

# Transboundary Aquifers of the Fergana Valley: Challenges and Opportunities

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## ABSTRACT

Many aquifers of the Fergana Valley have transboundary implications and are linked hydraulically with transboundary small rivers widely spread in the valley. The objective of this paper is to emphasize opportunities and constraints associated with the development of the aquifers of the Fergana Valley. Since 1990, there have been upstream/downstream impacts in the study area which have reduced surface inflow and increased subsurface inflow from the upstream to the downstream. This causes waterlogging and water-quality issues in some downstream locations. This is aggravated by reduction of the groundwater extractions in the downstream causing waterlogging and salinity issues in over 50% of the irrigated land. These issues could be negated by developing the groundwater resources. The zoning of the Fergana Valley on groundwater irrigation potential suggests that the potential area for groundwater irrigation is 32% of the total irrigated land of 900,000 ha while for conjunctive use of groundwater and canal water it is 27%. The system of canals can irrigate the rest of the irrigated area. Aquifer recharge would need to be managed to prevent issues related to groundwater depletion and degradation of groundwater quality. The studies indicated that free capacities of the aquifers exceed 3,000 Mm<sup>3</sup>, which could be used in winter for temporary storing of the excessive flow of the Fergana Valley rivers. In spite of the emphasized opportunities, there are low incentives for farmers to practice groundwater irrigation under the state cotton and wheat quota systems supplying subsidized canal water, and high cost of construction and maintenance of wells. This study suggests that under unstable access to the canal or lifted water farmers producing cash crops, such as orchards and vegetables, need to invest in groundwater development, while in many cases shallow bore wells could replace deep wells. The proposed strategy could be a part of the small river basin plans and requires cooperation of the riparian states.

**Keywords:** Groundwater recharge, groundwater irrigation, upstream/downstream impact, Central Asia

## INTRODUCTION

The Fergana Depression is located within a mountain system whose ridges coated with snow and glaciers favored originating the abundance of watercourses. From ancient times, these watercourses have been transporting coarse sediments into the depression creating favorable conditions for generating groundwater aquifers. Many of these aquifers have transboundary implications and are linked hydraulically with a transboundary river. These aquifers can be

described by the two main conceptual models: aquifers located completely within the territory of one state but linked hydraulically to a river across an international border; 2) aquifers intersected by an international border and linked hydraulically with a river that is also intersected by the same international border (Eckstein and Eckstein, 2005).

Since 1990, there have been upstream/downstream impacts in the aquifer areas. The shift in the upstream from the rangelands and rain-fed systems to the irrigated cereal production has resulted in reduced surface inflow and increased subsurface inflow from the upstream to the downstream. This causes waterlogging and water-quality issues in some downstream locations. This is further aggravated by reducing the groundwater extractions in the downstream causing waterlogging and salinity issues on over 50% of the irrigated land.

## OBJECTIVES

The objectives of this paper are twofold: to emphasize opportunities associated with the development of the Fergana Valley aquifers with transboundary implications; to suggest solutions to constraints for groundwater irrigation.

Studies carried out earlier suggested temporary storage of the small river flow in the subsurface aquifers of the Fergana Valley (Mirzaev, 1974; Akramov, 1991). Raising competition between hydropower and agriculture focuses attention on the groundwater aquifers as the storage for temporarily accumulating the winter hydropower releases on the Naryn River (Karimov et al., 2010). This paper starts with describing the upstream/downstream impacts in the study area. Then the potential of the groundwater development in the downstream is analyzed. Subsurface water storage opportunities in the aquifers are highlighted. This opportunity relates to free subsurface capacities available in the upper part of the river basins. Then potential capacities are emphasized which could be created by intensive groundwater extractions. Then constraints are analyzed for groundwater development. Finally, the study proposes solutions for the constraints and emphasizes the need for conjunctive management of surface water and groundwater.

## RESULTS AND DISCUSSIONS

### *Aquifers of the Fergana Valley*

The aquifers of the Fergana Valley having transboundary implications associated with groundwater resources can be described by the two main conceptual models: 1) Aquifers located completely within the territory of one state but linked hydraulically to a river across an international border. Examples of this model are the Sokh and Yarmazar aquifers. In this model the river is international, while the aquifer is geographically domestic. According to Eckstein and Eckstein (2005), this type of river-aquifer system falls within the scope of the Watercourse Convention; 2) Aquifers intersected by an international border and linked hydraulically with a river that is also intersected by the same international border. Examples of this model are the Osh-Aravan and Isfara aquifers. This model also falls within the scope of the Watercourse Convention because of the hydrological connection between the transboundary aquifers and the transboundary river.

Formation of the groundwater resources upstream and downstream of the aquifers with the transboundary implications has distinct features which are to be considered for groundwater management. Since 1990, in the upstream of the aquifers, there has been a trend of increasing

water diversions from the small rivers for irrigation purposes. Farmers are moving from rain-fed agriculture and livestock on the rangelands to irrigated cereal production. Thus winter crops, such as winter wheat and oats occupy 40% of the irrigated land upstream of the Shahimardan River Basin. Increasing the area of the irrigated land is indicated in the upstream of the Sokh River and other small river basins. This, in combination with low delivery efficiency of irrigation canals and small-size irrigated fields, creates significant recharge of the groundwater in the upstream. Combined surface and subsurface outflows to the downstream are less than at the previous stage due to increased diversions of the river flow for irrigation and evapotranspiration from the upstream irrigated land. As a consequence, there are upstream/downstream impacts due to reduction of the surface flow and increasing the subsurface flow.

In the downstream, features of the groundwater recharge are as follows:

- 1) On average, subsurface inflow to the Fergana Valley downstream makes 18% of the total groundwater recharge for the aquifers having transboundary implications. In some cases, it creates waterlogging issue. Moreover, salinity of the groundwater entering the downstream is relatively high due to leaching salts from the upstream irrigated land. This affects the quality of groundwater which is the source of the drinking water supply.
- 2) The main source of groundwater downstream is losses from canals and irrigation. On average, irrigation contributes 49% of the groundwater recharge of the aquifers of the Fergana Valley, and the corresponding value for Sokh, Isfara and Mailisu exceeds 60%.
- 3) Groundwater recharge in the downstream is reduced due to several causes. First, since 1990, following the state food independence policy, 40% of the irrigated land was transferred under wheat production. The shift from cotton and alfalfa to winter wheat production has reduced crop water requirements and, as a consequence, water diversions from the Naryn River to the Fergana Valley have been reduced. Second, increasing the upstream water diversions results in seasonal downstream low flow from April to June.
- 4) In spite of reduction of the groundwater recharge, the current reduced groundwater extraction from 4,400 Mm<sup>3</sup>/yr in 1993/94 to 2,700 Mm<sup>3</sup>/yr contributes to rising water table and waterlogging issues.

### *Opportunities*

Studies carried out in the Fergana Valley on the territory of Uzbekistan have found significant subsurface capacities which could be used for regulating the river flow, and in particular the winter flow of the Naryn River. Free capacities of the aquifers exceed 3,000 Mm<sup>3</sup>, which could be used for banking the excessive winter flow of the small rivers. This capacity is more than the winter flow of small rivers totaling 1,000 Mm<sup>3</sup>/yr. This study found that additional capacities can be created at 141 Mm<sup>3</sup>/m of drawdown by intensive groundwater extraction in the summer season. This shows that the physical capacities for groundwater banking do exist. However, careful economic analyses and modeling of each aquifer are required to assess to what extent groundwater banking is economically viable. Also, the groundwater banking will need to be seen in connection with groundwater extraction for irrigation purposes. The zoning of the Fergana Valley on groundwater development potential for irrigation suggests that the potential area for groundwater irrigation is 290,000 ha while for conjunctive use of groundwater and canal water it is 243,000 ha. The system of canals can irrigate the rest of the 367,000 ha area. Currently, the groundwater extraction in the Fergana Valley is at 31% of the total recharge on average, while for Chimion-Aval, Sokh and Almaz-Varzyk aquifers it exceeds 50%. Extraction of the annual groundwater recharge in summer may significantly lower the water table. Aquifer recharge would need to be managed to prevent issues related to groundwater depletion, degradation of

groundwater quality and high cost of extraction. These data show that there is unused subsurface capacity which could be used for regulating the Naryn and small rivers flows. Extraction of the renewable groundwater resources in summer for agricultural needs will lower the water table. The subsurface inflow causing waterlogging and water quality issues could be extracted for beneficial use. In spite of the indicated opportunities, several constraints to groundwater development are found, some of which are as given below.

### *Constraints*

*Low incentives for water saving under the state cotton and wheat quota system.* Cotton and wheat cover over 80% of the irrigated land of the Fergana Valley. Farmers producing cotton and wheat receive purposeful state credits, calculated based on planned yield and covering up to 60% of the input costs for the crop production. Farmers have to return the credit after 18 months plus 3% of the state/bank interest rate. Water is delivered free of charge to the farmers except small fees for services of water user associations (WUAs). Under such conditions, these farmers have low incentives to save “free of charge” water and to look for other sources, such as groundwater.

*High cost of construction and maintenance of wells.* Until the beginning of the 1980s groundwater extraction in the Fergana Valley aquifer was low, mostly for drinking water supply and maintaining the deep water table in the populated areas. Groundwater use for irrigation was practiced only in years with low water. However in 1985, during the severe water shortage, a step was taken to increase the water extraction for irrigation needs. As a consequence, the water extraction increased from 1986 to 1993-1994 from 3,760 Mm<sup>3</sup> to 4,400 Mm<sup>3</sup>/yr. By the end of 1992, the number of wells had exceeded 8,000. These wells were drilled to obtain water for drinking, drainage and irrigation needs. Most of the wells for irrigation were 60-100 m deep, with centrifugal pumps and power supply. The deep wells have high yields of 30-50 l/s. These wells were installed under an environment with centralized water management; collective farms had 3,000-10,000 ha area; and the irrigated fields were 15-25 ha in size. Under such conditions, high-yielding wells had the capacity to supply high irrigation demands. Groundwater extraction has become one of the main factors preventing salinization of the topsoil and is an important source of irrigation.

Since 1990, after fragmentation of the farming system into small farms each of 3-10 ha area, there was a lack of a groundwater governance, which could facilitate farmers' cooperation on operation and maintenance (O&M) of the wells. Most of the private farmers, gaining low incomes from cotton and wheat, are not able to cover O&M costs or to install new wells costing US\$15,000-25,000/well, while they have access to free canal water subsidized by the state. Reduction of the state investment in O&M of wells since 1990 has made their centralized exploitation difficult. As a consequence, from 2001 to 2005, groundwater extraction has gradually decreased to 2,700 Mm<sup>3</sup>/yr and, moreover, there is a risk that groundwater extraction will further reduce to the levels of the 1980s. The reductions in groundwater extractions were followed by raising the water table and increasing the treating of salinity build-up in the topsoil, especially in the lower part of the basin. For example in 1992, the irrigated area with water table less than 2 m amounted to 38% which made up 74% of the total in 2007. High evaporation from the shallow water table has increased the treating of salinity build-up in the topsoil.

*Lack of the groundwater use governance.* There are several cases when farmers own deep wells and sell water to the neighboring farmers. The payment share of each farmer getting groundwater is based on operational expenses of the well. Since distribution of groundwater by inter-farm

water distribution ditches results in significant losses, farmers are indeed applying these practices, and as soon as possible they try to shift to separate shallow wells.

*High power consumption.* High power consumption is considered to be one of the limitations of groundwater development. Under these conditions of the Fergana Valley canal irrigation is supplemented by lift irrigation, covering a third part of the irrigated area and requiring high-power supply. Lift irrigation also requires high-power supply due to the great height of the water lift and the old low-effective pumps. Further analysis is required to estimate power consumption for one of the irrigation systems, considering different water supply options.

### *Opportunities for revitalization*

There are several strategies that, at least, bring back groundwater irrigation scales.

The first is often applied in the development projects and based on rehabilitation of old and deep wells and installing new ones. Since the cost of deep wells is high, it is difficult to expect low-income farmers to be able to cover O&M costs of the wells in the very near future. This strategy requires high investment from the state budget.

The second is reducing the area under the subsidized crops, letting farmers themselves select a cropping pattern on the released area to improve access to water. Farmers growing orchards and vegetables do not get purposeful credit in most cases but they can sell the products in the open market. These farmers have higher profits as compared to wheat and cotton producers. In many cases, they pay higher fees for water delivery services of the WUAs. They are interested in guaranteed water and they try to get access to different water sources, including groundwater. The study of farmer practices of the Fergana Valley shows that under unstable access to canal or lifted water they are ready to invest in groundwater extraction, even if it is more expensive than subsidized canal water.

The third is the possibility for coordination of the water users and establishing informal groups that will shoulder responsibility for maintenance of the existing wells and sharing expenses. This practice is already monitored for groups of farmers producing orchards and vegetables in the Sokh River Basin. They apply time-based water distribution for sharing water from the same well. The fee for water delivery is time-based. Relatively rich farmers producing grape and orchards preferring to have own high-yielding wells and are ready to invest in the construction of expensive deep wells.

The fourth strategy is to revert to bore wells and shallow wells. Bore wells or shallow wells yielding less than 1 l/s are widely used for irrigation of home yards and domestic needs in the Fergana Valley. From 2010, some innovative farmers are using similar bore wells yielding 2-3 l/s for irrigation of orchards, vegetables and other cash crops. These bore wells have many advantages as compared to deep wells. Low-yielding wells are much cheaper than deep wells. They are easy to maintain; spares of low-yielding pumps are much cheaper than those of high-yielding ones.

The fifth strategy is to apply managed aquifer recharge. Natural recharge can be enhanced to improve groundwater quality. Adoption of water saving technologies will reduce irrigation water demands, and the saved water could be recharged into the aquifers for temporary storage. There are many other options, requiring further studies, which will permit using opportunities related with management of aquifers of the Fergana Valley.

## CONCLUSIONS

Shifts from rangelands and rain-fed systems to irrigated agriculture in the upstream may create upstream/downstream impacts by reducing the surface flow and increasing the subsurface flow available for the downstream. Low groundwater extraction conditions and poor water use practices in the downstream result in widespread water table and salinity issues in the areas where groundwater aquifers have transboundary implications. These challenges could be shifted to benefits through active management of these aquifers. Groundwater development for agriculture and other purposes will lower the water table and extract the excessive flow for beneficial use. Created by the water table drawdown free capacities of the aquifers could be used for temporary storing of the river's excessive flow. The future of the proposed strategy depends on overcoming constraints to groundwater development. They are as follows: low incentives for farmers to shift from subsidized canal irrigation to groundwater, especially under a state quota system for crop production, and high cost of construction and maintenance of wells. The study suggests that farmers growing cash crops such as orchards and vegetables facing water shortage are ready to invest in groundwater development while, in many cases, shallow bore wells could replace deep wells. The need for management of the transboundary aquifers as a part of the river basin development plan is emphasized which will bring mutual benefits for the riparian states.

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## REFERENCES

- Akramov, A.A. (1991): Regulating fresh water storages in underground water aquifers (in Russian). Fan, Tashkent, Uzbekistan, 207 pp.
- Borisov, V.A. (1990): Underground Water Resources and their Use in Uzbekistan (in Russian). Fan, Tashkent, Uzbekistan.
- Eckstein, Y. and Eckstein, G. E. (2005): Transboundary Aquifers: Conceptual Models for Development of International Law. *Ground Water*, 43 (5): 679-690.
- Karimov, A., Smakhtin, V., Mavlonov, A. and Gracheva, I. (2010): Water 'banking' in the Fergana Valley aquifers - A solution to water allocation in the Syrdarya Basin? *Agric. Wat. Man.*, 97 (10): 1461-1468
- Mavlonov, A. A., Borisov, V.A. and Djumanov, J. Kh. (2006): Assessment of underground water resources of Fergana Valley (in Russian). Paper presented in the Regional Conf. on: Conjunctive use of ground and surface water resources of Fergana valley for irrigation. 2 November 2006. Tashkent
- Mirzaev, S. Sh. (1974): *Underground water reserves of Uzbekistan* (in Russian). Fan, Tashkent, Uzbekistan, 150 pp.