Water **2015**, *7*, 4657-4684; doi:10.3390/w7094657

OPEN ACCESS

water

ISSN 2073-4441

www.mdpi.com/journal/water

Article

Water Security in the Syr Darya Basin

Kai Wegerich [1,*], Daniel Van Rooijen [2], Ilkhom Soliev [3] and Nozilakhon Mukhamedova [1]

[1] Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Theodor-Lieser-Str. 2, Halle (Saale) 06120, Germany; E-Mail: nozilar@gmail.com

[2] International Water Management Institute—East Africa and Nile Basin Office, IWMI c/o ILRI, PO Box 5689, Addis Ababa 1000, Ethiopia; E-Mail: d.vanrooijen@cgiar.org

[3] Chair of Landscape and Environmental Economics, Technical University of Berlin, Straße des 17, Juni 145, Berlin 10623, Germany; E-Mail: isoliev@daad-alumni.de

* Author to whom correspondence should be addressed; E-Mail: wegerich@iamo.de; Tel.: +49-345-2928138; Fax: +49-345-2928199.

Academic Editor: Marko Keskinen

Received: 13 May 2015 / Accepted: 19 August 2015 / Published: 27 August 2015

Abstract: The importance of water security has gained prominence on the international water agenda, but the focus seems to be directed towards water demand. An essential element of water security is the functioning of public organizations responsible for water supply through direct and indirect security approaches. Despite this, there has been a tendency to overlook the water security strategies of these organizations as well as constraints on their operation. This paper discusses the critical role of water supply in achieving sustainable water security and presents two case studies from Central Asia on the management of water supply for irrigated agriculture. The analysis concludes that existing water supply bureaucracies need to be revitalized to effectively address key challenges in water security.

Keywords: water security; supply water security; irrigation bureaucracy; polycentric water management; transboundary; Central Asia

---

1. Introduction

Since the 1990s, water infrastructure security and security of water supply became important topics with regards to conflict [1] and terrorism [2,3] specifically related to water. Today, water security is even more dominant on the agenda of the international water community and three international organizations (the Global Water Partnership, the United Nations University, and the International Water Management Institute) adopted the term as a guiding framework. Current water security definitions refer to key demands or objectives of users and the ecosystem in a changing environment [4,5]. In addition to this global focus on water security, the water, energy and food nexus builds around water security objectives [6]. With the emphasis put on these objectives, more traditional approaches to water supply security, such as direct and indirect water security measures, are omitted.

An important factor of indirect water security is infrastructure. Infrastructure development for irrigated agriculture had its peak in the late 1970s (measured by World Bank lending) and was from then on a decline [7]. Today, mainly because of population pressure, new water infrastructure development is again on the agenda [8]. New large scale water infrastructure could also be an important aspect of polycentric water management within basins [9,10]. Some of the past investments in large scale water infrastructure are based on the fragmentation of former colonies and new national water security approaches, such as the construction of link-canals in the Indus Basin in Pakistan [11]. This paper contributes to the literature on indirect water security approaches in a recently fragmented basin, the Syr Darya in Central Asia. International literature on water security in the Syr Darya Basin often focuses on large transboundary infrastructure such as the Toktogul and Kayrakum reservoirs in Kyrgyzstan and Tajikistan, respectively, as well as the planned new Kambarata 1 and 2 reservoirs in Kyrgyzstan. The prominent nature of the water-energy nexus in large water infrastructures, such as in the Syr Darya Basin, has also brought a focus on related energy security [12,13]. Hence, in the Syr Darya Basin, water and energy security focus mainly on the main river as well as its larger reservoirs. This focus ignores important aspects of historical design. The Soviet Union designed and planned water management at basin level as well as Smaller Transboundary Tributaries (STTs) and smaller infrastructure such as main canals, reservoirs or pump station schemes [14–17].

Direct water security in large scale irrigation systems has been the responsibility of irrigation bureaucracies in the past [18,19]. However, with the exception of some early experiences, Irrigation Management Transfer (IMT) became a national strategy in most developing countries in the 1980s and 1990s [20]. IMT shifts the responsibility of direct water security from the government to the users, organized in newly created Water User Associations (WUAs). While IMT and WUAs have been in the past widely promoted [21,22], more recently there have been doubts [23,24]. With the focus on IMT the lower level bureaucracy is "handed over" [25,26] and the higher level bureaucracy focuses on other functions or focuses only on the higher level like basin management [27]. Here, a case study is presented on partial IMT in one province of Uzbekistan. When focusing on water security for irrigated agriculture within Uzbekistan, so far the emphasis has been on the introduction of winter wheat (as policy to increase food security) and therefore the reduction of irrigated area under cotton [28,29] as well as creating WUAs [30,31]. The water supply organizations, the irrigation departments, have received little international attention, although they were incorporated in some donor projects.

This paper discusses both indirect and direct water supply security measures in irrigated agriculture by drawing from evidence from the Syr Darya basin and Ferghana Province, Uzbekistan. The focus on water supply, rather than on water demand security, is meant to draw attention to the way in which water management, with particular focus on irrigated agriculture, was organized. This focus on past water supply security approaches attempts to challenge the current focus of the international research community on basins and large infrastructure [12,13]. This paper also points out weaknesses in the current promotion of IMT especially at the main canal level–which shifts water supply security from the government to the water users for agricultural water uses [32,33].

The presented case study is structured into two sections. The data for the first section is based on a literature review and interviews with a key informer of the Syr Darya basin water organization (BWO) in 2014. The data presented in the second section is based on archival research of annual reports of the Ferghana Province Irrigation Department in Uzbekistan. The annual reports studied cover a period from 1978 up to 2010. Key informers of the Ferghana and Andijan Province Irrigation Departments were interviewed regarding verification of reported trends.

The paper continues with a short framework section on water security. The following case study is structured into two sections. The first section focuses on water supply security within the Syr Darya and the associated challenges faced by past and current irrigation water management strategies at the irrigation district level. The second section focuses on water security approaches within Ferghana Province and highlights changing water demands as well as the water security approaches taken so far. Within the section, large emphasis is put on the irrigation departments which after Uzbekistan's independence were not incorporated in achieving water security. Each case study is followed by a short discussion. A broader discussion follows, highlighting the possibly national as well as international reasons for not focusing on water supply organizations, which appear to have become the weakest link in water security. The conclusion stresses the need to look at poly-centric water management and a refocus on water supply organizations.

2. Water Security

As Allouche *el al.* [34] noticed "historically security has been concerned with safety and therefore can be understood as the condition of being protected from, or not exposed to, danger". Water security by the turn of the century focused on these traditional aspects. The security of larger water supply infrastructure was voiced in the debate on water wars [1], terrorism [2,3] as well as cyber-attacks [35]. While these perceived insecurities have been dismissed, they have also triggered calls for heightened security and additional systems of resilience [35,36].

More recently, the term water security gained prominence in the international literature from a different perspective. UN-water [4] defines water security as "The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality of water for sustaining livelihoods, human well-being, and socio-economic development for ensuring protection against water-borne pollution and water-related disasters and for preserving ecosystems in a climate of peace and political stability". The definition mainly focuses on the demand side and objectives of water security. While this broad definition of water security focusses on access and is human centered ("capacity of a population"), it critically lacks reference to the supply-side of water security. Water supply is vaguely addressed and

seems to extend the responsibility of water security to the wider public by making reference to 'a population'. As answer to the current challenge of water security, UN-water [4] calls for "tailored policy responses", human "capacity development" and "improved water governance". Water service providers, their challenges and strategies how to meet water demands are not directly addressed. The focus on human "capacity building" seems to neglect the human ingenuity in developing countries to cope with water insecurity. As Allouche *et al*. [34] highlights, "Missing […] is the issue of security sought by households in the South, many of whom exist within the vast informal economy, through which they survive and cope with external circumstances".

Grey and Sadoff [5] define water security as "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies. Lautze and Manthrithilake [37] highlight that Grey and Sadoff's "broader treatment of risks strongly suggests inclusion of issues related to water for national security or independence". Sadoff *et al.* [38], when defining pathways to water security, put the emphasis on institutions, information and infrastructure. Sadoff *et al.* [38] see institutions as "formal laws, policies, regulations, and administrative organizations as well as informal networks and coalitions". According to them, institutions incorporate planning, financing, construction, operating, supplying, regulating, monitoring, enforcing and insuring. Hence, the main focus is on the public sector, and central are water supply organizations. Nevertheless, they [38] highlight the need for "a 'poly-centric' and multi-level governance system that has been described as an 'institutional tripod' involving water users, states and markets". The "institutional tripod" can be criticized from different perspectives such as diversity and power inequities of users within sectors [39–43] and competing sectors [44–46], market failure and the responsibility of markets for the water crisis [47,48] as well as states institutionalizing inequities through water rights reforms [42,49–51].

In the global debate on the water, energy and food nexus, although reference is made to water, energy and food security, the emphasis for all three is on "access" [6,47]. Different authors have highlighted that the water, energy and food nexus is under-conceptualized and that security in one is contradicting security of the other parts of the nexus [47,52,53]. Hoff [6] highlights "the emphasis on access in these definitions also implies that security is not so much about average (e.g., annual) availability of resources, but has to encompass variability and extreme situations such as droughts or price shocks, and the resilience of the poor". Hence, key would be to include in the debate the supply side of water security. Instead, Hoff [6] argues that "It is increasingly recognized that conventional supply side management is coming to an end in many cases". Nevertheless, he [6] calls for strengthening existing supply side institutions for building "new links across sectors and deal with the additional uncertainty, complexity and inertia when integrating a range of sectors and stakeholders". The assumption appears to be, that linking an undefined range of sectors and stakeholders together will by itself provide better "access". Overall, an analysis of existing water supply organizations, and their strategies to meet demands or encounter risks, is crucially missing.

Traditionally, securing water supply focused on planning and construction of large infrastructures to be able to capture and store water resources as well as satisfying urban and agricultural needs [54]. Infrastructure development was not only seen to increase indirect national water security within transboundary basins [11] but also to enable polycentric water management within basins [9,10].

Recently, due to population pressure, but also due to seasonal variability of water, a rising deficit of existing water infrastructure has been identified [8,55–57].

Looking at water supply security in irrigated agriculture, the aspect of service provision towards the users came to the forefront in the 1980s. There was a realization that the gap in maintenance of irrigation infrastructure [58] led to a deterioration of water supply services. In addition there was recognition of the failure of the irrigation bureaucracy for ensuring equity of water distribution between water users [59,60]. Both insights could be attributed to issues regarding the financial security of water supply services. However, colonial irrigation systems focused on water supply as well as demands. Water control was achieved through different components focusing on water infrastructure, the organization providing the service and water demand [61,62]. Looking at past colonial large scale irrigation systems Ertsen [18,19] highlights that water supply (infrastructure and organization) as well as demand was planned for in the British, French and Dutch irrigation systems. Because of rising political pressure, market development and also changes of land ownership and farm sizes the water control side in irrigated agriculture disintegrated [63,64]. The rising water demand within the existing irrigated area was not met with an expansion of water supply infrastructure and providing more water resources or a strengthening of the irrigation bureaucracy controlling the distribution of limited water resources. The failure to provide equitable distribution was attributed to the continuation of established control practices [65] as well as the overall low salaries of the irrigation bureaucracy and therefore the rise of corruption [66].

Similarly, in the 1990s with the fall of the iron curtain and with a focus on transitional economies, water service provision for urban areas rose high on the development agenda. Again, the focus was on maintenance of infrastructure as well as monitoring of water losses [67,68]. The failure of strengthening the supply side could be classified as financial insecurity triggering the decline in quality of water supply services.

Rising demands but also a failure to secure and increase water supply triggered the development of more resilient water supply systems, *i.e.*, cities established inter-linkages between different sources and water storage systems to cope with temporary supply shortages [69]. Similarly, for supporting irrigated agriculture, countries or even smaller administrative units (like provinces) established resilient systems to cope with international or national transboundary water supply insecurities [11,70–73]. Common in all these formal systems of resilience is a diversified access to water resources as well as less reliance on one main supply infrastructure.

Looking at the debates within the water sector, risks to water security have been identified as transboundary and inter and intra sectorial competition, water pollution, unsustainable operation and maintenance as well as reliance on a single source or supply network. Therefore, water supply security could be defined as a resilient system capable of coping with shocks, abuses and threats through direct security measures (surveillance and guards) and indirect or more passive measures through increasing maintenance and additional or alternative water supply sources, duplication of or less reliance on critical infrastructure to better cope with temporary shortages in water source availability as well as water rights or allocations to cope with competitions.

3. Water Security Approaches in the Syr Darya Basin

3.1. Geographic Background to the Syr Darya Basin

The Syr Darya rises in the Tien Shan Mountains of Kyrgyzstan and terminates in the Aral Sea in Kazakhstan. It is the longest river in Central Asia, at 3019 km, with a catchment area of 219,000 km^2. Up to the confluence with the Karadarya (also from Kyrgyzstan) the Syr Darya is called the Naryn. The Syr Darya is shared between four riparian states, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan. On its way to the Aral Sea, the Naryn crosses international boundaries between Kyrgyzstan and Uzbekistan when entering the Ferghana valley and within the valley between Uzbekistan and Tajikistan as the Syr Darya. When leaving the Farghana valley, the Syr Darya enters first Uzbekistan and then crosses into Kazakhstan (Figure 1).

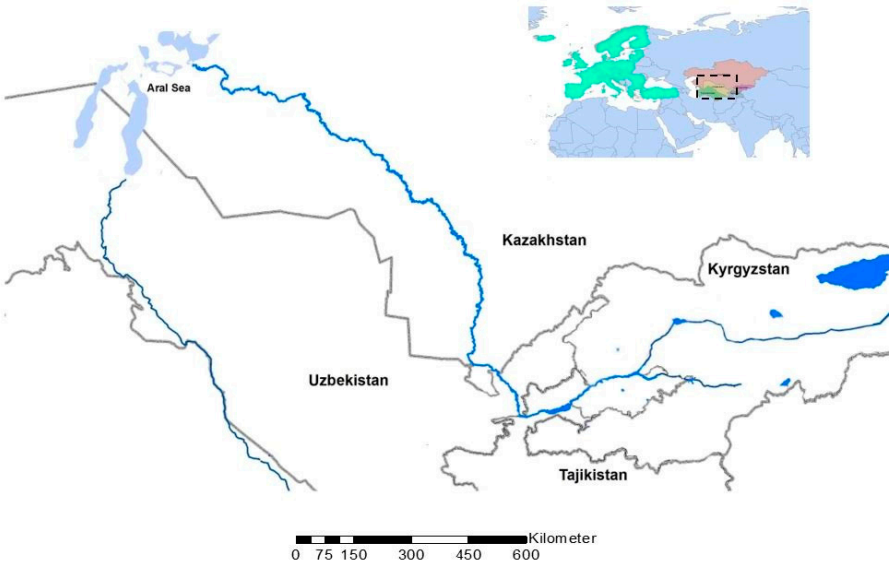

Figure 1. The Syr Darya Basin.

Due to large scale irrigation expansion, facilitated through the construction of multiple use reservoirs (Toktogul and Kayrakum), the Syr Darya basin closed in the 1980s [73,74]. The water allocation principles developed under the Schemes of Complex Use and Protection of Water Resources in the 1970s and early 1980s became the guiding principles of water allocation between the riparian states [17]. Later in 1987 the Syr Darya Basin Water Organization (BWO) was established [75]. Directly after independence, in 1992, the five Central Asian states came to an agreement to continue with these principles. However, while during the time of the Soviet Union the multiple use reservoirs operated to facilitate irrigated agriculture, after independence the operation of the reservoirs shifted mainly to winter releases for energy production to cover upstream riparian needs. The reason for the shift of operation is based on the collapse of existing compensation mechanisms. During the Soviet Union era, downstream states compensated for excess electricity produced at the reservoirs during the summer, by supplying fossil fuels and electricity during the winter.

3.2. The Common Approach to Look at Water Insecurity within the Syr Darya Basin

After independence the international emphasis on water security within the Syr Darya Basin focused on the conflicting interests of upstream hydropower production during the winter and downstream water needs for the agricultural sector during the summer. Therefore, the main emphasis was on the operation of the Toktogul reservoir and the brokering of an agreement on water and energy use in 1998. The agreement was amended to include the Kayrakum reservoir in Tajikistan in 1999. According to the agreement, purchases of energy and therefore water allocations from Toktogul are determined annually [76–78]. The implementation of the agreement has been seen as problematic in reference to water delivery to Kazakhstan [79,80] and as generally failed because of the late signing of annual bilateral agreements [78]. Overall, the primary focus of the international attempts to foster water security focused on the infrastructure controlling the main stem of the Syr Darya Basin, the Naryn, only [81]. However, the Naryn supplies about 40 percent (14.5 km^3) of the average annual flow of the Syr Darya River (37.2 km^3) only [81]. The focus on the Naryn River and the Toktogul reservoir assumed that basin management was the overarching principle. In addition, the agreement focused on national levels and did not incorporate Tajikistan as downstream water user [15].

3.3. Water Insecurity at the Meso-Level: Irrigation Districts and Within

Other research highlights that within the Syr Darya Basin, water management was organized according to "water-use regions" or "irrigation districts", which in some cases even crossed republican boundaries [82–84]. Within the Syr Darya Basin there were six irrigation districts during the Soviet era, these were: Upper Naryn, Ferghana Valley, Chirchik-Akhangaran-Keles (Chakir), Midstream, Arys-Turkestan (Artur) and Downstream (Figure 2). Three of these irrigation districts were transboundary: the Ferghana Valley irrigation district incorporated irrigated areas within the valley from Kyrgyzstan, Tajikistan and Uzbekistan; Chakir incorporated irrigated areas of Kazakhstan, Kyrgyzstan and Uzbekistan; and Mid-stream incorporated irrigated areas from Kazakhstan, Tajikistan and Uzbekistan.

Figure 2. Irrigation districts in the Syr Darya Basin.

Irrigation districts can be categorized into different groups with focus on the utilization of water sources, having access to alternative resources, and capturing winter flow (Table 1). The implication of former management according to irrigation districts is that the past system focused on poly-centric [9] and not basin-level water management and therefore crafted poly-centric water security approaches (storage and reliance on multiple sources). Therefore, the collapse of the Soviet Union and the emergence of independent states, as well as the shift of operation of the larger Toktogul reservoir in Kyrgyzstan did not create water insecurity for the whole basin, but created water insecurity for individual irrigation districts or parts of them.

Table 1. Features of irrigation districts (Source: adapted from [84,85].

Irrigation District	Source (km^3)	Storage (km^3)	Republic	Irrigated Land (1000 ha)	Total Water Use (km^3/year)
Upper Naryn	Naryn (14.5)	–	Kyrgyz SSR	130.3	–
Ferghana Valley	Naryn (14.5)	Toktogul: Total Storage (TS)-19.4 Active Storage (AS)-14.0	Uzbek SSR	409.8	4.69
			Tajik SSR	97.7	1.36
			Kyrgyz SSR	22.5	0.74
	Karadarya (3.9); Small Transboundary Tributaries (STT) (total 7.8)	Andijan: TS-1.9; AS-1.8; Some smaller transboundary reservoirs	Uzbek SSR	471.7	5.75
			Kyrgyz SSR	293.7	3.21
			Tajik SSR	30.5	0.23
Chakir	Chirchik (7.8); Akhangaran (0.7); Keles (0.3)	Charvak: TS-2.0; AS-1.6	Uzbek SSR	347.2	3.43
			Kyrgyz SSR	9.5	0.04
			Kazakh SSR	89	0.89
Mid-stream	Main stem	Kayrakum: TS-4.0; AS-2.6 Farkhad TS-0.15	Uzbek SSR	629.7	7.19
			Tajik SSR	87.6	1.03
			Kazakh SSR	117	1.34
	Small Tributaries (0.3)	–	Uzbek SSR	33.6	0.3
			Tajik SSR	30.5	0.23
Artur	Arys (1.2)	–	Kazakh SSR	200	–
Downstream	Main stem	Chardara:TS-5.7; AS-4.7	Kazakh SSR	374	–

The implication of looking at irrigation districts rather than the whole basin is that local water insecurity becomes more visible. Hence, after independence, irrigation districts were most water insecure if they were either dependent on one transboundary source only or if they were dependent on one transboundary infrastructure for capturing winter flows. Looking at the largest irrigator within the irrigation district only, the most potentially water insecure irrigation district would be Mid-stream. Here, the largest benefiter of the Mid-stream Kayrakum Reservoir is Uzbekistan; however, the reservoir is controlled by Tajikistan. In the case of the Ferghana Valley, although the main benefiter is Uzbekistan and the main reservoir is controlled by Kyrgyzstan, having access to alternative sources (Karadarya and small tributaries) as well as smaller reservoirs (Andijan as well as on small tributaries) could be interpreted as being in a less water insecure situation.

However, Table 1 also reveals that some irrigation districts are transboundary. Hence, within irrigation districts there is a second layer of potential water insecurity for transboundary parties. Within the Ferghana Valley irrigation district some areas experienced more potential water insecurity than others. These

potential insecurities are not related to the shift of Toktogul reservoir operation but more due to smaller transboundary infrastructure. Examples of these smaller infrastructures are the Big Namangan Canal, which is mainly supplying farmers in Uzbekistan. The diversion structure for the canal is located in Kyrgyzstan. In addition, within the Ferghana Valley and within smaller tributary basins downstream Uzbek areas are potentially water insecure, such as in the Isfara tributary [15]. Irrigated areas within Tajikistan are potentially water insecure if they depend on transboundary infrastructure, for example Tajikistan is at the tail-end of the Big Ferghana and North Ferghana Canals [15]. Although Kyrgyzstan is mainly upstream from the Ferghana valley, areas in Kyrgyzstan receive water through pump stations located in Uzbek territory or diversion from transboundary main canals, such as the South Ferghana Canal [14].

Within the mid-stream irrigation district, the Dustlik canal is transboundary and shared between Uzbekistan at the head-end and Kazakhstan at the tail-end [79,80]. Within the Dustlik canal Uzbekistan irrigates 98 thousand ha and Kazakhstan 125 thousand ha. Wegerich [86], comparing data from the years 1990 and 1991 with the years 2004 and 2005, shows that after independence Kazakhstan received less water and later during the cultivation period. Hence, for Kazakhstan along the Dustlik canal not the operation of Kayrakum reservoir appears to be the main factor, but the withdrawals along the Dustlik canal within Uzbekistan.

The Chakir irrigation district is independent of the operation of the Toktogul reservoir and is mainly based on water of tributaries, with only small diversion through lift from the Syr Darya to Uzbekistan (Dalverzin canal's command area) [87]. Within the irrigation district, Uzbekistan transfers water through three canals (Zakh, Khanym, and Big Keles) from the Chirchik river to the Keles massif irrigation system in Kazakhstan irrigating about 66 thousand ha [88], the same canals return water to Uzbekistan to irrigate about 17 thousand ha in Tashkent and Kibray districts [89]. Dukhovny *et al.* [88] report variation of water supplied to Kazakhstan. In the period 1995–2003 water supply varied between 347 and 595 km^3/year. It is not evident whether the mentioned 89 thousand ha [84] in Kazakhstan are all within the Keles massif and that therefore a major reduction of water supply occurred after independence. The major reduction could either be caused by a reduced total flow, or again as in the case of the Dustlik canal by withdrawals along the three main canals within Uzbekistan.

Overall, the irrigation district which was most water insecure after independence was dependent on one transboundary source (the main stem of the Syr Darya) and one transboundary infrastructure (reservoir). Similarly, areas within irrigation districts which were most water insecure to water supply shortages were dependent on transboundary infrastructure (main canals, pump stations) and had access to one transboundary water source (small transboundary tributary (STT) or main stem of the Syr Darya). The irrigation district which is the most water insecure is Mid-stream, and the areas being most water insecure within irrigation districts are some Uzbek and Tajik areas within the Ferghana Valley, Kazakh areas within the Mid-stream, and Kazakh as well as minor Uzbek areas within the Chakir irrigation districts.

4. Past and Current Water Security Approaches: Capturing Winter Flow and Alternative Sources

4.1. Past Water Security Approaches–Example the Ferghana Valley Irrigation District

Looking particularly at the Ferghana Valley, in the past, different strategies have been used to facilitate adaptation to seasonal fluctuations. Early on, Soviet Engineers started linking the main

tributaries with smaller tributaries of the Syr Darya through main canals [90–92]. Later on, water security was increased through the construction of small reservoirs for capturing winter flows of tributaries [16,17]. Finally, with the increase of irrigated areas in small tributaries within upstream Kyrgyzstan, pump stations were constructed to lift water from main canals towards small tributaries [15,93]. Hence, within the Ferghana Valley, a meshed system was constructed which allowed switching from the main water source to an alternative water source and winter flow on tributaries as well as main stem was captured. Therefore, water security within the Ferghana Valley was achieved through tapping from alternative water sources through additional infrastructure (duplication) and storing winter flow.

4.2. Current Water Security Approaches

After independence from the Soviet Union, whenever possible, all states tried and are still trying to find solutions for becoming independent from each other. These solutions are based on capturing current unused winter flow or through duplication of access infrastructure for the exploration of alternative water sources. Dukhovny [94] highlights that "Uzbekistan is striving for almost full satisfaction of its demand for additional water through releases from the Andijan reservoir and, partially, through construction of in-stream reservoirs".

Within the Ferghana Valley irrigation district, Uzbekistan constructed the Rezaksay reservoir (0.3 km^3) between the North Ferghana and the Big Namangan Canals and the Markaziy (Central) reservoir (0.35 km^3) along the Big Andijan Canal to store unused winter flow of Toktogul. Different riparian states are also trying to attempt water security through duplication of access infrastructure and shifting to alternative sources. Uzbekistan plans additional pump stations from the North Ferghana to the Big Namangan Canal to compensate for the inoperative diversion structure for the Big Namangan Canal in Kyrgyzstan. In addition, Uzbekistan plans new pump stations for utilizing ground water in the Ferghana province, here the aim is to compensate for less water received along smaller tributaries (key informant from BVO Syr Darya, January 2014). Still within the Ferghana Valley irrigation district, Tajikistan first started to negotiate water allocation issues regarding Big Ferghana Canal with Uzbekistan through issue linkages with the Kayrakum reservoir. More recently, Tajikistan started to divert water from the Isfara tributary directly into the tail-end part of the Big Ferghana Canal which is within its territory. Hence, although water allocations between Tajikistan and Uzbekistan were negotiated, Tajikistan was still not able to receive its water share on the Big Ferghana Canal. As consequence of the recent Tajik strategy, Uzbekistan's irrigated areas in the downstream Isfara tributary became more water insecure [15].

In the late 1990s, within the Midstream irrigation district, Uzbekistan anticipated to use the flood spills towards Arnasai Lake for irrigation [82,95]. Hence, Uzbekistan anticipated to making use of an existing "reservoir" to facilitate alternative water supply or duplication to existing canal infrastructure. More recently, Uzbekistan started to construct the Sardova reservoir (1.0 km^3) along the South Golodnyesteppe canal (key informant from BVO Syr Darya, January 2014). The reservoir will enable Uzbekistan to secure winter flow below the Kayrakum reservoir. Within the Downstream irrigation district, Kazakhstan built the Koksarai reservoir (3.0 km^3) below Chardara, and has planned two additional reservoirs for flood protection and to store unused winter flow (Figure 3). Regarding alternative water supply and duplication, Kazakhstan made use of its existing Chardara reservoir and constructed pump-stations towards the Dustlik canal to reduce its dependence on transboundary infrastructure.

So far, no alternative sources or duplication seem to be anticipated for the Kazakh part of the Chakir irrigation district. However, Dukhovny *et al.* [88] mentions that Kazakhstan is planning the expansion of its irrigated area to 98 thousand ha, with a total withdrawal of 1140 Mm^3/year. To secure the additional water needs Kazakhstan might consider a similar approach as taken in the Mid-stream and Downstream irrigation districts and might attempt to reduce dependence on transboundary infrastructure. The potential source, could be the Chirchik directly, since, 0.75 km^3/year of its flow generation is within Kazakhstan [58].

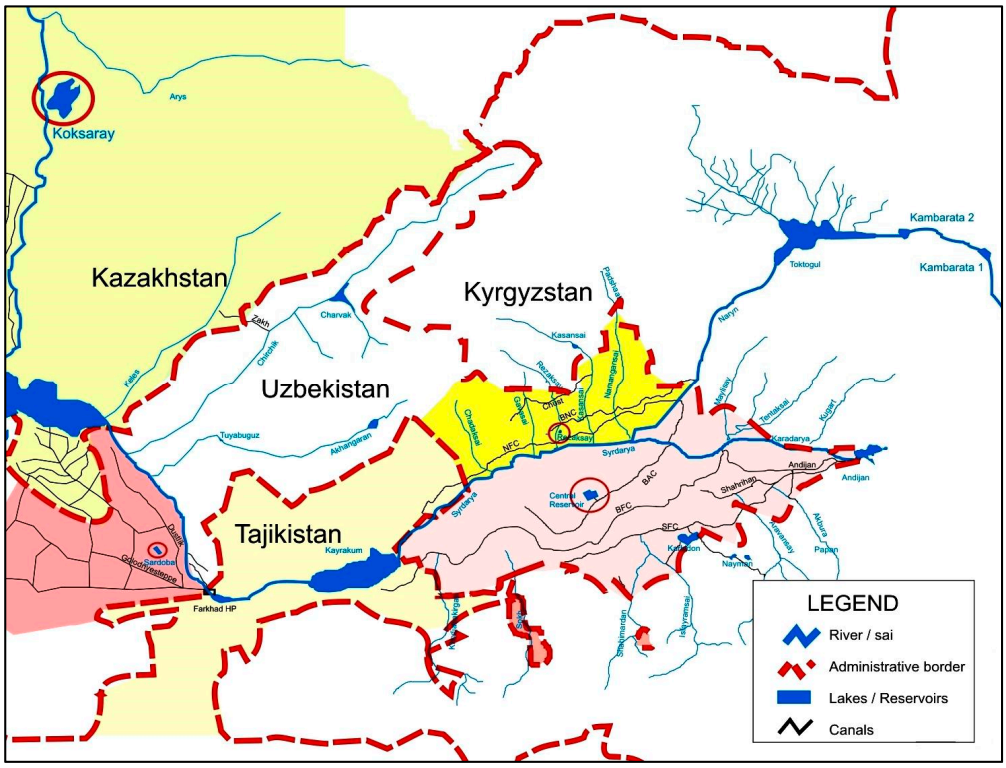

Figure 3. New reservoirs in the Syr Darya. (Source: Based on information compiled through GIS maps, as well as key informer BVO Syr Darya).

4.3. Short Discussion: Downstream Countries Increasing their Indirect Water Security

The two downstream riparian states, Uzbekistan and Kazakhstan, which were negatively affected by the operation of Toktogul within irrigation districts which depended to a larger extent on the main stem (Ferghana Valley, Midstream and Downstream) developed similar strategies regarding water security. Both are creating water storage within their territories for not having to depend on the Toktogul or Kayrakum reservoirs operation. With the creation of additional storage, the basin's downstream riparian states avoid having to negotiate summer operations and therefore paying for electricity from Toktogul. Within the Downstream irrigation district the reservoir has multiple functions; storing winter flows for flood mitigation and securing irrigation needs during the summer. However, water to the Koksarai reservoir has to be pumped. Overall, the creation of capacity to store winter flow not only reduces the dependence on other riparian states, but also decreased the bargaining power of upstream states. Given that off-season flows were already allocated within the closed Syr Darya basin, the creation of national storage, particularly in the midstream country Uzbekistan, might off-set the

existing but not anymore operationalized riparian states allocations to downstream states. In addition, the additional storage within the midstream and downstream countries (Uzbekistan and Kazakhstan) might put into question the water delivery to the Northern Aral Sea in Kazakhstan.

The creation of access to alternative water resources such as groundwater resources within the Uzbek part or the diversion of the transboundary tributary (Isfara) within the Tajik part of the Ferghana Valley irrigation district highlights the dividing up of the transboundary irrigation district according to national boundaries. Similarly, the creation of a pump station along the Chardara reservoir for supplying the Kazakh part of the Dustlik canal highlights the merging of parts of the former Midstream and Downstream irrigation districts along national boundaries. Hence, the identified water security solutions rely on national water security solutions, rather than on transboundary solutions. The implication is that although pumping costs such as on the Chardara might be economically higher, and the diversion of the STT might be more unstable due to seasonality, these solutions might provide more stability and reliability compared to the past transboundary water supply solutions.

Overall, these new water security solutions for water shortages are building on past security approaches practiced within Soviet Central Asia. However, these new solutions focus primary on national water security. While these are technical solutions to water shortages, it is questionable whether the water bureaucracy can safeguard the availability of water resources for their users.

5. Surveillance and Guards–Irrigation Bureaucracy (Example Ferghana Province)

While the previous section focused on poly-centers within the basin and on more passive security measures, here the focus turns to the meso-level, the Ferghana Province, and direct security measures, such as water metering devices, surveillance and guards. As mentioned in the introduction, here a historic approach is taken by looking at long term trends [96] (1978 to 2010) of the water supply control side of the irrigation department of Ferghana Province. Therefore it is first necessary to highlight the changes on the demand side during the Soviet period and after independence.

5.1. Geographic Background to Ferghana Province

Ferghana Province is located within the Uzbek part of the Ferghana Valley. The province occupies 6800 km^2 and consists of fifteen districts, four major cities and has a total population of about three million. The province borders Kyrgyzstan to the south-east, Tajikistan to its western side and two Uzbek provinces Andijan and Namangan to the east and north respectively. The province has access to different water sources, the Syr Darya, the Big Ferghana Canal (BFC)-diverting water from the Naryn (controlled by Toktogul reservoir in upstream Kyrgyzstan), Karadarya (controlled by Andijan Reservoir operated by Uzbekistan), the South Ferghana Canal (SFC) (taking water directly from the Andijan Reservoir) and the Big Andijan Canal (BAC) (also diverting water from the Naryn), as well as five Smaller Transboundary Tributaries (STTs): Kuvasai, Isfayramsai, Shakhirmadansai, Sokh and Isfara (from east to west), which all, with the exception of the Kuvasai, intersect with either the SFC or BFC [14]. On all main canals and small tributaries Ferghana Province is at the tail-end. With independence, the water situation for Ferghana Province was aggravated on the main canals BFC and BAC as well as some STTs (Figure 4).

Before independence, within Ferghana Province the irrigated area increased from 285,000 ha in 1969 up to 368,300 ha in 1988. After independence in 1991, the irrigated area first declined, but

stabilized at about 361,000 ha from 2006 onwards. According to Bucknall *et al*. [97] about one third of the irrigated area in the province, 115,000 ha, is supplied via pumps and pump stations (lift). Recently Wegerich *et al.* [93] showed that 151,000 ha are supplied via pump stations and of these 69,000 ha have a lift of over 50 meters. About one third of these pump stations can be classified as transboundary pump stations, which were constructed to mitigate upstream expansion in transboundary tributaries [93].

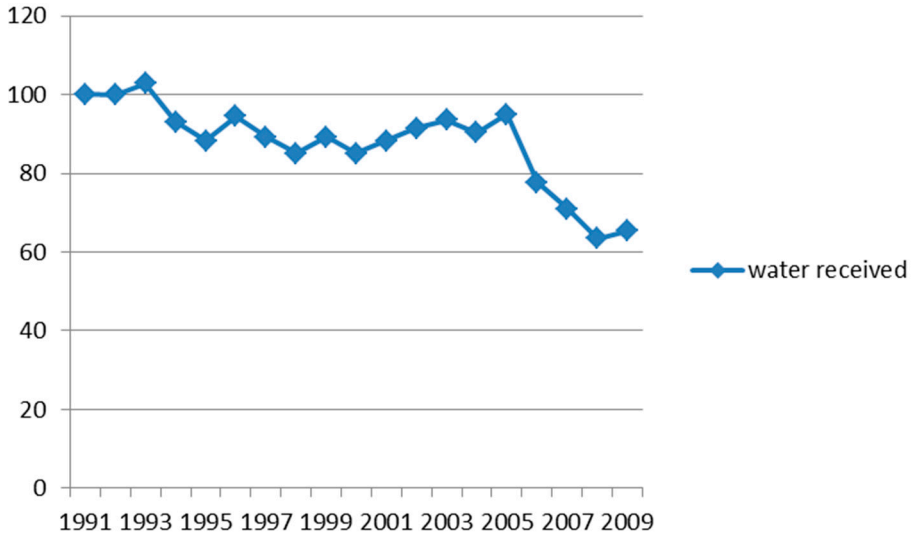

Figure 4. Total water received and utilized in Ferghana Province from 1991 to 2009 (deviation from 1991), (Source: compiled from data of the irrigation department of Ferghana Province).

5.2. Demand Side Changes-Farming Units and Crops

During the Soviet period, agricultural production was organized in crop specialized state owned large scale collective farms, varying in sizes between 2000 and 8000 ha. Within Ferghana Province were a total of 120 collective farms in 1975, which changed to 162 by 1991. During the 1990s, collective farms were transformed into semi-cooperative farms, with an average size of 2000 to 3000 ha. Within Ferghana Province a total of 164 semi-cooperative farms were registered. Although already in 1992 the law on peasant farms [98] (peasant/dehkan farms) was issued, privatization did not kick off until 2001, based on a new law concerning farms in 1998 [99]. Within the province, the number of private farms rose from about 3000 in 2000 to below 26,000 in 2007. In 2009, a Presidential Decree [100] on farm optimization was issued, which led to decrease in the number of private farms. Already prior to the Presidential Decree [100], the number of private farms dropped again in Ferghana Province. The total number was below 12,000 in 2010 (Figure 5).

Usually, when reference is made to the Uzbek SSR and its agricultural production during the Soviet period, cotton monoculture and alfalfa are mentioned. It is also argued that because of state planning the Uzbek SSR increased its irrigated area for further expanding its cotton monoculture [91,101]. The data of Ferghana Province shows that from 1978 the increases of irrigated area did not lead to an increase of the area under cotton cultivation, the area under cotton even decreased. According to Anderson [102] after the cotton scandal in the 1980s and to soften the social conditions the Uzbek SSR Leader (Nishonov) asked

permission to reduce the cotton quota for Uzbekistan. Consequently, the area under cotton decreased further in the Ferghana Province from 196,000 ha (56 percent) in 1987 to 164,000 (46 percent) in 1990.

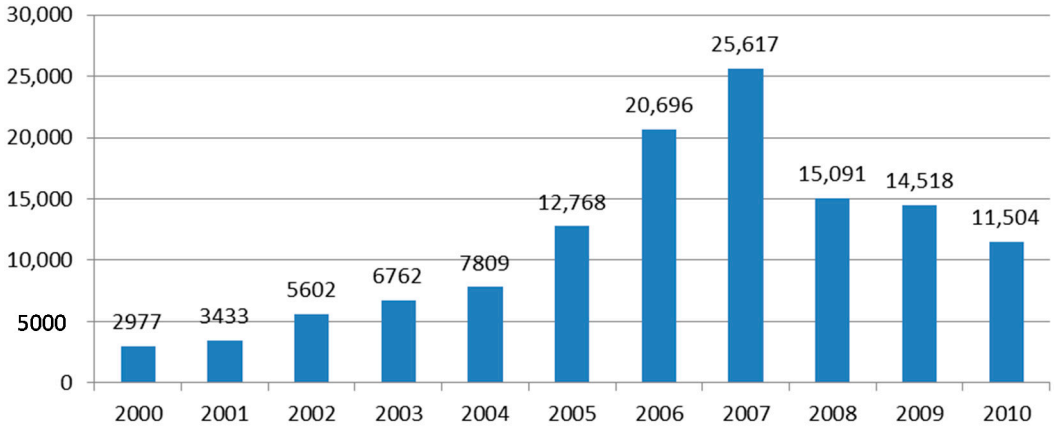

Figure 5. Dynamics of private farms in Ferghana Province 2000–2010 (total numbers).

5.3. Current Water Security Approaches Focusing on the Demand Side

After independence, Uzbekistan shifted to a policy of food self-sufficiency and therefore expanded the area under wheat cultivation. Although usually emphasized as food security policy, one could argue that the food security policy was in fact a water security policy. Within Ferghana Province winter wheat was grown from 1995 onwards. In the period from 1995 to 2010, the area allocated to cotton decreased from 36% to about 30% and the area allocated to winter wheat increased from 0% in 1994 to 31% in 2010 (Figure 6). Within Ferghana Province, winter wheat has mainly replaced alfalfa. Although winter wheat would imply less water demand during the summer season, farmers utilize the period between harvest and sowing to grow a second crop [103,104]. Recent studies have shown that the ratio of second crops after winter wheat is between 60% and 80% within Ferghana province [105]. Given the large ratio of second crops the potential for water savings is reduced (Figure 7).

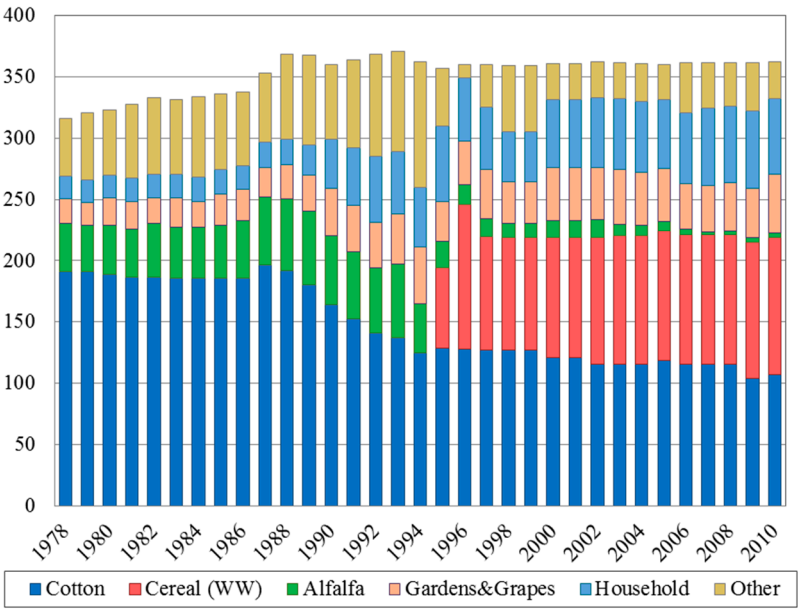

Figure 6. Changes of cropping patters 1978 to 2010 (1,000 ha).

Being concerned about the fragmentation of former collective farms and based on international recommendations, the Cabinet of Ministers of the Republic of Uzbekistan approved the Procedure for organizing Water User Associations (WUAs) in 2002 [106]. Within Ferghana Province, the Integrated Water Resources Management project, funded by the Swiss Agency for Development and Cooperation (SDC), established WUAs along the SFC and Shakhirmadansai STT. By 2011, Ferghana Province had 119 WUAs. WUAs have been mainly established on the territory of the former semi-cooperative farms (with the exception in the donor funded project). Because of the difference in numbers, it is not evident whether the process of creating WUAs was completed within the province. WUAs are newly created organizations and therefore it is questionable whether they can plan and allocate water according to requests of farmers and available water resources supplied by the irrigation department.

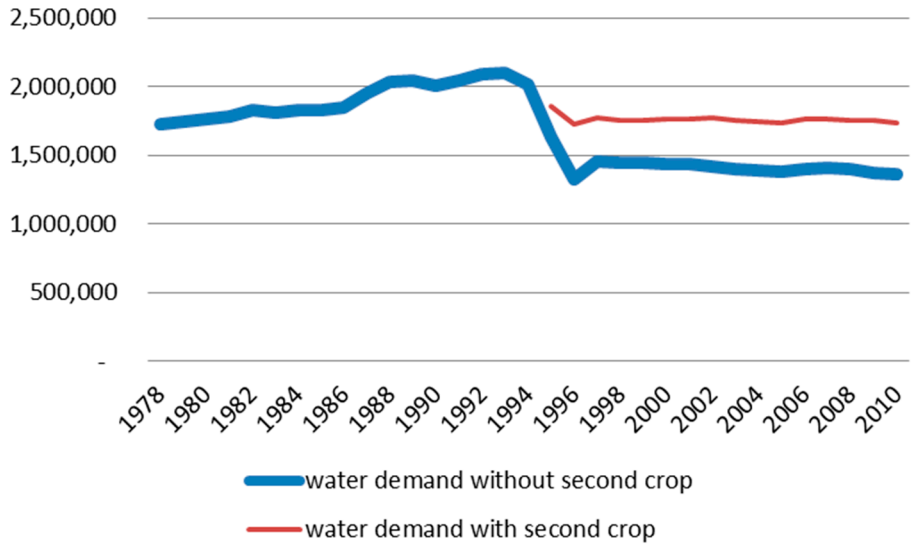

Figure 7. Irrigation norms and trends of water demand during summer season 1978 to 2010 (m^3).

5.4. Current Water Security Approaches Focusing on the Supply Side

There were few projects that focused on the water supply organizations (irrigation departments). A SDC funded project, focusing on main canal management, brought governance issues forward and therefore established a "union of canal water users" along the SFC (2002 to 2012), with less emphasis on infrastructure or finance which was demanded by the irrigation department [33]. An additional SDC project focused on main canal automation along the SFC (2005 to 2010). Towards the end of the main canal automation project key problems were raised regarding sustainability of operation and maintenance as well as capacity of irrigation departments' operating staff [107]. A Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) project (2009 to 2011) focused on GIS capacity building of water supply organizations and on creating transparency of water flow information [108]. However, also here, long term sustainability was voiced regarding staff issues. Given the early start of these different projects, one has to note that when the first SDC project started in 2002, there were no international publications on the irrigation departments in Central Asia, except some donor reports.

5.5. Supply Side Changes—The Irrigation Bureaucracy

According to Dukhovny and de Schuetter [101] "the beginning of the 1980s saw the first signs that governments were paying attention to the problems of managing the large river basins (Amu Darya and Syr Darya) in Central Asia". During the 1980–1985 period "more than 70 rubles (US$ 45 in 1980, which converts to US$ 137 buying power in 2014) per irrigated hectare were annually allocated to water management organizations. Accordingly fixed assets at the inter-farm level increased by 36%, the number of service staff at the inter-farm level increased by 20%, the number of inter-farm irrigation networks equipped with water-measuring structures increased by 93% and water-distributing structures increased by 94%" [101]. After independence, the situation changed. Thurman [109] highlighted limiting factors of the irrigation departments for controlling water supply to the users, "very low salaries, small operational budgets, and very little equipment". Wegerich [110,111] looking at staffing and logistics of the irrigation department of Khorezm province argued that the past procedure of controlling off-takes from main canals was not anymore possible. Other studies have highlighted that the 1997 merger between the Ministry of Agriculture and the Ministry of Water Resources, led to a downgrading of the Water Ministry as merely dependent department [70,111–115].

5.6. Case Study the Ferghana Province Irrigation Department

At the time of basin closure in the beginning of the 1980s, the Ferghana Province Irrigation Department controlled water supply through hydroposts (measuring infrastructure within main canal and at off-take level) and flexible guarding (motor bikes and staff) (Figure 8). The long-term trend up to 1997 shows that the number of staff of the irrigation department was set on expansion. This is similar to the trend with the number of hydroposts, showing a rapid increase from the mid-1980s to 1990, and a slowing increase up to 1997. Flexible guarding through motor bikes expanded rapidly in 1983 and 1984, and stabilized at a lower level in 1987. However, after independence in 1991, motor bikes were not mentioned anywhere within the annual reports of the irrigation department.

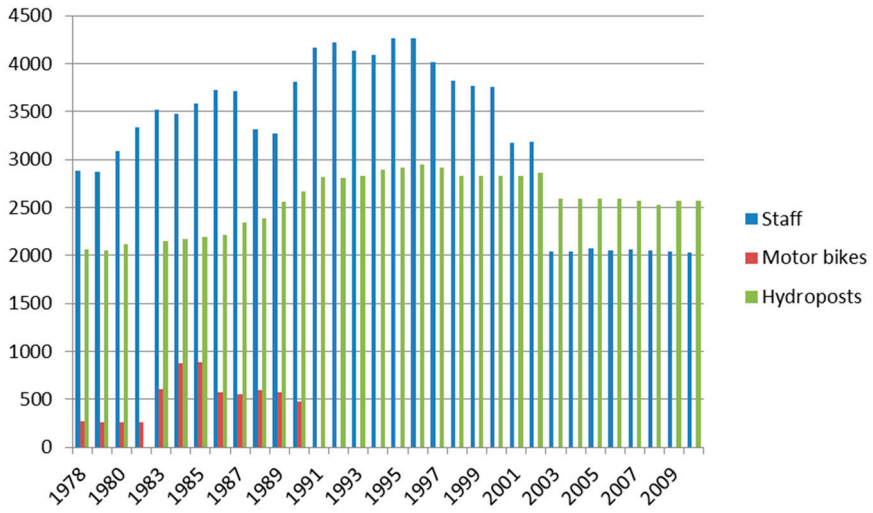

Figure 8. Dynamics of supply side control-surveillance and guards in Ferghana Province (total numbers).

While the most staff increases of the irrigation department can be attributed to the construction of pump stations during the 1980s [93], the rapid fall of staff numbers in 1988 to 89 and 1992 to 93 appear to be due to wider social, nationalistic and economic changes[116–118]. In 1997 the Ministry of Water Resources merged with the Ministry of Agriculture 1997 marks the turning point for trigging a downward trend regarding staffing as well as hydroposts. In 2003, a main canal dispatch center was created in Ferghana Valley, which as consequence had a reduction of the number of staff as well as the reported number of hydroposts under the Ferghana Province Irrigation Department.

As mentioned before, there has been a major increase of operation and maintenance from 1980s onwards [101]. Until 1985, expenditure on operation and maintenance appears to have been nearly stable with rapid increases during the period from 1986 to 1990 (Figure 9). Hence, it appears that the Soviet Union put high emphasis on water supply security and control of water supply. During the economic crisis which followed independence, the operation and maintenance expenditure decreased rapidly, and regained the level of 1986 only by 1996. However, with the merger between the two Ministries operation and maintenance as well as rehabilitation expenditure declined to insignificance. Although from 1996 onwards the Uzbek Gross Domestic Product (GDP) started to increase again [119], this increase has not triggered a reinvestment in the Ferghana Province Irrigation Department.

Figure 9. Expenditure for Operation and Maintenance and Rehabilitation (in 1,000 Soviet Union Rubles for the period 1978–1991 and 1,000 Uzbek Sums for the period 1995–2010, the secondary axis is in 1,000 USD buying power as of 2014).

The disappearance of motor bikes and the increasing total number of staff and hydroposts could suggest that there was a shift from flexible to static (staff being posted at the hydroposts directly) water supply control after independence up to 1997. However, the declined salary level combined with an overall rising staff number suggest that full-time employment within the irrigation department might not have guaranteed livelihood security. Kandiyoti mentions that often employees were only formally employed but in fact did not receive salaries [120]. Therefore, it is questionable whether after independence surveillance and guarding continued. Similarly, the decreasing expenditure on maintenance after independence suggests that the number of functioning hydroposts has declined, but that dysfunctional hydroposts are still recorded.

5.7. Short Discussion: Losing Direct Water Security

During the time of the Soviet Union, rising water demands (due to expansion as well as change in cropping patterns) triggered an adaptation process of the irrigation department. During this period there was an increase of water supply control noticeable with the increasing numbers of staff, hydroposts and motorbikes. More funding was allocated to operation and maintenance as well as rehabilitation of water supply infrastructure. After independence water demand continued to increase; however this was not anymore matched with increases in water supply or an increased water supply security. Therefore, there appears to be an apparent mismatch between official figures of water supplied and evidence of water utilized.

An adaptation process for the new situation came only in 1995 with the introduction of winter wheat and therefore an assumed reduction of overall water demand. The adaptation of crops cannot only be interpreted as a response to a decrease of water supply, but possibly also as a political attempt to avoid strengthening the organizational capacity of the irrigation department, through increases of finances and logistics. In this respect, the merger between the two ministries, which followed the introduction of winter wheat, could be interpreted not only in terms of budget savings, but also that the solution for water supply insecurity was seen through controlling agriculture rather than water supply. However, given that about 60% to 80% of winter wheat area is utilized for second crops, this attempt did not reduce the need for water supply security solutions but aggravated the situation further, since the second crop diversity demands more irregular irrigation compared to mono cropping of cotton. The merger triggered further budget and staff cuts within the irrigation department and therefore the water supply security was lost completely. With the implementation of land reforms, the need for water supply security would have increased significantly. However, there is no evidence that water supply security has been strengthened.

Looking at past projects (SDC and GIZ) it is evident that the first focus on governance through "union of canal water users" was misplaced, since water supply security was not possible. Looking at the total operation and maintenance budget of the irrigation department, it is also evident that canal automation would have added an additional burden, which was unlikely to be sustainable. Looking at the salary of irrigation department staff, it is also evident that staff after having gained additional knowledge would look for other job opportunities. Therefore, unfortunately, these projects appear to have been too ambitious and possibly too premature, assuming that the irrigation department would have an existing capacity of supply security. It appears that these projects focused on a piecemeal

approach, omitting key questions of capacity, and mainly not considering that irrigation departments are government organizations, and the potential of donor influence on these established bureaucracies could be limited if it is single focused and project based.

Given the deteriorating position of funding and therefore capacity of the irrigation department to control and the negative aspects for its staff, regarding salary, it is evident that the diversity and power inequities of WUAs along main canals might increase. Given the lack of capacity to control, it is likely that the foremost rising inequity will be based on the location along main canals. In addition, Platonov *et al* [105] have highlighted that within Ferghana Valley the inequity depends also on the off-take infrastructure. The implication is, that irrigated area which rely on more costly infrastructure (such as pump stations), which are operated and maintained by the irrigation department, are less likely to be able to produce profitable second crops. In addition, there is already evidence, that the lack of control on the main canal level has negative effects and has increased power disparities within WUAs. Mukhamedova and Wegerich [45] highlight how water scarcities are inequitably distributed within WUAs and affecting mainly the most vulnerable part of the communities, kitchen gardens in villages.

Although this second section only presented the case of the Uzbek Ferghana Province, it is assumed that Ferghana Province is not only representative regarding its budget limitations for Uzbekistan, but also for other riparian states (Kazakhstan, Kyrgyzstan and Tajikistan). However, Uzbekistan and Tajikistan compared to Kazakhstan and Kyrgyzstan are late implementers of land reforms as well as lifting slowly the restrictions on agricultural production. Therefore, in Uzbekistan, agricultural water demand and the subsequent need for increasing water supply has likely expanded more slowly compared to its neighboring countries.

6. Discussion Linking Irrigation District to Meso-Level Water Security

The first section demonstrated that after independence in 1991, water supply security was high on the agenda with building resilience through additional or alternative water supply sources (from existing national reservoirs, groundwater sources, or small transboundary tributaries) as well as duplication of or less reliance on critical infrastructure (through the construction of smaller reservoirs within the country, pump-stations or diversion canals for small transboundary rivers). The second section showed for the Uzbek Ferghana Province that less attention was paid to surveillance and guards in the irrigation schemes, and that consequently the irrigation department lost its capacity to secure water supply to the water users. Hence, water supply security appears to focus on technical solutions (new infrastructure), while old and deteriorating infrastructure as well as operational sustainability of the water departments are neglected. Possibly, the focus on capturing more water and setting up additional supply lines might postpone the strengthening of existing organizations. Consequently, the chosen approach might secure more water resources, but possibly will not lead to more equitable water distribution within irrigation systems. Furthermore, there appears to be little reflection of the government on past infrastructure strategies and subsequent consequences for the irrigation departments. The past strategy on duplication (switching sources through the construction of pump stations) proved to be very costly and financially unsustainable for the Ferghana Province irrigation department [93]. Although these strategies could imply more water security through avoidance of transboundary dependence, the short and long term financial sustainability is questionable.

Although these strategies increase national water security they also increase the energy demand for supporting irrigated agriculture. Therefore these strategies move the water-energy nexus from the basin to the national or provincial level.

The different water security approaches after independence were: (1) introduction of winter wheat in 1995 (adjusting demand); (2) creation of WUAs in 2002 (direct security approach at the local level) and (3) infrastructure projects starting by 2010 (indirect security approach at the meso-level). None of these initiatives directly addressed the main water supply organizations. Hence, there was no direct security approach at the meso-level. It is likely that this was a conscious decision. Possibly for Uzbekistan the merger between the Ministry of Water Resources and the Ministry of Agriculture decreased the focus on water supply organizations. A direct security approach would have increased the potential power of the former Water Resources Ministry. However, since globally public irrigation management is viewed negatively and as having failed [26], it is likely that also from the donor side strengthening the irrigation departments was off the agenda. At least, looking at Kyrgyzstan, the donor community attempted to circumvent irrigation departments by establishing top-down "bottom-up" WUA federations for replacing irrigation departments (as in the case of World Bank projects) [121]. Nevertheless, it is not evident, how WUA federations would be able to take over managerial responsibility or would have the capacities to cover operation and maintenance costs, especially looking at the high past expenditures of the Ferghana Province Irrigation Department.

7. Conclusions

So far, neither polycentric water management nor water supply organizations (irrigation departments) have received broad international attention within the Syr Darya Basin. Instead, so far the main focus has been on the creation of WUAs at the local level and basin management at the international level. The implication is that there is a widening gap regarding promoted and actual water security approaches as well as a missing link, which in the past have been the province irrigation departments. Hence, by looking at meso-level water security ("irrigation districts" as well as irrigation departments) the paper has attempted to close an important gap of the current water security focus in the Syr Darya Basin.

Irrigation departments are negatively viewed as public sector organizations, and are perceived as having failed to adapt to wider socio-political or environmental changes [26]. However, the long term data on the Ferghana Province highlighted that the irrigation department was capable of adapting by increasing staffing and mobility as well as creating resilience through new infrastructure during the Soviet period. Only after independence and due to the economic crisis, the administrative changes (merger between the two Ministries) and possibly the exposure to the global "neo-liberal" donor community focusing on water user governance, led to the decline of the irrigation department's capacity. There is great potential for the current discourse on water security and the water, energy and food nexus to refocus attention to the challenges of existing water supply organizations. However, at least based on suggestions from some of the global literature [4,6], the essential element of water supply security, have been either taken for granted or overlooked. Similar, although Sadoff *et al.* [28] puts key emphasis on water supply organizations, the mentioned "institutional tripod" (water users, states and markets) might imply an emphasis on governance, without strengthening the capacity of the water supply

organizations first. The findings of the case study demonstrated the loss of technical and organizational water control and therefore the loss of the capacity of the irrigation department. The implication of not strengthening the water supply organizations are already evident; increased inequality of water distribution along the main canals, which negatively affects water distribution within WUAs. Given the already identified weaknesses of governance due to the diversity and power inequities of users, these inequities could further increase.

As indicated by our analysis the weakest link for water security is the public administrations, it is therefore essential to finally engage with the water bureaucracy. This calls for a comprehensive analysis regarding past and current internal as well as external challenges for the water bureaucracy for enabling its revitalization on key water security challenges. This call for revitalizing the water bureaucracy challenges the neo-liberal paradigm. Given that the bureaucracy is a public administration, a revitalization will not be possible in a piecemeal approach of donor sponsored "projects" (like the SDC and GIZ project mentioned in the case study) but instead calls for a long-term approach for reinvestment and modernization and therefore strengthening the public administration.

Acknowledgments

During the article preparation, Kai Wegerich was based at the International Water Management Institute (IWMI). The data analyzed in this article were gathered during IWMI's Irrigation Bureaucracy project in Central Asia funded by the Consultative Group on International Agricultural Research (CGIAR-wide) Research Program on Water, Land and Ecosystems (WLE).

Author Contributions

Kai Wegerich developed the initial and final versions of the framework, analyzed the data, organized the systematic discussion and led the drafting process of the manuscript. He incorporated the study incorporating the contributions from co-authors as well as from reviewers at TU Berlin and IWMI. Daniel Van Rooijen provided substantial comments on the initial framework section as well as the initial version of the manuscript. Ilkhom Soliev and Nozilakhon Mukhamedova contributed by providing their expertise and insights on the study area as well as on transboundary arrangements as well as local level land and water reforms.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Wolf, A. Conflict and cooperation along international waterways. *Water Policy* **1998**, *1*, 251–265.
2. Deininger, R.A; Meier, P.G. Sabotage of public water supply systems. In *Security of Public Water Supplies*; Deininger, R.A., Literathy, P., Bartram, J., Eds.; Springer: Berlin, Germany, 2000; pp. 241–248.
3. Gleick, P.H. Water and terrorism. *Water Policy* **2006**, *8*, 481–503.

4. United Nations University. *Water Security and the Global Water Agenda, a UN-Water Analytical Brief*; United Nations University: Hamilton, PA, USA, 2013.
5. Grey, D.; Sadoff, C. Sink or swim? Water security for growth and development. *Water Policy* **2007**, *9*, 545–571.
6. Hoff, H. Understanding the Nexus. In Proceedings of the Bonn Conference: The Water, Energy and Food Security Nexus, Stockholm, Sweden, 16–18 November 2011.
7. Faures, J.M.; Svendson, M.; Turral, H. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*; Earthscan: London, UK, 2007; pp. 353–394.
8. Tortajada, C.; Biswas, A.K. Editorial: Infrastructure and development. *Int. J. Water Resour. Dev.* **2014**, *30*, 3–7.
9. Lankford, B.; Hepworth, N. The cathedral and the bazaar: Monocentric and polycentric river basin management. *Water Altern.* **2010**, *3*, 82–101.
10. Lautze, J.; Wegerich, K.; Kazbekov, J.; Yakubov, M. International river basin organizations: Variation, options and insights. *Water Int.* **2013**, *38*, 30–42.
11. Wescoat, J.L.; Halvorson, S.J.; Mustafa, D. Water management in the Indus basin of Pakistan: A halfcentury perspective. *Int. J. Water Resour. Dev.* **2000**, *16*, 391–406.
12. Stucki, V.; Sojamo, S. Nouns and numbers of the water-energy-security nexus in central Asia. *Int. J. Water Resour. Dev.* **2012**, *28*, 399–418.
13. Granit, J.; Jägerskog, A.; Lindström, A.; Björklund, G.; Bullock, A.; Löfgren, R.; de Gooijer, G.; Pettigrew, S. Regional options for addressing the water, energy and food nexus in central Asia and the Aral sea basin. *Int. J. Water Resour. Dev.* **2012**, *28*, 419–432.
14. Wegerich, K.; Kazbekov, J.; Kabilov, F.; Mukhamedova, N. Meso-level cooperation on transboundary tributaries and infrastructure in the Ferghana Valley. *Int. J. Water Resour. Dev.* **2012**, *28*, 525–543.
15. Pak, M.; Wegerich, K.; Kazbekov, J. Re-examining conflict and cooperation in central Asia: A case study from the Isfara river, Ferghana Valley. *Int. J. Water Resour. Dev.* **2014**, *30*, 230–245.
16. Pak, M.; Wegerich, K. Competition and benefit sharing in the Ferghana Valley: Soviet negotiations on transboundary small reservoir construction. *Cent. Asian Aff.* **2014**, *1*, 225–246.
17. Soliev, I.; Wegerich, K.; Kazbekov, J. The costs of benefit sharing: Historical and institutional analysis of shared water development in the case of the Ferghana Valley in the Syr Darya basin. *Water* **2015**, 7, 2728–2752.
18. Ertsen, M.W. Colonial irrigation: Myths of emptiness. *Landsc. Res.* **2006**, *31*, 147–167.
19. Ertsen, M.W. The development of irrigation design schools or how history structures human action. *Irrig. Drain.* **2007**. *56*, 1–19.
20. Vermillion, D.L. Impacts of Irrigation Management Transfer: A Review of the Evidence. Available online: http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub011/REPORT11.PDF (accessed on 7 February 2007).
21. Water Sector Policy Review and Strategy Formulation: A General Framework. Available online: http://www.fao.org/docrep/v7890e/v7890e00.htm (accessed on 9 February 2007).
22. Irrigation Management Transfer: Worldwide Efforts and Results. Available online: http://www.fao.org/3/a-a1520e.pdf (accessed on 21 April 2014).

23. Irrigation Reform in Asia: A review of 108 Cases of Irrigation Management Transfer. Available online: https://ideas.repec.org/p/iwt/rerpts/h042851.html (accessed on 20 April 2014).
24. Wegerich, K.; Warner, J.; Tortajada, C. Water sector governance: A return ticket to anarchy. *Int. J. Water Gov.* **2014**, *2*, 7–20.
25. Rap, E.; Wester, P. The practices and politics of making policy: Irrigation management transfer in Mexico. *Water Altern.* **2013**, *6*, 506–531.
26. Surhardiman, D.; Giordano, M. Is there an alternative for irrigation reform? *World Dev.* **2014**, *57*, 91–100.
27. Molle, F.; Mollinga, P.P.; Wester, P. Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power. *Water Altern.* **2009**, *2*, 328–349.
28. Spoor, M.; Krutov, A. XI. The power of water in a divided central Asia. *Perspect. Glob. Dev. Technol.* **2003**, *2*, 593–614.
29. Abdullaev, I.; de Fraiture, C.; Giordano, M.; Yakubov, M.; Rasulov, A. Agricultural water use and trade in Uzbekistan: Situation and potential impacts of market liberalization. *Int. J. Water Resour. Dev.* **2009**, *25*, 47–63.
30. Hirsch, D. Water User Associations in Uzbekistan: Theory and Practice. Ph.D. Thesis, University of Bonn, Cuvillier Verlag, Göttingen, Germany, June 2006.
31. Abdullaev, I.; Kazbekov, J.; Manthritilake, H.; Jumaboev, K. Water user groups in central Asia: Emerging form of collective action in irrigation water management. *Water Resour. Manag.* **2009**, *24*, 1029–1043.
32. Abdullaev, I.; Kazbekov, J.; Manthritilake, H.; Jumaboev, K. Participatory water management at the main canal: A case from South Ferghana canal in Uzbekistan. *Agric. Water Manag.* **2009**, *96*, 317–329.
33. Abdullaev, I.; Kazbekov, J.; Jumaboev, K.; Manthritilake, H. Adoption of integrated water resources management principles and its impacts: Lessons from Ferghana Valley. *Water Int.* **2009**, *34*, 230–241.
34. Nexus Nirvana or Nexus Nullity? A Dynamic Approach to Security and Sustainability in the Water-Energy-Food Nexus. Available online: http://steps-centre.org/wp-content/uploads/Water-and-the-Nexus.pdf (accessed on 30 April 2015).
35. Critical Infrastructure Partnership Advisory Council Water Sector Strategic Planning Working Group. Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/170644/28307_Cm_8583_v0_20.pdf (accessed on 29 April 2015).
36. Contest: The United Kingdom's Strategy for Countering Terrorism Annual Report. Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/170644/28307_Cm_8583_v0_20.pdf (accessed on 29 April 2015).
37. Lautze, J.; Manthrithilake, H. Water Security. In *Key Concepts in Water Resource Management*; Lautze, J., Ed.; Routledge: Oxford, UK, 2014.
38. Sadoff, C.W.; Hall, J.W.; Grey, D.; Aerts, J.C.J.H.; Ait-Kadi, M.; Brown, C.; Cox, A.; Dadson, S.; Garrick, D.; Kelman, J.; *et al. Securing Water, Sustaining Growth: Report of the GWP/OECD Task Force on Water Security and Sustainable Growth*; University of Oxford: Oxford, UK, 2015.

39. Saldías, C.; Boelens, R.; Wegerich, K.; Speelman, S. Losing the watershed focus: A look at complex community-managed irrigation systems in Bolivia. *Water Int.* **2012**, *37*, 744–759.
40. Dill, B.; Crow, B. The colonial roots of inequality: Access to water in urban East Africa. *Water Int.* **2014**, *39*, 187–200.
41. Boelens, R.; Seemann, M. Forced engagements: Water security and local rights formalization in Yanque, Colca Valley, Peru. *Hum. Organ.* **2014**, 73, 1–11.
42. Boelens, R. *The Shotgun Marriage: Water Security, Cultural Politics, and Forced Engagements between Official and Local Rights Frameworks*; Routledge: Oxford, UK, 2013.
43. Tortajada, C. Water management for a megacity: Mexico City metropolitan area. *AMBIO J. Hum. Environ.* **2003**, *32*, 124–129.
44. Molle, F.; Berkoff, J. *Cities Versus Agriculture: Revisiting Intersectoral Water Transfers, Potential Gains and Conflicts*; International Water Management Institute: Colombo, Sri Lanka, 2006.
45. Mukhamedova, N.; Wegerich, K. Integration of villages into WUAS—The rising challenge for local Water management in Uzbekistan. *Int. J. Water Gov.* **2014**, *2*, 153–179.
46. Earle, A. The role of cities as drivers of international transboundary water management processes. In *Water Security: Principles, Perspectives and Practices*; Routledge: Oxford, UK, 2013.
47. Allan, T.; Keulertz, M.; Woertz, E. The water-food-energy nexus: An introduction to nexus concepts and some conceptual and operational problems. *Int. J. Water Resour. Dev.* **2015**, *31*, 301–311.
48. Keulertz, M.; Woertz, E. Financial challenges of the nexus: Pathways for investment in water, energy and agriculture in the Arab world. *Int. J. Water Resour. Dev.* **2015**, *31*, 312–325.
49. Boelens, R.; Doornbos, B. The battlefield of water rights. rule making amidst conflicting normative frameworks in the ecuadorian highlands. *Hum. Organ.* **2001**, *60*, 343–355.
50. Swyngedouw, E. Dispossessing H_2O: The contested terrain of water privatization. *Capital. Nat. Soc.* **2005**, *16*, 81–98.
51. Wegerich, K. The Afghan water law: "A legal solution foreign to reality"? *Water Int.* **2010**, *35*, 298–312.
52. Dimitrov, R.S. Water, conflict and security: A conceptual minefield. *Soc. Nat. Resour.* **2002**, *15*, 677–691.
53. Zeitoun, M. The web of sustainable water security. In *Water Security: Principles, Perspectives and Practices*; Routledge: Oxford, UK, 2014.
54. Gleick, P.H. The changing water paradigm: A look at twenty-first century water resource development. *Water Int.* **2000**, *25*, 127–138.
55. Lankford, B. Infrastructure hydromentalities: Water sharing, water control and water (in) security in Lankford. In *Water Security: Principles, Perspectives and Practices*; Routledge: Oxford, UK, 2014; pp. 256–272.
56. Molden, D.J.; Vaidya, R.A.; Shrestha, A.B.; Rasul, G.; Shrestha, M.S. Water infrastructure for the Hindu Kush Himalayas. *Int. J Water Resour. Dev.* **2014**, *30*, 60–77.
57. Biswas-Tortajada, A. The Gujarat state-wide water supply grid: A step towards water security. *Int. J. Water Resour. Dev.* **2014**, *30*, 78–90.
58. Bottrall, A.F. Comparative Study of the Management and Organization of Irrigation Projects. Available online: http://documents.worldbank.org/curated/en/1981/05/438966/comparative-study-management-organization-irrigation-projects (accessed on 25 April 2015).

59. Chambers, R. *Managing Canal Irrigation*; Oxford & IBH Publishing: New Delhi, India, 1988.
60. Uphoff, N.T. *Managing Irrigation: Analyzing and Improving the Performance of Bureaucracies*; Sage publication: Thousand Oaks, CA, USA, 1991.
61. Uphoff, N.T. *Improving International Irrigation Management with Farmer Participation: Getting the Process Right*; Westview Press: Boulder, CO, USA, 1986.
62. Mollinga, P.P. *On the Water Front*; Orient Longman: New Delhi, India, 2003.
63. Ali, I. *The Punjab under Imperialism 1885–1947*; Princeton University Press: Princeton, NJ, USA, 1988.
64. Bolding, A.; Mollinga, P.P.; van Straaten, K. Modules for modernization: Colonial irrigation in India and the technological dimension of agrarian change. *J. Dev. Stud.* **1995**, *31*, 805–844.
65. Ul-Haq, A. *Case Study of the Punjab Irrigation Department*; International Water Management Institute: Colombo, Sri Lanka, 1998.
66. Wade, R. Irrigation reform in the conditions of populist anarchy: An Indian case. *J. Dev. Econ.* **1984**, *14*, 285–303.
67. Deininger, R.A.; Literathy, P.; Bartram, J. *Security of Public Water Supplies*; Springer: Berlin, Germany, 2000.
68. Davis, J.; Whittington, D. Challenges for water sector reform in transition economies. *Water Policy* **2004**, *6*, 381–395.
69. Managing Singapore's Water. Available online: http://www.businesstimes.com.sg/opinion/managing-singapores-water (accessed on 24 April 2015).
70. Wegerich, K. Shifting to hydrological/hydrographic boundaries: A comparative assessment of national policy implementation in the Zerafshan and Ferghana Valleys. *Int. J. Water Resour. Dev.* **2015**, *31*, 88–105.
71. Bakker, K. Archipelagos and networks: Urbanization and water privatization in the South. *Geogr. J.* **2003**, *169*, 328–341.
72. Shah, T. *Taming the Anarchy: Groundwater Governance in South Asia*; Routledge: Oxford, UK, 2010.
73. Molle, F.; Wester, P.; Hirsch, P. River basin closure: Processes, implications and responses. *Agric. Water Manag.* **2010**, *97*, 569–577.
74. Saiko, T.A.; Zonn, I.S. Irrigation expansion and dynamics of desertification in the Circum-Aral region of Central Asia. *Appl. Geogr.* **2000**, *20*, 349–367.
75. Zonn, I.S.; Glantz, M.; Kosarev, A.N.; Kostianoy, A.G. *The Aral Sea Encyclopedia*; Springer: Berlin, Germany, 2009.
76. Kasymova, V. National Constraining Factors to the Agreement on Water and Energy Use in the Syr Darya Basin. Available online: http://rmportal.net/library/content/tools/environmental-policy-and-institutional-strengthening-epiq-iqc/epiq-environmental-policy-and-institutional-strengthening-cd-vol-1/epiq-cd-1-tech-area-dissemination-of-policy-knowledge-environmental-communication/national-constraining-factors-to-the-agreement-on-water-and-energy-use-in-the-syr-darya-basin-the-tajik-republic/view (accessed on 30 January 2015).
77. Weinthal, E. Sins of omission: Constructing negotiating sets in the Aral Sea basin. *J. Environ. Dev.* **2001**, *10*, 50–79.
78. The World Bank. *Water Energy Nexus in Central Asia: Improving Regional Cooperation in the Syr Darya Basin, Europe and Central Asia Region*; The World Bank: Washington, DC, USA, 2004.

79. Ryabtsev, A.D. Threats to Water Security in the Republic of Kazakhstan in the Transboundary Context and Possible ways to Eliminate them. 2008. Available online: http://www.icwc-aral.uz/workshop_march08/pdf/ryabtsev_en.pdf (accessed on 7 February 2009).
80. Libert, B.; Orolbaev, E.; Steklov, Y. Water and energy crisis in central Asia. *China Eurasia Forum Q*. **2008**, *6*, 9–20.
81. Antipova, E.; Zyryanov, A.; McKinney, D.; Savitsky, A. Optimization of Syr Darya water and energy uses. *Water Int.* **2002**, *27*, 504–516.
82. McKinney, D.; Kenshimov, A.K. Optimization of the Use of Water and Energy Resources in the Syr Darya Basin under Current Conditions. Available online: http://www.caee.utexas.edu/prof/mckinney/papers/aral/00-06-W/00-06-W_eng/Vol-1/Front1e.htm (accessed on 24 April 2015).
83. Wegerich, K.; Kazbekov, J.; Lautze, J.; Platonov, A.; Yakubov, M. From monocentric ideal to polycentric pragmatism in the Syr Darya: Searching for second best approaches. *Int. J. Sustain. Soc.* **2012**, *4*, 113–130.
84. Pak, M. International River Basin Management in the Face of Change: Syr Darya Basin Case Study. Ph.D. Thesis, Oregon State University, Corvallis, OR, USA, November 2014.
85. Strengthening Cooperation for Rational and Efficient Use of Water and Energy Resources in Central Asia. Available online: http://www.unece.org/fileadmin/DAM/env/water/damsafety/effuse_en.pdf (accessed on 10 May 2010).
86. Wegerich, K. Have your cake and eat it too: Agenda setting in central Asian transboundary rivers. In *Water, Environmental Security and Sustainable Rural Development: Conflict and Cooperation in Central Eurasia*; Arsel, M., Spoor, M., Eds.; Routledge: Oxford, UK, 2010.
87. Dukhovny, V.A.; Sorokin, A.G.; Tuchin, A.I.; Sorokin, D.A; Temlyantseva, Y. Concept of Integrated Model for Chirchik-Ahangaran-Keles Sub-Basin. Available online: http://cawater-info.net/rivertwin/documents/pdf/concept6_e.pdf (accessed on 30 March 2015).
88. Dukhovny, V.A.; Sorokin, A.G.; Tuchin A.I.; Rysbekov U.H.; Stulina G.V.; Nerosin S.A.; Rusiev, I.B.; Sorokin, D.A.; Katz, A.; Shahov, V.; Solodky, G. A regional model for integrated water management in twinned river basins. Available online: http://s3.amazonaws.com/zanran_storage/www.rivertwin.de/ContentPages/2493962769.pdf (accessed on 30 March 2015).
89. Rysbekov, Y.K. Rivertwin Central Asia: The basic Results of Work Package 7. Available online: http://www.cawater-info.net/rivertwin/documents/pdf/rysbekov2_presentation_e.pdf (accessed on 30 March 2015).
90. Benjaminovich, Z.M.; Tersitskiy, D.K. *Irrigation of Uzbekistan II*; Fan Publishing House: Tashkent, Uzbekistan, 1975. (In Russian)
91. Weinthal, E. *State Making and Environmental Cooperation*; The MIT Press: Cambridge, MA, USA, 2002.
92. Wegerich, K.; Kazbekov, J.; Mukhamedova, N.; Musayev, S. Is it possible to shift to hydrological boundaries? The ferghana valley meshed system. *Int. J. Water Resour. Dev.* **2012,** *28*, 545–564.
93. Wegerich, K.; Soliev, I.; Akramova, I. Estimation of the long term costs to cope with upstream irrigation expansion in the transboundary setting of Ferghana Province. *Int. J. Water Gov*. **2015**, submitted for publication.

94. Dukhovny, V.A. Water and globalization: Case study of Central Asia. *Irrig. Drain.* **2007**, *56*, 489–507.
95. Central Asia: Water and conflict. Available online: http://www.crisisgroup.org/en/regions/asia/central-asia/034-central-asia-water-and-conflict.aspx (accessed on 9 December 2014).
96. Ferghana Province Irrigation Department. *Annual Reports 1978–2010*; Ferghana Province Irrigation Department: Ferghana, Uzbekistan, 2011.
97. Bucknall, J.; Klytchnikova, I.; Lampietti, J.; Lundell, M.; Scatasta, M.; Thurman, M. Irrigation in Central Asia: Social, Economic and Environmental Considerations. Available online: http://siteresources.worldbank.org/ECAEXT/Resources/publications/Irrigation-in-Central-Asia/Irrigation_in_Central_Asia-Full_Document-English.pdf (accessed on 5 October 2014).
98. Law of the Republic of Uzbekistan. *On Dehkan Farms*; No. 654-XII; The Senate of the Republic of Uzbekistan: Tashkent, Uzbekistan, 1992. (In Uzbekistan)
99. Law of the Republic of Uzbekistan. *On Farms*; No. 599-I; The Senate of the Republic of Uzbekistan: Tashkent, Uzbekistan, 1998. (In Uzbekistan)
100. Orders of Cabinet of Ministers and Presidential Decree. *On Measures to Further Optimize the Size of Land Plots of Farms*; No. F-3287 and F-3212; The Senate of the Republic of Uzbekistan: Tashkent, Uzbekistan, 2009. (In Uzbekistan)
101. Dukhovny, V.A.; de Schuetter, J.L.G. *Water in Central Asia: Past, Present, Future*; CRC Press: Boca Raton, MA, USA, 2011.
102. Anderson, J. *The International Politics of Central Asia*; Manchaster University Press: Manchaster, UK, 1997.
103. Pomfret, R. Agrarian reform in Uzbekistan: Why has the Chinese model failed to deliver? *Econ. Dev. Cult. Chang.* **2002**, *48*, 269–282.
104. Djanibekov, N.; Rudenko, I.; Lamers, J.P.A.; Bobojonov, I.; Pros and cons of cotton production in Uzbekistan, case study of the program: "Food policy for development countries: The role of government in the global food system. 2010. Available online: http://chatt.hdsb.ca/~blairj/course_files/FOV1-001625C2/cotton%20case%20study.pdf (accessed on 14 January 2014).
105. Platonov, A.; Wegerich, K.; Kazbekov, J.; Kabilov, F. Beyond the state order? Second crop production in the Ferghana Valley, Uzbekistan. *Int. J. Water Gov.* **2014**, *2*, 83–104.
106. Resolution of the Cabinet of Ministers Republic of Uzbekistan. *On Measures for the Reorganization of Agricultural Enterprises into Farms*; No. 8; Cabinet of Ministers Republic of Uzbekistan: Tashkent, Uzbekistan, 2002. (In Uzbekistan)
107. Swiss Agency for Development and Cooperation (SDC). *Regional Water Sector Programme Central Asia—Water Management Backstopping (Irrigation)*; Swiss Agency for Development and Cooperation: Bern, Switzerland, 2008.
108. Abdullaev, I.; Rakhmatullaev, S.; Platonov, A.; Sorokin, D. Improving water governance in central Asia through application of data management tools. *Int. J. Environ. Stud.* **2012**, *69*, 151–168.
109. Thurman, M. *Irrigation and Poverty in Central Asia: A Field Assessment*; World Bank Group: Washington, DC, USA, 2001.
110. Wegerich, K. Organizational problems of water distribution in Khorezm, Uzbekistan. *Water Int.* **2004**, *29*, 130–137.

111. Wegerich, K. What happens in a merger? Experiences of the state department for water resources in Khorezm, Uzbekistan. *Phys. Chem. Earth* **2005**, *30*, 455–462.
112. Yalcin, R.; Mollinga, P.P. Institutional Transformation in Uzbekistan's Agricultural and Water Resources Administration: The Creation of a New Bureaucracy. Available online: http://www.econstor.eu/dspace/handle/10419/88374 (accessed on 11 June 2008).
113. Djalalov, A.A.; Mirzaev, N.N.; Horst, M.G.; Stulina, G.V.; Abdurazakov, Z.B.; Ergashev, O.; Khoshimov, A.; Rasulov, F.; Alesandrova, N.G. *Comprehensive Hydrographic Study of the Ferghana Valley: Vision of the Integrated Water Resources Management based on the IWRM-FV Project Experience in Uzbekistan*; Scientific Information Centre of the Interstate Commission on Water Coordination: Tashkent, Uzbekistan, 2011.
114. Dukhovny, V.A.; Sokolov, V.I.; Galustyan, A.; Djalalov, A.A.; Mirzaev, N.N.; Horst, M.G.; Stulina, G.V.; Muminov, S.; Ergashev, I.; Kholikov, A.; *et al. Report on Comprehensive Hydrographic Study of the Ferghana Valley*; Scientific Information Centre of the Interstate Commission on Water Coordination: Tashkent, Uzbekistan, 2012.
115. Suhardiman, D.; Giordano, M.; Rap, E.; Wegerich, K. Bureaucratic reform in irrigation: A review of four case studies. *Water Altern.* **2014**, *7*, 442–463.
116. Bichsel, C. *Conflict Transformation in Central Asia: Irrigation Disputes in the Ferghana Valley*; Routledge: Oxford, UK, 2009.
117. Inagamov, S.R. The Uzbek model, the Sunday Indian. Available online: http://www.thesundayindian.com/en/story/the-uzbek-model/7/26310/ (accessed on 5 July 2014).
118. Peyrouse, S. *The Russian Minority in Central Asia: Migration, Politics, and Language*; Woodrow Wilson International Center for Scholars: Washington, DC, USA, 2008.
119. Taube, G.; Zettelmeyer, J. Output Decline and Recovery in Uzbekistan: Past Perfarmance and Future Prospects. Available online: https://www.imf.org/external/pubs/cat/longres.aspx?sk=2745.0 (accessed on 14 August 2014).
120. Kandiyoti, D. Poverty in transition: An ethnographic critique of household surveys in post-soviet central Asia. *Dev. Chang.* **1999**, *30*, 499–524.
121. WUA Workshop-Country Summary: Kyrgyz Republic. Available online: http://go.worldbank.org/W02GK2LE70 (accessed on 2 May 2015).