. The project uses modeling and simulation techniques to assess current conditions and the impact of possible future changes on water conditions at each of the three spatial levels of study: basin, irrigation system, and farm.

The project is funded by the Government of the Islamic Republic of Iran through the Ministry of Agriculture, the Iranian Agricultural Engineering Research Institute, and the Department of Agricultural Engineering of the Esfahan Agricultural Research Center.

The Zayandeh Rud Basin

The Zayandeh Rud is the most important river in the Esfahan Province in central Iran. Largely fed by snowmelt from the Zagros mountains, it flows down into the basin where the city of Esfahan is located. It is a closed basin with no outflow to the sea: the river terminates in the Gavkhuni swamp, which is a natural salt pan.

The river has provided the basis for centuries of important economic activity, including the growth and establishment of Esfahan itself as the former capital city of Persia. The region has been able to support a long tradition of irrigated agriculture in addition to meeting the domestic needs of a substantial population. More recently, a huge increase in industrial activity has increased the demand for water, and the Zayandeh Rud is showing typical signs of a river basin under threat.

The continued growth of urban population and the recent rapid increase for industrial uses have led to a competition for water with the agriculture sector, and there has normally been insufficient water to irrigate the total irrigable area. This has resulted in the development of saline soils in the lower portions of the basin, significant gaps between actual and potential yields, and a reduction in the quality of return flows into the Zayandeh Rud. In addition to increased salinity in the river downstream of the major irrigated areas, there is more urban and industrial effluent being returned into the river, so that downstream water is badly polluted. Although some of the gross shortfalls in water are met through trans-basin diversions from other catchments in the Zagros mountains, these will not au-

tomatically reverse the trends towards less water, and water of poorer quality, for both agricultural and nonagricultural uses.

Threats to sustainable agriculture

The primary threats to sustainable irrigated agriculture are: a) reductions in water for agriculture because of competition from other sectors, b) declining water quality in both groundwater and surface water resources, and c) soil salinization.

Several measures have been adopted over the past couple of decades to help alleviate these problems, including installation of drains and augmenting water supplies through trans-basin diversions. However, these structural measures require proper management to be effective: merely adding more water and more drains will not automatically overcome the threats to sustainable agriculture. Should drains fail, for example, there will be increased threats to agriculture as water tables will rise and salinity will increase.

Competition for water between different sectors

Agriculture remains the largest single user of water in the basin despite increased demands from other users of water. The data on extractions show that in a typical year as much as 90 percent of water released from the Chadegan reservoir is diverted into irrigation systems. Although there are also substantial return flows to the Zayandeh Rud their quality is poorer than that of the diverted water and may not be suitable for downstream users.

Esfahan is the second largest city of Iran with a population of some 2 million. In recent years, the province has seen a significant industrial expansion with steel mills, refineries, cement works, and a host of smaller industries established along the Zayandeh Rud. As in most other countries, industries are more capable of paying for water than farmers, so there is a potential for decreased supplies for irrigated agriculture. Similarly, urban demand is rising annually not merely through population growth but also because more affluent people consume more water per capita.

Finally, and increasingly important, is the growing concern with environmental degradation, with pressure to maintain higher base flows to dilute pollutants so that acceptable standards in water quality can be maintained.

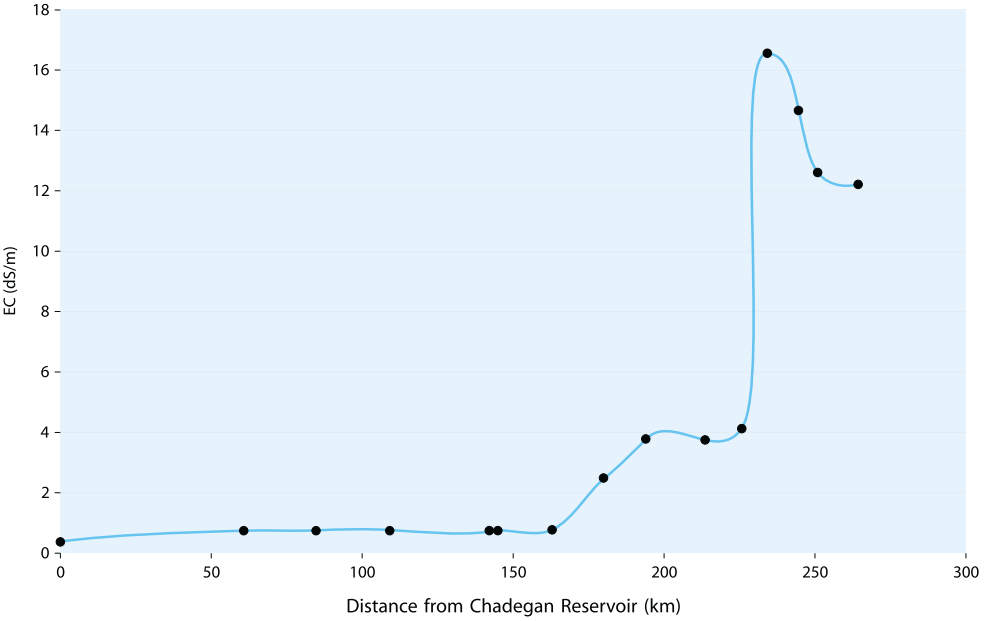
The measure seen as most effective in this regard has been the construction of diversion tunnels from the Kuhrang river in the Chaharmahal-va-Bakhtiari province. The two tunnels already constructed can deliver 540 million cubic meters of water a year into the upper reaches of the Zayandeh Rud and make a significant contribution to the total water supply in the basin. A third tunnel, expected to be ready in a few years, will deliver a further 250 million cubic meters of water annually.

Declining quality of groundwater and surface water resources

As the river flows downstream, an increasing proportion is being used for irrigation. The solute content of the irrigation return flow into the aquifers and the river, combined with urban and industrial effluents, is much higher than that of the water flowing in the river. The mixing leads to progressively increasing levels of salinity (EC) and total dissolved solids along the Zayandeh Rud. At the regulating dam, EC values are about 0.3 dS/m. A significant increase occurs as the water passes through Esfahan (fig. 2) with values going up to 2.5 dS/m. As the river receives return flow from the Abshar irrigation scheme, the values further climb to 4 dS/m. With the inflow of water from the main northern drain after Ejiyeh, the EC reaches a maximum of 16 dS/m, after which it slowly decreases to 12 dS/m because of mixing with less-saline tributaries. Finally, after 280 km the remaining river water spills into the Gavkhuni swamp.

Hydrochemical analyses of groundwater from boreholes along the Zayandeh River reveal the same pattern, which is not surprising as the aquifers are recharged by the river water and return flow and with leakage from the irrigation schemes. A detailed hydrochemical study of a small sub-catchment (Lenjanat), along the Zayandeh Rud upstream of Esfahan over a 10-year period, has shown that the groundwater composition is subject to long-term trends. In some parts of the aquifer, salts are slowly being flushed out, whereas in other parts concentrations are rising. It appears that the groundwater composition is slowly changing in response to expanding or variable cultivation practices. Further studies on groundwater chemistry are underway using the existing database for different aquifers, notably in the more-saline parts downstream of Esfahan, especially in the Rudasht area.

Figure 2: Salinity levels along the Zayandeh Rud.



Soil salinization

It is estimated that about 23.5 million hectares (or 14.2% of the total area of the country) are salt-affected, which is equivalent to about 50 percent of Iran's irrigated potential. Therefore, salinization poses a serious threat to the sustainability of irrigated agriculture in Iran.

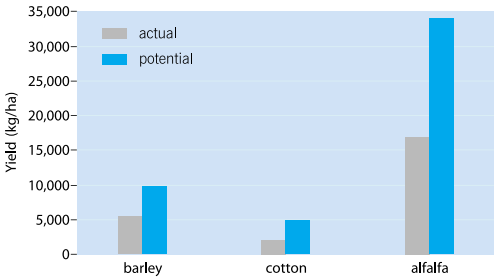
Salinity levels of water used for irrigation in the Zayandeh Rud vary substantially from values of less than 1 dS m^{-1} upstream up to around 6 dS m^{-1} at the Rudasht irrigation scheme located downstream. As salts will not leave the system by evaporation, a salt accumulation is likely to occur if no surplus of water is applied to leach them. Due to this accumulation, salinity levels of soil can be higher those of the irrigation water. A dramatic example of this can be seen in the Rudasht area where the salinity of soil is reported to be about 14 dS m^{-1}, while that of irrigation water is about 6 dS m^{-1}. Obviously, these high salinity levels of soil have a severe negative impact on crop yields, as evidenced by the big gap between actual and potential yields obtained from some field experiments in the Rudasht irrigation system (fig. 3).

Two hazards are likely to occur if no proper water management is applied to reduce this soil salinization. First of all, irrigation applications are too low, causing a salt accumulation in the soil. In an attempt to reduce this salt accumulation, a surplus of irrigation

water will be supplied to leach these salts from the root zone. This, in many cases, leads to the second problem, waterlogging due to rising groundwater. Often, this groundwater is also very saline and will increase the salinity level of the root zone substantially. So, irrigation applications must be high enough to minimize salt accumulation in the root zone and low enough to limit the hazard of waterlogging. Obviously, problems related to waterlogging can also be diminished by an adequate drainage system.

These threats, either singly or in combination, result in two main effects: declining irrigation intensities and a significant shortfall in actual yields compared to potential (fig. 3).

Figure 3: Actual and potential yields of some crops in the Rudasht irrigation system.



Reducing threats to sustainable agriculture

The Iran-IWMI Collaborative Research project was established to identify how the main threats to sustainable irrigated agriculture could be alleviated. The program is a 4-year collaboration between the Iranian Agricultural Engineering Research Institute (IAERI), based in Karaj, the Agricultural Engineering Department of the Esfahan Agricultural Research Center (EARC), and the International Water Management Institute (IWMI).

The project has adopted a joint program of training and research to accomplish its aims, and uses the Zayandeh Rud as its main research location. In the later stages of the project, it is hoped to extend the methodologies developed in Esfahan to other parts of Iran.

Three elements of the project distinguish it from other water management studies in Iran:

- The use of an integrated approach to studies at basin/irrigation system/field level (referred to as the IWMI water resources paradigm) that not only looks at problems at different levels in a river basin but also examines the interactions between them. The scope of the study ranges from operation and management of water resources at the main reservoir downwards through irrigation system management to farm-level irrigated agricultural practices.

- The use of information technology and modeling to understand the dynamics within each level, as well as the interrelationships between them. Currently, five different model approaches are being adopted:

– basin-level hydrological modeling that assesses inflows into the reservoir and the downstream hydrology as affected by extractions of water for different uses;

– modeling of the quality of river water to examine relationships between the main sources of pollution and the rate of decrease in water quality in the Zayandeh Rud;

– modeling of the quality and quantity of groundwater to determine the changes in water-table levels, the deterioration of groundwater resources over time, and the impacts of groundwater-based irrigation on water availability and quality;

– soil-water-atmosphere-plant (SWAP) modeling to assess water and salt balance at field level, determine the productivity of water at field level and to examine causes of yield gaps; and

– irrigation system assessment using aggregated field-level models that determine performance for different combinations of soil, crop, and irrigation water application.

• The extensive use of already existing information and remotely sensed data (IWMI researchers have already demonstrated that basin modeling can be successfully performed using publicly available datasets and remote sensing data).

At the end of the current phase of the project, a series of possible remedial actions will have been proposed whose adoption can provide a sustainable basis for irrigated agriculture in the Zayandeh Rud.

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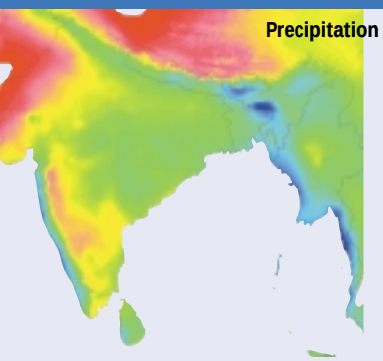
This research has been funded by the Government of Iran.

World Water and Climate Atlas



Where can rain-fed agriculture be expanded? Where can supplemental irrigation increase yields in marginal rain-fed crop areas where the majority of poor people live? Where is irrigation necessary to increase crop yields? The IWMI World Water and Climate Atlas helps to answer these questions by providing water and agricultural planners with a complete worldwide dataset of water and climate information spanning the past 40 years.

The data has a resolution of 18 square kilometers at the equator, the highest resolution currently available for a global dataset. This is the first tool of its kind that brings data from some 30,000 weather stations to users in an open and easy-to-use format.

Using the Atlas, agricultural planners can reduce the time needed to plan irrigation systems or evaluate agricultural plans—from months to weeks; in some cases days or even hours. The data covers precipitation, temperature, humidity, hours of sunshine, evaporation estimates, wind speed, total number of days with and without rainfall and days without frost.

Many useful applications are possible with the Atlas. IWMI is working with other CGIAR centers and national research partners to help them use the Atlas to sharpen their crop research. The World Water and Climate Atlas can be downloaded at the IWMI website www.iwmi.org