

Chapter 10

Irrigation Infrastructure in Fergana Today: Ecological Implications – Economic Necessities

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Abstract Managing water sustainably and efficiently is important for the Fergana Valley's (FV) irrigation-dominated agricultural system and, subsequently, for its rural population and environment. During the past decade, national water legislation and the organisation of integrated water resources management have been reformed in FV and this development continues. Nevertheless, their implementation has been limited by the lack of resources and the weakness of the institutions. Moreover, the future challenges water management faces in the region's agriculture are increasing all the time. These challenges include low water-use efficiency, fewer incentives for water users to increase land and water productivity, water shortages within the system, salinity and declines in key crop yields. Current irrigation strategies in the region are not adaptable enough to cope with variations in water supply and crop water requirements caused by land use and climate change. The objective of this chapter is to provide an overview of the irrigation water management in the region and to lay down some of the concepts and complexities in maintaining the existing irrigation infrastructure with the aim of increasing water productivity and environmental sustainability. We hope that this will help set the stage for productive discussions and to identify research needs.

Keywords Irrigation infrastructure • Water management • Water resources • Fergana Valley • Syrdarya River • Agricultural water use • Ecological impact

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10.1 Introduction

This chapter outlines the problems existing in the management of the irrigation infrastructures in the FV and evaluates the benefits of irrigated agriculture and also the costs of environmental degradation and pollution caused by changes in water management.

The Fergana Valley, one of the oldest *world* oases, is unique with its highly fertile lands (Irrigation of Uzbekistan 1975), manageable river waters and adequate natural (hilly areas or *adyrs* in local language) and artificial (central plain part of Fergana) drainage. Combine the above with the local climatic conditions and we have the reason for the area's agricultural importance.

Despite this, there are obstacles to the well-being of the region's population, the key ones being the high rates of population growth, interdependence of water and energy (Baker 2011) and limited land resources (Dukhovny and Stulina 2012).

The geographical location of the FV is also a peculiarity. The valley is blocked in by high mountains in Tajikistan and Kyrgyzstan, while the valley itself is rather plain and arid. The specific climate and topography conditions limit the further development of land and water resources. Agriculture, accounting for about 90 % of withdrawal from the total water resources available in the region (CAWATERinfo 2012), heavily depends on irrigation. Moreover, agricultural production is highly vulnerable to climate change (Lioubimtseva and Henebry 2009). High fluctuations in precipitation and temperature increases may influence land use in irrigated lands, create difficulties in water management at regional and local levels and increase competition for scarce water resources amongst water users in various sectors.

Demographic pressure will further limit the availability of the water and land resources. Population density in the valley increased from an average 135.5 people per km² in 1980 to 229.1 people per km² in 2010 (CAWATERinfo 2012). Consequently, food demand has increased and the area of irrigated land has expanded, leading to further degradation of the surface and groundwater quality as agricultural activities have increased. The expansion of irrigated land has resulted in increasing water withdrawals from two main rivers, Amudarya and Syrdarya, and induced the problems of land degradation and water resource contamination and, as a final consequence, has led to the Aral Sea environmental disaster.

In their natural state, many of these lands, especially the plain lands within the Uzbek part of the valley, are poorly drained. Therefore, the irrigated lands were intensively developed in the second half of the twentieth century increasing the artificially drained area to about 682×10^3 ha in the valley (CAWATERinfo 2012). There are no doubts that the development of the collector-drainage network (CDN) had a positive impact on irrigated lands by preventing salt accumulation in soils and creating favourable soil aeration conditions. However, as a consequence of the development of the irrigation and drainage systems, a steady rise of return water was observed. This increase was caused by low irrigation and drainage efficiencies on the one hand and misuse (over-irrigation) of water resources on the other. At the same time, the collector-drainage infrastructure in the region is designed, naturally

and artificially, to discharge most of its effluent back into the rivers (SIC ICWC 2004). Thus, a gradual increase of water salinity in the Syrdarya and Amudarya Rivers was observed since the 1950s (SIC ICWC 2004). As a result, environmental and epidemiological fragility and hygienic and sanitary conditions are emerging as a major problem, especially in the lower course provinces of the river basins (SC RUz 2006).

10.2 General Overview of Fergana Valley

10.2.1 Geography (Geomorphological Structure)

The Fergana Valley is one of the water-rich upstream subregions of the Syrdarya River basin. The valley is 300 km in length and 170 km in width with floor elevation of about 450 m above sea level (aSL) (Irrigation of Uzbekistan 1975). Some literature sources quote the administrative territory of the valley as 122,100 km² (Table 10.1). However, according to recent publications (UNECE 2011), the valley's basin area is 142,200 km². It is characterised as a locked intermountain depression, embosomed in the spurs of the Ala-Tau Range in the north, the Tian Shan Mountains in the east and the Alay Mountains in the south, with only a narrow mouth to the west through which the Syrdarya River drains the valley (see Fig. 10.4). The uppermost part of the geological profile (100 m or thicker) in and around the central valley varies from location to location, and it is primarily of Quaternary origin. The central part merges with outwash fans near the valley foothills.

Table 10.1 Administrative-territorial and demographic data in provinces of the Fergana Valley

Provinces	Established in	Number of districts	Territory (km ²)	Population density (people per km ²)			% rural population in 2010	Annual increase 2000–2010 (%)
				2000	2005	2010		
Andijan	1941	14	4303	515	552	621	72	1.7
Fergana	1876	15	6759	399	426	478	74	1.5
Namangan	1941	11	7440	263	283	320	64	1.7
Osh	1939	7	28,934	41	36	39	92	1.6
Djalalabad	1939	8	32,418	27	29	32	77	1.5
Batkent ^a	1999	3	17,049	22	24	25	76	1.2
Sogd ^b	2000	14	25,200	75	82	89	75	1.2

Author's compilation from different sources

^aBatkent was established in 1999

^bSogd was named Leninabad from 1936 till 2000

10.2.2 Climate

The average air temperature in the valley is 13.1 °C, ranging from –8 °C to 3 °C in winters (January) and 17 °C to 36 °C in summers (July). Annual precipitation ranges from 109 to 502 mm, whereas evaporation ranges from 1133 to 1294 mm throughout the valley (Abdullaev et al. 2010; Reddy et al. 2012). The limited precipitation on the lowland plain coupled with high temperatures, low humidity and high degree of solar radiation causes a greater level of potential evapotranspiration. A steady transfer of air temperature from 0 °C starts in the second half of February. This is the time when the early fruit, such as apricot and almond, growing period begins. The autumn transfer from 0 °C is observed in the second half of December. The duration of the period with $T \geq 0$ °C is 280–310 days per annum. When air temperature increases above 5 °C, the renewal period of lucerne, grains (winter wheat) and the majority of fruit plants and spring regrowth of pasture grasslands start. This transfer of air temperature is favourable to sow cotton and summer corn. The period with $T \geq 10$ °C lasts 200–220 days per annum. The best conditions to sow heat-loving crops (cotton) begins around 1–15 April when the mean daily air temperature increases above 15 °C; during this time, the soil at a depth of 10 cm also warms up to 16–18 °C (Fig. 10.1).

Climate change, apart from anthropogenic influences, is a significant impact factor on the hydrologic cycle of the river (Stucker et al. 2012). The most hazardous and complex consequences are the increasingly frequent extreme floods and droughts (Dukhovny et al. 2008). In the Syrdarya basin, the frequency of years in which droughts occurred between 1990 and 2007 is less, compared to those which occurred during 1950–1990, while the occurrence of floods (prob. ≤ 25 %) and extreme floods (prob. ≤ 10 %) increased, respectively, by 1.4 and 2 times (Dukhovny et al. 2008). In drought years, water withdrawal rates increase at the main intake points. Consequently, surface runoff rates from fields are minimised and collector-drainage water (CDW) is used as an additional source instead. Therefore, low water years are characterised by low CDW effluents into the rivers. And, in order to cope with the water shortage, water withdrawal from CDN increases twofold (Dukhovny et al. 2012).

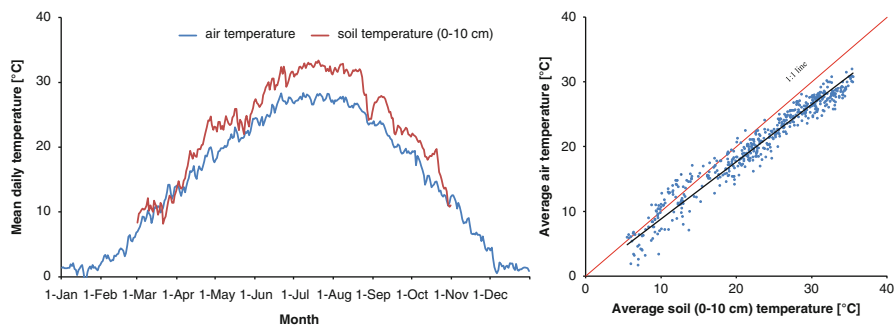


Fig. 10.1 Average daily air and soil temperatures (*left*) and their relationship (*right*) (Source: Fergana agro-meteorological station: averaged from 2001 to 2011)

10.2.3 Demography

The valley is a highly populated area in Central Asia (CA). An average population growth rate of 1.5–2 % per year is common in the provinces of FV (Dukhovny and Stulina 2012). According to different sources, population density in the valley ranged between 25 and 621 inhabitants per km² in 2010 (Table 10.1), being as high as 320–620 persons/km² in Uzbek provinces and as low as 25 persons/km² and 90 persons/km² in Kyrgyz and Tajik provinces, respectively. All provinces in the valley are dominated by high rural populations as in Table 10.1 with densities of 200–500 persons/km².

Given the importance of agriculture for the whole FV, natural resources, such as land and water, have historically been amongst the most important factors in the development of the region (Qadir et al. 2009). Data from other sources depict that 44–45 % of the irrigated lands of the Syrdarya Basin are located in the FV (Toryanikova and Kenshimov 1999; UNEP et al. 2005). However, the amount of irrigated lands available shared by the three countries is already limited and demand for scarce natural resources will continue to rise with population growth. Hence, the size of the population depending upon these resources is consequently a key factor in political security and environmental issues. High population density also increases the risk of depleting natural resources (Dukhovny and Stulina 2012), and therefore, competition and even conflict for their control would be self-explanatory.

10.2.4 Land Use and Agricultural Production

The agricultural system in Central Asian countries, especially in Uzbekistan, has experienced continuous intensification with increased cultivation of winter wheat in the last two decades. Once the predominant crop in FV, cotton cultivation has declined rapidly since the 1990s while the cropping area under cereals for food security is increasing together with gardens and vineyards (primarily by the introduction of new lands in adyrs) (Fig. 10.2). The decline of lands under forage crops can be explained by the reduction in livestock in all CA states since 1991 (Lioubimtseva and Henebry 2009) and by the increase in winter wheat and consequent cultivation of secondary crops (maize for silage, sorghum, legumes, etc.) after the wheat harvest. Although highly profitable unregulated cash crops (vegetables, grapes and fruits) are extensively grown in the provinces, cotton and wheat (*Triticum aestivum* L.) are still the dominant crops in the valley taking up more than 46 % of irrigated lands. Upland cotton (*Gossypium hirsutum* L.) is cultivated more extensively than pima cotton (*G. barbadense* L.) due to its short growing period and relatively higher yield (WARMAP 1997; Ibragimov et al. 2008).

During the Soviet period, 3:6 or 3:7 crop rotations (3 years alfalfa and 6–7 years cotton) were recommended (Nerozin 2010) and considered as one of the methods to decrease the soil salinity (by reducing soil evaporation and lowering groundwater

level (GWL)). After independence, this rotation was radically changed and nowadays includes 2:1 or 2:3 (2 years winter wheat and 1–3 years cotton). The cotton in Uzbekistan is cultivated in the first half of April and harvested in September (last harvest in November); winter wheat is broadcast seeded in late September (most cases in October) and harvested from mid-June till mid-July. In the remaining period, following the winter wheat harvest, secondary crops such as rice, maize, sorghum, sunflower or vegetables are sown from July to November.

According to Dukhovny et al. (2012), agriculture in FV contributes between 20.8 % (Fergana province) to 58 % (Sogd province) to the gross regional product.

The total production of cotton, due to reducing areas sown in the valley, (see Fig. 10.2) decreased from 2116.7×10^3 t in 1980 to 971.8×10^3 t in 2010. In contrast, in the same period, the cereal production increased almost sixfold (Fig. 10.3). The production of cash crops (e.g. vegetables) also increased in line with their increased growing area. These enabled the gross agricultural production to increase

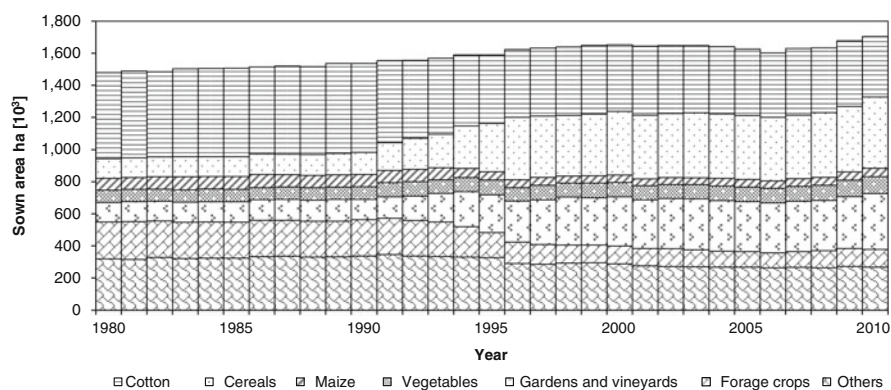


Fig. 10.2 Cropping acreages in Fergana Valley during 1980–2010 (Source: CAWATERinfo 2012)

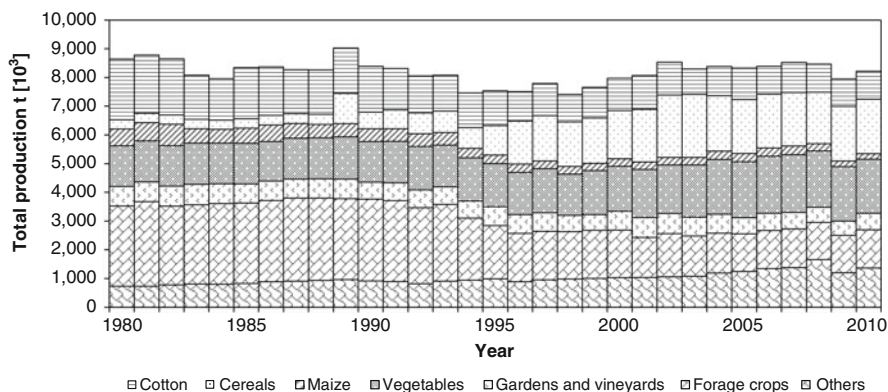


Fig. 10.3 Total production of agricultural crops (10^3 t) in the Fergana Valley during 1980–2010 (Source: CAWATERinfo 2012)

on average from USD 162 per capita in 2001 to USD 240 per capita in 2010 in the valley provinces (Dukhovny et al. 2012).

However, agricultural production in the valley is hampered not only by the unreliable irrigation water supply but also by the unreliable supply of fertilisers and seeds, inappropriate crop cultivation methods, limitations in the allocation of seasonal credits and funding of capital investments, limitations in marketing and processing of produce, control of cropping patterns and poor agricultural development informational services. These issues will need to be addressed through agricultural reforms and measures dealing with the intensification of the agricultural production system.

10.3 Water Resources Management in the Fergana Valley

Water resources in FV are predominantly of a transboundary nature. Most of the region's surface water resources are generated in the mountains of the upstream countries Kyrgyzstan and Tajikistan.

Figure 10.4 shows the main irrigation and drainage systems in the valley and, indeed, provides an insight into the complexity of this unique water management system. Taking into account the dozens of large and hundreds of small towns; thousands of rural settlements with various industrial, utility and other enterprises; thousands of kilometres of irrigation and drainage systems and dozens of reservoirs and pump stations available within the seven provinces of the three riparian countries in this scheme, one can understand that harmonising the management system is not only difficult but also the collection, comparison and assessment of data from various water resources are also key and challenging tasks in themselves.

At present, the main problems in managing the existing irrigation infrastructure in FV are linked to the following shortcomings and constraints:

- The state maintains administrative governance and financial support for the upper layer of water hierarchy without involving the integrated water resources management (IWRM) mechanisms at a national level. Moreover, local stakeholders' engagement in water management within the vertical hierarchy meets resistance from the state.
- The establishment of water user associations (WUAs) and canal management organisations with involvement of the community in the form of a union of canal water users (UCWU) and canal water committees (CWC) has certain effects on the enhancement of uniformity, stability and water supply. However, institutional restructuring is impossible without a strong legal framework. In general, the financial, organisational, legal and technical aspects of these institutions have not been solved (including WUA support by Ministries of Agriculture and Water Management).
- There are no contractual obligations and methodical interrelationships between basin administrative irrigation systems (BAIS), hydrogeologic melioration expeditions (HGME), administrative irrigation systems (AIS) and WUAs.

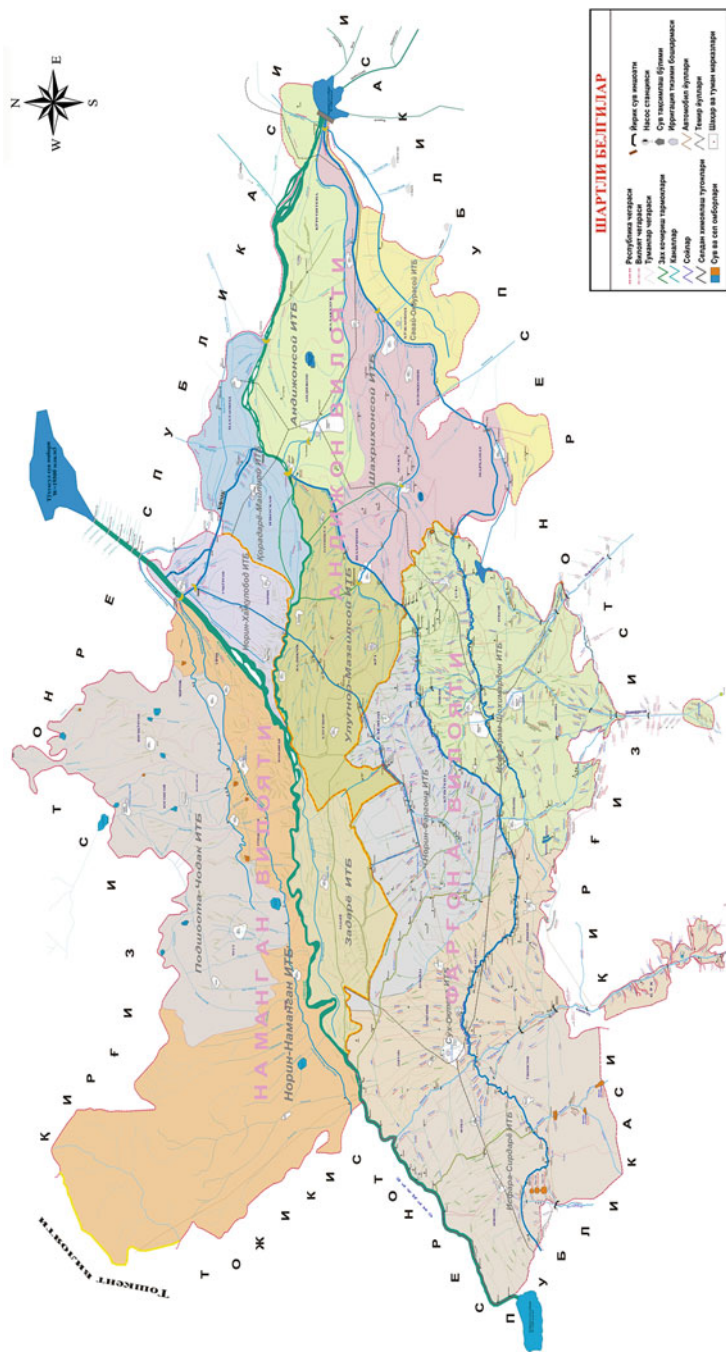


Fig. 10.4 Irrigation and drainage network in the Fergana Valley (Source: author's composition from three BAIS maps Uzbekistan)

- Land degradation and control measures are weakly monitored.
- Consequently, issues of practical support for farmers and end water users in improving land and water productivity have not been solved.
- There is no general programme on water saving taking into account climate change.
- Water accounting and hydrometrics at all water hierarchy levels from trans-boundary rivers to the ultimate water user should become a strategic objective.
- There are no informational systems and software packages to solve operational water distribution tasks at both canal level and WUA level.
- The majority of the irrigation and drainage infrastructures are outdated and require frequent maintenance and repairs and, consequently, huge investment.

10.3.1 Hydrological Characteristics

The natural annual runoff of the Syrdarya River averages $37.9 \times 10^9 \text{ m}^3$ and ranges from 18.3 to $72.5 \times 10^9 \text{ m}^3$ (CAWATERinfo 2012). Surface water resources of the Naryn and Karadarya tributaries, which are generated in the Kyrgyz region, are estimated to amount to 13.7 and $7.1 \times 10^9 \text{ m}^3/\text{year}$ accordingly (UNECE 2011). These rivers are strongly regulated by major reservoirs and dams (Kayrakkum, Chardara and Koksarai along the Syrdarya River; Naryn, Krupsai and Uch-Kurgan in the Naryn River and Andijan, Teshiktash, Kujganyar and Bazar-Kurgansky in the Karadarya River).

In addition, a number of small tributaries feed its runoff. The contribution of the transboundary small rivers (TSR) within the valley to the Syrdarya River ranges from 2.9 to $4.1 \times 10^9 \text{ m}^3/\text{year}$ (Dukhovny et al. 2012). However, due to intensive irrigation, most of the rivers, especially on the left bank, do not reach the Syrdarya River anymore. Moreover, the natural hydrological regime of the Syrdarya River within the valley is disturbed by numerous irrigation withdrawals, water storage and return waters into the river (SIC ICWC 2004).

10.3.2 Irrigation Network

Before the Soviet government in CA, a set of ring irrigation systems existed in the FV, mainly on removal cones of Sokh, Isfara, Isfairam-Shakhimardan, Andijan, downstream part of the Naryn, Akbura and Aravan, while the lands located in the desert and desert-steppe part of the Central Fergana were undeveloped (Khamraev et al. 2011).

During the Soviet administration period, the construction of large dams and water reservoirs in the mountainous areas of upstream countries (Tajikistan and Kyrgyzstan) was initiated for irrigation purposes as a first priority and for hydro-power generation as a second priority. In contrary, the lands in downstream coun-

tries (Uzbekistan, Kazakhstan and Turkmenistan) were suitable for practising irrigated agriculture and for growing water-intensive agricultural crops (cotton, rice, cereals, etc.).

As a consequence, irrigated lands for agricultural production, particularly in the Uzbek part of the valley, expanded rapidly, mainly for cotton monoculture (Kandiyoti 2005). These expansions resulted in the development of lands in the Central Fergana (Laktaev and Ermenko 1979) and promoted the construction of a number of large main canals and CDN within the command area of the Big Fergana Canal (BFC), South Fergana Canal (SFC) and North Fergana Canal (NFC) as well as Akhunbabayev's Canal, Big Andijan Canal (BAC) and Big Namangan Canal (BNC) (Fig. 10.5). These led to the improvement of irrigation infrastructure and changes to the Syrdarya River flow regime. Due to these constructions, 92 % of the Syrdarya River's flow was regulated (Toryanikova and Kenshimov 1999).

The length of inter-farm canals in the valley is 10,474 km (Table 10.2), of which 5010 km are lined to reduce seepage. The on-farm network has a total length of 53,570 km, and only 18 % of which is lined.

The irrigation infrastructure is in a poor condition and much of it is worn out. Considering the low efficiency of the irrigation system in FV, ranging from 55 % in the Fergana province to 63 % in Namangan province (Ikramov 2007), main and inter-farm canals require reconstruction and anti-seepage measures. Existing regulation structures need to be rehabilitated and new ones constructed; outlet structures and flow measurement stations also need to be constructed. Measures to improve the operation and management system of the irrigation infrastructure are also needed. The on-farm network is very complex, passing through settlements, and is frequently lined with trees, which complicates construction/reconstruction work.

10.3.3 Collector-Drainage Network

The expansion of the irrigated lands in the valley from 675,000 ha in 1932 (Irrigation of Uzbekistan 1975) to 1,572,970 ha in 2010 (CAWATERinfo 2012) has resulted in increasing water withdrawal from main rivers and induced the problems of land degradation and contamination of the Syrdarya River water resources. In their natural state, many of these lands are poorly drained. Therefore, intensive development of irrigated lands in the second half of the twentieth century increased irrigated lands with an artificially drained area by about 685,834 ha. About 70 % of the CDN out of a total length of 31,654 km is on farm. In total, 2861 operating vertical drainage wells, including provisions for running the pumps and surface drains to dispose the excess of water, were built in the valley as a network to lower the groundwater level. These drainage wells are mainly installed in areas with high soil permeability and preferably fresh groundwater that can be reused for irrigation. Consequently, this system is operation and maintenance intensive and requires a continuous electrical power supply. Therefore vertical drainage, a complicated engineering complex, was not used at full capacity after the collapse of the Soviet Union.

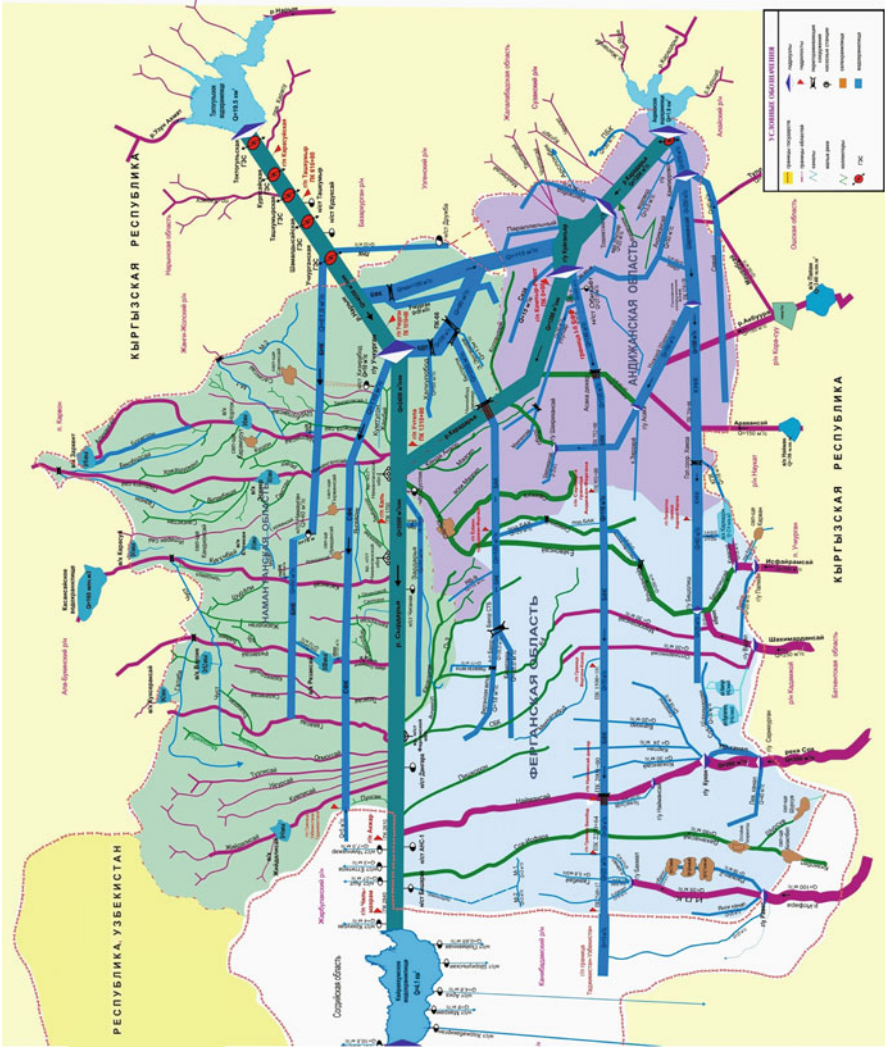


Fig. 10.5 Linear scheme of the irrigation network in the Fergana Valley (Source: author's composition based on UNDP 2007 and BWO Syrdarya maps)

Table 10.2 The type and length of the irrigation network in provinces of the Fergana Valley

Provinces	Gross irrigated lands (10 ³ ha)	Inter-farm irrigation network				On-farm irrigation network			
		Total length (km)	% earthen	% concrete	Specific length (m/ha ⁻¹)	Total length (km)	% earthen	% concrete	Specific length (m/ha ⁻¹)
Andijan	274	2200	53	47	8.0	12,000	79	21	43.9
Fergana	366	2400	47	53	6.6	18,400	89	11	50.3
Namangan	282	2600	61	39	9.2	8200	81	19	29.0
Osh	184	1212	70	30	6.6	2934	91	9	15.9
Djalalabad	133	656	54	46	4.9	3632	77	23	27.3
Batkent	31	361	N/A	N/A	11.8	N/A	N/A	N/A	N/A
Sogd	304	1045	29	71	3.4	8402	73	27	27.7

Data for 2010

Data source: CAWATERinfo (2012), Dukhovny et al. (2012), NWO EECCA (2010)

Note: N/A – no information available

It also needs to be noted that irrigated lands in Kyrgyzstan provinces have not been strongly affected by the deficit of drainage (Dukhovny et al. 2014). For example, the irrigated lands of Kyrgyzstan within the valley are characterised as in good condition (90–96 % of the irrigated lands) in terms of land reclamation, while irrigated lands in Uzbek and Tajik parts of the valley are relatively poor owing to shallow GWL with higher mineralisation and varying levels of soil salinity.

The design parameters (e.g. cross section, slopes, bottom width) in most of the open drainage systems were altered, and a discharge capacity was reduced due to over siltation and eutrophication. This is mainly connected with ageing of the CDN since it was constructed more than 40 years ago on the one hand and low effectiveness of the drainage systems that have decreased to half capacity due to lack of investments in operation and maintenance on the other. To maintain the system in an effective manner, it is necessary to carry out regular and comprehensive technical maintenance (including observation and minor, major and emergency repairs, etc.). Periodicity of these works was set up during Soviet period and is still carried out. However, to cope with land restructuring and changes in cropping patterns, these regulations need to be reviewed and renewed.

10.3.4 Management Structures

The Fergana province has been chosen to describe the water management structures in the valley due to its hierarchy level being similar to the other provinces (Dukhovny et al. 2009).

The water requirement for irrigation is based on cropping patterns and scheduled by the centrally controlled state water management organisations (WMO) in 10-day intervals. Within the irrigation system, the cropping acreage planned for the forthcoming growing season thus needs to be submitted to water user

associations (WUAs) at the end of February with the latest clarification by 1 June for the summer period and 1 December for the winter period (Mirzaev et al. 2009). WUAs as a key organisation within the hierarchy of WMOs (water supplier) and farmers including other water users (water consumer) then estimate planned water use within the territory. As a rule, the water-use plan is carried out using a bottom-up approach starting from the field plots up to the water intake point in main canals and integrates all plans within the hierarchy levels (Dukhovny et al. 2009; Mirzaev et al. 2009). Water distribution is achieved by applying a top-down method (Fig. 10.6) based on water-use limits (quotas). The Ministry of Agriculture and Water Management of the Republic of Uzbekistan (MAWR RUz) establishes the seasonal limits (quotas) based on the forecasted water availability in the sources (Basin Water Management Organisation, BWO Syrdarya and UzHydromet). The basin administrative irrigation system (BAIS) establishes the limit quotas for the districts based on the limit given by MAWR RUz, AIS to WUAs and WUAs to farmers and the other water users within their territory.

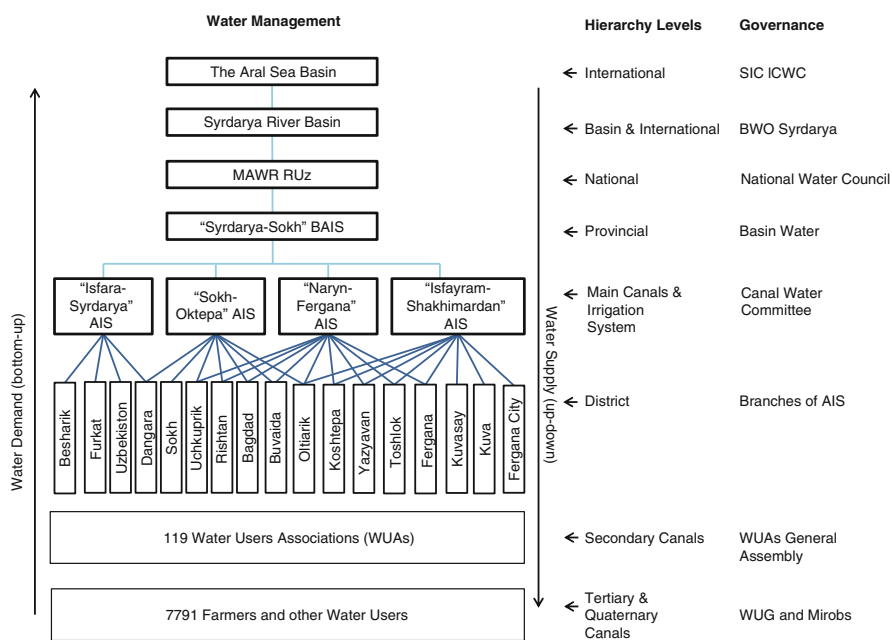


Fig. 10.6 Water management, hierarchy levels and governance linked to Fergana province (Source: Kenjabaev 2014. Note: The number of WUAs and farmers given as for December 01, 2011 according to BAIS "Syrdarya-Sokh" 2012)

10.3.5 *Agricultural Water Use*

In the valley, agricultural development and the well-being of the rural population depend on the water availability in the transboundary small rivers (TSRs) and on the flow regime of the Syrdarya River.

The agricultural sector constitutes the largest (consumptive) water user in the valley. More than 90 % of water resources actually withdrawn out of $10\text{--}14 \times 10^9 \text{ m}^3/\text{year}$ are allocated to the agricultural sector.

According to Dukhovny et al. (2012), the share of water withdrawal from TSRs and CDN for land irrigation in the valley in the last decade is, respectively, on average 26 and 2.7 %. The water withdrawal from TSRs in the Uzbek part of the valley is as high as 86 %, because 62 % of the irrigated lands of the valley are located in the provinces of Uzbekistan (Jaloobayev 2007). The highest share of water withdrawal from CDN in the valley occurs in provinces located downstream.

Supported by the materials of the Institute of Hydrogeology and Engineering Geology, the Central Asian Scientific Research Institute of Irrigation, SANIIRI (2008) has assessed the annual groundwater resource in the valley to be $8.2 \times 10^9 \text{ m}^3/\text{year}$, of which about $1.3 \times 10^9 \text{ m}^3/\text{year}$ and $1.9 \times 10^9 \text{ m}^3/\text{year}$ are annually used for drinking and irrigation (including pumping by the vertical drainage wells during non-vegetation period) purposes.

Well balanced in the Soviet era, centrally planned water resource distribution amongst riparian countries changed after gaining the independence and thus required improvements. Consequently, a legal framework for cooperation on the Syrdarya River was put into place in the early 1990s (Dukhovny 2010).

However, looking at the then agreed arrangements on water allocation, these have not been fully implemented to present, or it has proven impossible to agree on water allocation. One limiting factor is that the energy sector (e.g. hydropower) is not addressed by the existing regional organisations engaged in water management cooperation (Rakhmatullaev et al. 2010). Therefore, water supply in FV is not sustainable due to the non-inclusion of the hydropower regime of Naryn and Syrdarya Rivers.

10.4 **Ecological Impact of Water Management and Irrigation Practices**

Environmental quality issues are significant in relation to irrigated agriculture. Subsurface drainage water quality reflects the groundwater quality and soil water constituents of the soil being drained. Because of the soil salinisation, inefficient irrigation and inadequate drainage, large amounts of water are annually withdrawn from the rivers for land washing (the so-called salt leaching). This activity implies considerable volumes of return water containing salts, agrochemicals and trace elements to rivers and streams associated with the discharge of the CDW.

There is a hydrodynamical connection between groundwater and filtration fluxes from the irrigation canals and drains. The groundwater mainly recharges from the surface water. Hence, shallow groundwater levels, especially in the lower and central parts of the valley, are a major problem. Recent increases in areas under rice in Burgandin Massif in Kadamzhai district of Batken province have been causing waterlogging in most areas in Bagdad, Altyarik and Rishtan districts of the Fergana province (MAWR RUz 2009). Further development of lands in the highlands in Kyrgyzstan (IMF 2012) has aggravated the situation.

Although FV is a relatively water-rich region compared to the lower course regions along the Syrdarya River, water shortage is common in some areas because of mismanagement of water resources, e.g. excessive water use for irrigation and leaching, and water allocation within the systems. As irrigation in an arid climate is needed to create optimal soil moisture for plant growth, it significantly alters natural hydrogeological soil and other land reclamation conditions, causing the salinisation and waterlogging of soils (Dukhovny et al. 1979). The groundwater level rises because of the high water seepage from the canals (about 52 % of main canals and 82 % of field canals are earthen (Table 10.2)); available artificial CDN has deteriorated, while natural drainage is insufficient.

Although shallow GWL enables the reduction of irrigation norms due to the contribution of capillary rise, at the same time, it brings up the existing salts, if they exist, into the adjacent soil layers. To cope with the situation, Dukhovny et al. (1979) proposed to increase the canal system's efficiency and stop water flow in canals during October–March. However, high capital investment and regular maintenance work are required to increase the system's efficiency. Stopping the water flow in canals during October–March is impossible under the current situation due to the following:

Cultivation of cereals, particularly winter wheat (at the expense of the reducing cotton area), has increased since the 1990s (see Fig. 10.2).

Release of winter water from the Toktogul reservoir and the pressure on the Syrdarya River (Abbink et al. 2005). Distribution of excessive winter flows through canals to the fallow lands and temporary storage of water (groundwater banking) in the aquifers of the FV could become a solution until reliable water-energy consensus is found between upstream and downstream countries (Karimov et al. 2010).

The leaching of salt-affected lands, particularly in Central Fergana, is recommended in the winter periods (World Bank et al. 2013).

Improper management of irrigation and drainage systems and altering the hydrological regime of the Syrdarya River have led to the deterioration of water quality from upstream to downstream (SIC ICWC et al. 2011). The water salinity observed in the Syrdarya River has increased in the last 40 years from 300 to 600 mg/l in the upper reaches to 3000 mg/l in the lower reaches within the valley, with a prevailing salt composition of $MgSO_4$, $Ca(HCO_3)_2$, $NaCl$ and $CaSO_4$. Moreover, concentrations of some metals including sulphates and chlorides have increased overall. This has impaired the water resources for drinking purposes in the middle course and sometimes serves as a source of diseases, such as hepatitis, typhoid and gastrointestinal disorders causing morbidity in the local people (SIC ICWC et al. 2011).

10.5 Economical Necessities to Maintain Irrigation Infrastructures

It is important to note that there is a certain discrepancy between the priorities of the government and those of the water users in irrigated farming. The government, in spite of providing the appropriate volume of water resources for irrigated agriculture, is interested in decreasing expenses involved in the transportation and diversion of excess water and allotment of released water between sectors of economy including the demands of environmental supply, e.g. in increasing productivity of water use and water saving, whereas water users are interested in gaining the maximal profit from their agricultural farming in irrigated lands, especially as there is no charge for the volume of water used. Therefore, water supply-related problems should be solved on a foundation of a balancing of interests and by searching for compromises. To this end, applying sound scientific practices, approaching problem solving rationally and neutrally and, whenever necessary, adequately participating the relevant stakeholders are regarded as essential.

Irrigation and drainage were subject to significant investment in the Soviet era, but water management did not occur at a correct level (Ikramov 2007), i.e. the degree of water use was very high, resulting in a rise of GWL and salinity, which in turn led to degradation of the agricultural land. Often, construction of the canals and their maintenance were not thorough, bringing the irrigation and drainage system in dire straits even before the independence of the Central Asian countries in 1991.

After independence, the situation has worsened considerably. The maintenance of the canals has been repeatedly postponed, and consequently, many irrigation and drainage systems have come into disrepair. In many regions, water supply has been undertaken intermittently. Moreover, farmers often do not have enough choice in what to grow and often have limited access to information regarding seed quality, agricultural inputs, services and markets that would enable them to adapt to new conditions. In these circumstances, interruptions in the water supply can lead to catastrophic consequences. Yields per hectare have declined sharply, depressing agricultural incomes for both farms and states even more. With reduced incomes, agricultural workers have fewer funds for maintenance, meaning the infrastructure is continuing to deteriorate, water is becoming even less reliable, and this is a cycle that is ongoing.

Central governmental departments, which once controlled the operation and maintenance of irrigation and drainage facilities in Central Asia during the Soviet era, have weakened considerably. Shrinking budgets mean that wages in water management organisations and their local offices have dropped significantly and qualified technical employees have left (brain drain).

10.5.1 *Water Productivity*

As Seckler et al. (2003) stated, “current efficiency of water use is so low, especially in irrigation, that most, if not all, of future water needs could be met by increased efficiency alone, without development of additional water supplies”. Therefore,

substantially increasing water productivity in agriculture is essential to meet the goals of food and environmental security. To achieve it, research that spans the wide range of analysis is required.

Studies of Kenjabaev (2014) in Fergana province showed that irrigation water productivity for cotton and wheat tended to increase while the irrigation water supply decreased. Deficit irrigation could be one of the factors ensuing water productivity variability for cotton and wheat. Ergo, there is a high potential for farmers to save irrigation water through the improved water management and agronomic practices that ensure high water productivity.

10.6 Conclusions

Management of irrigation and drainage infrastructure is very complex in the Fergana Valley. Although temporary water withdrawal from collector-drainage systems is complicating water accounting, irrigation water management within hydrographic units is in accordance with the morphology of the river basin.

Improved water management should provide reliable (with minimal fluctuations) and manageable flow rates to all water consumers within the canal command area. Currently, the process of agricultural restructuring is not complete; therefore, questions about the financial and economic aspects in agriculture and water management are still in the development stage.

Deterioration of irrigation and drainage systems and lack of maintenance are common problems in the region. Specific water consumption is high because of water losses, evaporation and overwatering. Efforts have been made in riparian countries to enhance irrigation systems and their efficiency, particularly through introduction of the integrated water resources management (IWRM) principles (Dukhovny et al. 2013); however, a shortage of financial resources for renovation, maintenance and further upscaling within the entire basin persists. Further efforts are also needed to improve water efficiency; to increase effectiveness of irrigation systems, including repairs and maintenance of the existing infrastructure; to switch to less water demanding crops and to limit the irrigated land area.

Environmental impact assessments of planned transboundary projects should be carried out in a more systematic manner, involving the countries and populations affected. This is particularly relevant for planned hydropower projects in Kyrgyzstan and Tajikistan. Also, cooperation on the management of reservoirs can bring benefits by addressing the needs of different sectors; different reservoirs in a cascade can have complementary operating modes. Developing small-scale hydropower projects, which do not disrupt water flows and are less damaging to the environment, could be considered as an option for energy generation.

Transboundary monitoring needs to be significantly strengthened, especially that of water quality. Research on groundwater, which plays a potentially important role in sustaining ecosystems and limiting land degradation, should also be intensified.

Developing and training employees will lay the foundation for unlocking people potential in the implementation of the best management practices (BMP) and integrated water resources management (IWRM) principles.

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