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Evaluating planning and delivery performance of Water User Associations (WUAs) in Osh Province, Kyrgyzstan

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ABSTRACT

The primary objective of an irrigation organization is to provide efficient and effective management of water resources to achieve enhanced agricultural production. Performance assessment studies provide a tool to evaluate and promote this objective. The study examines the existing planning procedures and assesses irrigation performance of four Water User Associations (WUAs) located in Osh Province, Kyrgyzstan. Performance was evaluated using indicators of adequacy, efficiency, dependability and equity. Indicators were calculated for each irrigation season over the period 2003 to 2007. In general, all WUAs were found to be strong in terms of adequacy and efficiency standards. However, performance with respect to dependability and equity was poor. The results suggest that more effort is needed to improve temporal uniformity and equity in water distribution. In order to achieve this, estimations of irrigation requirements by WUA managers needs to be improved and mechanisms developed to request water in quantities, which are needed to maintain equity across the WUA outlets and among water users. The study concludes that the establishment of WUAs in Kyrgyzstan has helped to address the problem of water distribution and allocation among a large number of farmers. However, further training of farmers and managers is required to build their capacity to share water and ensure equity among users particularly during periods of less than optimal water supply. The findings of this research suggest that application of a pre-determined set of indicators can be a useful and cost effective tool to measure the performance of WUAs. This is particularly important for Central Asia where the performance of the recently established and state initiated WUAs to replace former collective farms is now a key element in future sustainable water management. The study identified uncertainties in the estimation of WUA water demands based on previous methods and suggests more attention and care required in calculating water requirements.

1. Introduction

In order to increase agricultural production in Kyrgyzstan, the Soviet administration initiated an expansion program of the irrigation sector in 1945 that resulted in the irrigated area growing from 200,000 to over 1 million ha by 1990. After independence from the Soviet Union in 1991, Kyrgyzstan introduced agricultural reforms that resulted in the dismantling of collective farms (*kolkhozes*)[1] and the establishment of small farmers with average land sizes ranging from 1.5 ha for individual farmers to 670 ha for cooperatives (Abdullaev et al., 2006). Due to these land and agrarian reforms, approximately 53% of the population (each citizen who reached the age of 18 at that time) was allotted their own parcels of land. Rural committees coordinated the process. The size of land depended on the number of family members at the time of allocation. These parcels of land are effectively on a 99-year lease from the state with land certificates being issued to the family head with names of other family members who would take over the lease. While land cannot be sold, farmers can form farmers associations and cooperatives and have no restrictions on the crops they produce and sell into markets. There is no state order system for crop production (DFID, 2003).

Soon after the former Kolkhozes were dismantled, it became glaringly evident that there were no institutional structures that were responsible for on-farm irrigation (Johnson and Stoutjesdijk,

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[1] Kolkhoz (Russian): A collective owned farm (semi-state and self sufficient) comprising farmers, agricultural experts and farm laborers. They are all responsible for collective management of the production system and delivery of targeted outputs to the state.

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2008). This situation resulted in chaos and anarchy in water delivery from district water departments to individual farmers (Yakubov and Ul Hassan, 2007; Abdullaev et al., 2006).

To address this impasse, individual farmers attempted to rectify problems associated with water delivery but due to a lack of technical and financial resources these efforts failed. In some cases water users created hydro-services by recruiting former irrigation brigade staff, while other water users formed informal farmers' organizations to address problems farmers faced in managing their on-farm irrigation needs. These organizations were formed without any technical assistance and had no legal basis to function as participatory farmer organizations (Johnson and Stoutjesdijk, 2008). In 1997, the Government passed a bill that encouraged the establishment of Water User Associations (WUAs). This bill was upgraded into a law in 2002, which provided the basis for established WUAs to take over on-farm irrigation water management and infrastructure development. Currently there are 450 registered WUAs in the country covering an area of approximately 710,000 ha with more than 166,000 members (Herrfahrdt et al., 2006). Most of these WUAs were established in 2003–2004 and now play an important role in the allocation and distribution of irrigation water, the collection of irrigation service fees and the maintenance of the irrigation infrastructure. However, the degree of functionality of these fledgling institutions is still fraught with serious problems and deficiencies that include: (i) provision of irrigation water to the numerous water users, (ii) sustaining crop yields and productivity of water in mostly subsistence farming systems, (iii) ability of small farmers to support WUAs through irrigation service fees and (iv) institutional sustainability of WUAs (Abdullaev et al., in press).

To improve the effectiveness of WUAs and to ensure that they are more compatible with the local situation, it is important to review their progress and difficulties that they face. One of the fundamental tasks of a WUA is to accurately plan irrigation water requirements for the growing season and ensure the implementation of the plan, e.g. to deliver and distribute water among farmers. An important aspect in assessing the performance of the plan is to assess delivery of water against the set targets as estimated in the plan. Proper planning skills, together with appropriate monitoring of actual flows (measured or collected), convert a performance assessment into a useful management tool (Murray-Rust and Snellen, 1993).

A number of studies have been undertaken on performance assessment of irrigation systems under a range of management regimes (Abernethy, 1986; Chambers, 1988; Molden and Gates, 1990; Bos et al., 1994; Meinzen-Dick, 1995; Bos et al., 2005). These studies have focused on defining performance indicators, calculation and development of guidelines for practitioners (Gorantiwar and Smout, 2005; Bos et al., 2005). These indicators are divided into two main groups: internal – to assess the water allocation (Molden and Gates, 1990; Bos et al., 1994) and external – to assess outcomes of water allocation such as economic revenues, environmental impact and agricultural production (Molden et al., 1998). Indicators that include adequacy, efficiency, dependability and equity, that were proposed by Molden and Gates (1990) have been widely used to assess the performance of WUAs and tertiary canals by various researchers (Jahromi and Feyen, 2001; Unal et al., 2004; Vandersypen et al., 2006; Akkuzu et al., 2007).

In this study, four widely used performance indicators of Molden and Gates (1990) were used to evaluate general irrigation planning performance of four WUAs along the Aravan Akbura Main Canal in Osh Province of Kyrgyzstan. According to (Molden and Gates, 1990), these indicators are defined as follows, "the objective of (i) *adequacy* states the desire to deliver the required amount of water over the command area served by the system; the objective of water delivery (ii) *efficiency* embodies the desire to conserve water by matching water deliveries with water requirements; an indicator of the degree of (iii) *dependability* of water delivery is the degree of temporal variability in the ratio of amount required that occurs over a region; and (iv) if *equity* is interpreted as spatial uniformity of the relative amount of water delivered, then an appropriate measure of performance relative to equity would be the average relative spatial variability of the ratio of the amount delivered to the amount required over the time period of interest."

The evaluation of performance in this study was undertaken using data sets collected over 5 years (2003–2007). The planned irrigation supplies by WUAs were compared with the actual delivered amounts by the canal authority. To investigate the current irrigation planning methods that are used widely by WUAs, the plans were compared with the irrigation requirements calculated using the FAO method (Clarke et al., 1998). The study presents the short-term impacts of an institutional initiative adopted to better manage water, improve user participation and strengthen the role of WUAs following IWRM[2] principles in the Ferghana Valley since 2002. This evaluation of the performance of WUAs is unique for Central Asia in that the study draws upon actual data collected in the field. It is therefore anticipated that the results of this evaluation will be of assistance in improving the performance of WUAs in maintaining equitable irrigation water distribution, which is directly linked to sustained irrigated agriculture and the livelihoods of millions of poor farmers in this region.

2. Materials and methods

Osh Province is located in southern part of the Kyrgyzstan, covers an area of 2900 km^2 and has about 1.2 million inhabitants. The climate of the Osh is continental, i.e. summers are hot and winters are cold. The winter temperatures range between +20 and −30 °C. In July, average temperatures range from +25 to +37 °C. Mean annual rainfall varies between 1100 mm in the western Ferghana valley ridges to a mere 150 mm in Osh Province. Reference evapotranspiration (ETo) is 1034 mm, which clearly indicates that no agriculture in this area is possible without assured irrigation. The main sources of irrigation water for Osh Province are the Naryn River and two small rivers: the Akbura and Aravan Rivers. The Naryn is a main tributary of the Syrdarya River, which after passing through Uzbekistan and Kazakhstan discharges into the Aral Sea. The Akbura River feeds the Papan Reservoir, one of the key flow allocation structures in Osh Province with 260 million m^3 storage capacity. Water from the reservoir discharges into two irrigation systems – the Right Bank Canal and the Aravan Akbura Canal (AAC). The total length of the AAC canal is 44.7 km and serves the Karasu and Aravan Districts of the Osh Province. The total irrigated command area of AAC is 8477 ha, of which 4231 ha are in Karasu District, 2048 ha in Aravan District, 2048 ha in Osh City and 150 ha of other lands. In this study, four WUAs were selected (Table 1), Japalak, Jani-Arik, Isan and Murza-Aji, all located along the AAC, as shown in Fig. 1. These WUAs are responsible for the operation and maintenance of all secondary and tertiary canals; the development and implementation of the water allocation; and distribution plans for water users. Water is delivered to the fields by means of open channels. Wheat, vegetables, maize and cotton are the dominant agricultural crops. Furrow irrigation is widely used for irrigating crops.

2.1. Irrigation planning by WUAs

Irrigation planning by the WUAs is based on predefined tables of irrigation requirements (locally referred as *hydro-modules or*

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[2] IWRM refers to Integrated Water Resources Management.

Table 1
Selected characteristics of the WUAs included in this study.

Parameter	Water User Associations (WUAs)			
	Japalak	Jani-Arik	Isan	Murza-Aji
Establishment year	2003	2003	2003	2003
Command area (ha)	2012	1037	2070	1607
Main crops	Vegetables, maize, wheat	Vegetables, wheat, maize	Wheat, maize, vegetables	Wheat, vegetables, cotton
Number of water users	4876	832	3940	1490
Water source	Papan Dam	Papan Dam	Papan Dam	Papan Dam
Conveyance network	Open channel	Open channel	Open channel	Open channel
Control structure	Manual gates	Manual gates	Manual gates	Manual gates

irrigation regimes), which were prepared in 1970s by the Central Asian Research Institute for Cotton. The irrigation season begins on April 1 and lasts through to September. Calculation of irrigation requirements in these hydro-modules is based on average climatic conditions of the area, soil type, depth to groundwater table and crop water requirements (Legostaev and Mednis, 1971). Prior to the irrigation season, managers of each WUA collect the necessary information on cropped area and cropping patterns from ditch riders and farmers that allow the calculation of the decadal (each month is divided into three 10-day periods) and seasonal water requirements of the network under its control and associated infiltration losses in delivery channels. The WUA manager then submits the water plan to the Canal Management Organization (CMO). The CMO reviews the requested requirements against the water availability in the reservoir and makes necessary adjustments in the water plan for the cropping season. The adjustments (locally referred to as an *introduction of limited water supply*) are particularly important for periods of drought or relative water deficiency when demands exceed available water. The requested amounts in the plan are reduced proportionally by a specified coefficient set by the Ministry of Agriculture, Water and Processing Industry of the Kyrgyz Republic. Adjusted plans are approved by the CMO and serve as the basis to sign seasonal water delivery agreements between the CMO and WUAs. The CMO is responsible for supplying water to the WUA during the season taking into account the demand in relation to the capacity of the canals and actual requests made by individual farmers or water user groups (WUGs). WUGs are informal groups of farmers formed along the same tertiary, or served by the same outlet, with elected leaders (*Aryk Aksakals*) that receive water from WUAs and distribute it among its users. Each WUG, where they exist, is independent in deciding water distribution within their area. Mirabs (water masters) of WUA deliver water to the head of the tertiary block, from where the WUG leader delivers water to the fields of farmers where the water is needed according to the informal irrigation schedules – turns – set up by the farmers.

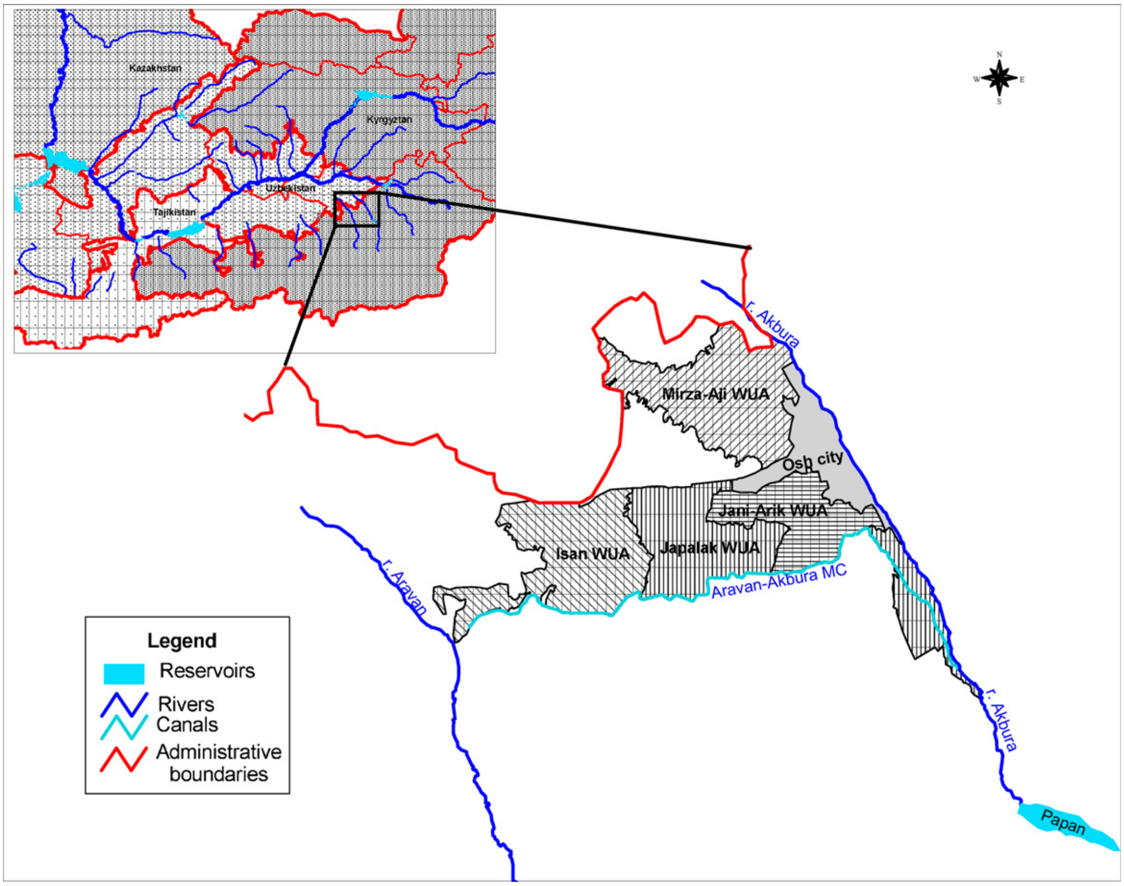

Fig. 1. Location of Osh Province, AAC and the four WUAs selected for this study.

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Table 2
Average monthly meteorological conditions of the study area (Osh Meteorological Station) for 2003–2007.

Month	Mean air temperature (C°)	Maximum air temperature (C°)	Minimum air temperature (C°)	Relative humidity (%)	Wind speed (m/s)	Precipitation (mm)	Sunshine duration (h/d)
1	0.3	4.1	–2.3	76.7	83.5	12.3	3.8
2	2.3	6.2	–0.6	73.7	103.7	19.6	4.9
3	8.2	12.0	5.2	70.3	115.2	25.3	4.3
4	15.5	19.8	11.5	62.3	126.7	28.2	6.3
5	20.1	25.2	15.2	54.0	129.6	22.0	8.8
6	25.5	31.0	20.4	47.3	129.6	11.5	9.7
7	27.7	33.5	22.2	45.3	112.3	3.4	11.2
8	25.3	31.3	19.8	47.3	106.6	2.2	10.1
9	21.0	27.4	15.5	53.3	89.3	4.2	9.6
10	14.3	20.1	9.9	62.7	83.5	8.6	7.8
11	5.8	10.4	2.8	77.0	74.9	12.1	4.6
12	2.2	6.1	-0.2	80.0	69.1	13.4	3.4

Table 3
Cropping pattern (area and percentage of coverage) by WUAs for 2003–2007.

WUAs	Planting date	Japalak (ha)	%	Jani-Arik (ha)	%	Isan (ha)	%	Murza-Aji (ha)	%
Wheat[a]	1 October	176	9	296	29	679	33	540	34
Maize	1 May	582	29	224	22	607	29	175	11
Cotton	20 March	0	0	0	0	90	4	370	23
Tobacco	10 May	0	0	26	3	24	1	2	0
Sunflower	15 April	100	5	100	10	183	9	25	2
Potato	1 April	108	5	18	2	77	4	98	6
Vegetables	10 April	951	47	312	30	282	14	379	24
Alfalfa	26 March	94	5	61	6	128	6	18	1
Total		2012	100	1037	100	2070	100	1607	100

[a] Crop water demand of wheat was considered only during the irrigation season for SWD calculations, which starts April 1–June 15, when the wheat is harvested.

2.2. Water requirement

CropWat 4 Windows Version 4.2 (Clarke et al., 1998) was used for calculation of water requirement. A computer program that uses the FAO Penman–Monteith method for calculating the reference crop evapotranspiration was used to calculate irrigation water requirement (Allen et al., 1998). Effective rainfall was calculated using the USDA Soil Conservation Service method (in Allen et al., 1998). The main reason for calculating seasonal water delivery requirements ($\mathrm{SWD}_{\mathrm{required}}$) for WUAs was to compare the required amounts with the currently planned and actually delivered water to identify general trends and differences. For this, a hypothetical water requirement for each WUA and year was calculated using the average climatic and cropping pattern data for the five-year period (2003–2007) and further used for other calculations. The climatic conditions for the four WUAs were very similar so the average values were used for calculations using data provided by the Osh Meterological Station for 2003–2007 (Table 2). Average data on cropping pattern and planting dates are presented in Table 3, which were taken from the WUA Registries. The calculations of $\mathrm{SWD}_{\mathrm{required}}$ were undertaken for the 6-month irrigation season for the same period over the five years (2003–2007). Only the main cropping season was considered in the water requirement calculations due to a limited number of farmers growing a second crop. Previous studies have indicated that only 3% of farmers surveyed in WUA Isan grow vegetables during the second crop season (Yakubov, 2006).

2.3. Planned and actual water deliveries

Evaluations of each of the WUAs in this study were undertaken over the period 2003–2007 using decadal (10-day periods) and seasonal data for planned and actual deliveries of irrigation water for all four WUAs. The data were collected from the Water Planning Department of the CMO of the AAC and cross-checked with WUAs' approved water use plans. The data on actual deliveries were obtained from *WUA Water Journals*, which contain certified details of actual flows received by the WUA from the CMO.

The seasonal amounts of actual, planned and required water delivery data per unit of irrigated area per season ($\mathrm{m}^3\ \mathrm{ha}^{-1}\ \mathrm{season}^{-1}$) are given in Table 4. These data where mainly used to compare planned ($\mathrm{SWD}_{\mathrm{planned}}$), required ($\mathrm{SWD}_{\mathrm{required}}$) and actual water deliveries ($\mathrm{SWD}_{\mathrm{actual}}$) per hectare to evaluate the current planning performance of the WUAs as well as to calculate two performance indicators i.e. adequacy (A_{WD}) and efficiency ($\mathrm{EF}_{\mathrm{WD}}$).

WUA irrigation planning and delivery of water by the CMO is undertaken in decadal format. Thus, the descriptive statistical

Table 4
Seasonal water delivery data per unit irrigated area ($\mathrm{SWD}_{\mathrm{actual}}$, $\mathrm{SWD}_{\mathrm{planned}}$ and $\mathrm{SWD}_{\mathrm{required}}$) ($\mathrm{m}^3\ \mathrm{ha}^{-1}\ \mathrm{season}^{-1}$).

Year	Parameter	WUAs			
		Japalak	Jani-Arik	Isan	Murza-Aji
2003	$\mathrm{SWD}_{\mathrm{actual}}$	4603	8569	8673	14930
	$\mathrm{SWD}_{\mathrm{planned}}$	10379	11556	19343	18517
	$\mathrm{SWD}_{\mathrm{required}}$	4761	5128	5574	5650
2004	$\mathrm{SWD}_{\mathrm{actual}}$	5458	9586	8053	12761
	$\mathrm{SWD}_{\mathrm{planned}}$	8717	8139	7983	7134
	$\mathrm{SWD}_{\mathrm{required}}$	4761	5128	5574	5650
2005	$\mathrm{SWD}_{\mathrm{actual}}$	4236	6871	8074	11477
	$\mathrm{SWD}_{\mathrm{planned}}$	7969	9544	8193	10562
	$\mathrm{SWD}_{\mathrm{required}}$	4761	5128	5574	5650
2006	$\mathrm{SWD}_{\mathrm{actual}}$	4371	5536	6343	11477
	$\mathrm{SWD}_{\mathrm{planned}}$	7969	6893	8193	10562
	$\mathrm{SWD}_{\mathrm{required}}$	4761	5128	5574	5650
2007	$\mathrm{SWD}_{\mathrm{actual}}$	4230	4509	6987	11898
	$\mathrm{SWD}_{\mathrm{planned}}$	7969	5580	8193	13409
	$\mathrm{SWD}_{\mathrm{required}}$	4761	5128	5574	5650

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Table 5
The statistical summary of the decadal values of water delivery data (WD_{actual}, $WD_{planned}$ and $WD_{required}$) (10^3 m^3).

WUA	Parameter	n	Average	StDev[a]	C_v[b]
Japalak	WD_{actual}	90	495	294	0.59
	$WD_{planned}$	90	983	279	0.28
	$WD_{required}$	90	532	347	0.65
Jani-Arik	WD_{actual}	90	404	264	0.65
	$WD_{planned}$	90	481	194	0.40
	$WD_{required}$	90	295	192	0.65
Isan	WD_{actual}	90	877	612	0.70
	$WD_{planned}$	90	1248	646	0.52
	$WD_{required}$	90	641	394	0.61
Murza-Aji	WD_{actual}	90	1096	599	0.55
	$WD_{planned}$	90	1028	574	0.56
	$WD_{required}$	90	504	296	0.59

[a] StDev represents standard deviation.
[b] C_v represents coefficient of variation.

summary of the decadal data associated with planned, required and actual water deliveries (10^3 m^3) for all four WUAs during the study period of 2003–2007 is presented in Table 5. There are three decades per month and a 6-month irrigation season per year, which makes 18 decades annually, and 90 decades over a 5-year period. Average values of actual, planned and required water volumes (10^3 m^3) range from 400 to 1100, from 480 to 1200, and from 400 to 650, respectively. The coefficient of variation of actually delivered water volume ranged between 55% and 70%, the planned and required – from 28% to 56% and from 59% to 65%, respectively. The decadal data on water deliveries were used to calculate two other performance indicators – dependability (D_{WD}) and equity (EQ_{WD}).

2.4. Performance indicators

A_{WD} assesses to what extent delivered irrigation water met requirements or, in other words, whether water allocated was sufficient for crops (Molden and Gates, 1990). In this study, A_{WD} was calculated as the ratio of the amount of water given to each WUA per season (SWD_{actual}) (m^3 ha^{-1} $season^{-1}$) to the amount required ($SWD_{required}$) based on calculations by the FAO method using CropWat (m^3 ha^{-1} $season^{-1}$), expressed as a dimensionless value:

$$A_{WD} = \frac{SWD_{actual}}{SWD_{required}} \quad (1)$$

Calculated A_{WD} values were interpreted in the following manner: if $A_{WD} < 1.0$, the water delivered is inadequate in relation to the required; if $A_{WD} \geq 1.0$, water delivery is adequate.

EF_{WD} expresses the desire to conserve water resources by bringing water requirements and water delivery into accord. In other words, it answers the question of whether there is excessive delivery of water (Molden and Gates, 1990). In this analysis, the EF_{WD} was calculated as the ratio of the amount required (by FAO method) for the irrigation season ($SWD_{required}$) (m^3 ha^{-1} $season^{-1}$) to the amount delivered (SWD_{actual}) (m^3 ha^{-1} $season^{-1}$), expressed as a percentage, as shown in the following formula:

$$EF_{WD} = \frac{SWD_{required}}{SWD_{actual}} \quad (2)$$

Efficiency values were evaluated as follows: if $EF_{WD} \geq 1.0$, water delivery was efficient according to the which is required and if $EF_{WD} < 1.0$, it was not efficient. In principle, there is a reciprocal relationship between the adequacy and efficiency measures. For example, if $EF_{WD} > 1.0$, water delivery was efficient but inadequate. If $EF_{WD} < 1.0$, water delivery is adequate but not efficient. Under ideal conditions of adequacy ($A_{WD} = 1.0$), it is also ideal with respect to efficiency.

Table 6
Performance standard.

Indicators	Good	Fair	Poor
A_{WD}[a]	0.90–1.00	0.80–0.89	<0.80
EF_{WD}[b]	0.85–1.00	0.70–0.84	<0.70
D_{WD}[c]	0.00–0.10	0.11–0.20	>0.20
EQ_{WD}[d]	0.00–0.10	0.11–0.25	>0.25

[a] Adequacy.
[b] Efficiency.
[c] Dependability.
[d] Equity.

D_{WD} indicates the temporal uniformity in the ratio of amounts of water delivered to amounts of water planned (Molden and Gates, 1990). This indicator is determined by calculating the coefficients of variation (C_v) for the ratio of actual water delivered (m^3 $decade^{-1}$) in the irrigation season (April–September) (WD_{actual}) to required delivery (m^3 $decade^{-1}$) ($WD_{required}$) in the same season (Jahromi and Feyen, 2001). When C_v tends towards zero, this indicates that water delivery was uniform from decade to decade. D_{WD} is the degree of temporal variability of adequacy over the region (R), in our case these are secondary canals:

$$D_{WD} = \frac{1}{R}\sum_{R} C_{v_T}(A_{WD}) \quad (3)$$

$C_{v_T}(A_{WD})$ – temporal coefficient of variation of the adequacy over the time period T.

EQ_{WD} addresses the question of extent of fairness of water distribution between users (Molden and Gates, 1990) and indicates the spatial variation of A_{WD} values. EQ_{WD} was calculated using the following formula:

$$D_{WD} = \frac{1}{T}\sum_{T} C_{v_R}(A_{WD}) \quad (4)$$

$C_{v_R}(A_{WD})$ – spatial coefficient of variation of the adequacy over the region R, e.g. over the secondary outlets.

If EQ_{WD} values were close to or equal to zero, this would suggest that water was delivered equitably between associations according to the water delivery plan.

In practice, it is usually impossible to achieve the ideal targets, hence performance standards we used (Table 6) were adopted from Molden and Gates (1990), which set acceptable and unacceptable limits for A_{WD}, EF_{WD}, D_{WD} and EQ_{WD}.

3. Results and discussions

3.1. Comparison of planned, required and actual water deliveries

Fig. 2 compares the average values of required, actual and planned deliveries of water during the irrigation season for each WUA (m^3 ha^{-1} $season^{-1}$) during the study period of 2003–2007. The required amounts, calculated using the FAO method, were similar due to almost identical soil, crop and climate conditions across all WUAs and ranged between 4700 and 5600 (m^3 ha^{-1} $season^{-1}$) during 2003–2007. The actual water delivered in response to the WUA requests suggests that all WUAs received allocations that are in close agreement to the amounts required and ranged between 4500 and 7600 m^3 ha^{-1} $season^{-1}$ in all cases except WUA Murza-Aji. Murza-Aji, in general received more water than required (up to 12,500 m^3 ha^{-1} $season^{-1}$) in order to compensate for conveyance losses as this WUA is located some

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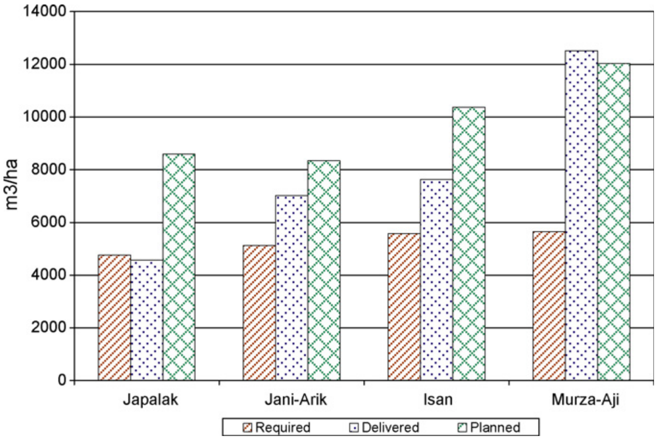

Fig. 2. Seasonal average values of required, delivered and planned water per hectare for 2003–2007 ($m^3\ ha^{-1}\ season^{-1}$).

distance from the point of intake from the main canal. The state of infrastructure and conveyance losses in WUA Murza-Aji are included in calculations of water use plans but the accuracy of the plan and its basis is in question. Fig. 2 shows that there was no consistency in irrigation planning compare to the required and actually delivered amounts. The set targets were too high and varied between 8300 and 12,100 $m^3\ ha^{-1}\ season^{-1}$ although climatic, soil and cropping situations of all these WUAs are comparable. Inconsistencies in irrigation planning were, despite the analogous conditions mentioned, due to the inaccurate calculation of plans that are based on previous irrigation norms and as a result, lead to failures in irrigation scheduling. Consequently more attention and care is needed in estimating irrigation requirement for WUAs. The current methods to develop water use plans (water requirement) should be re-considered and be more demand based.

3.2. *Complexity of existing planning*

The heterogeneity of the ever-changing soil, climate, cropping, and infrastructure conditions in gravity irrigation systems makes water allocation planning complicated. The main principles and concepts of irrigation planning in Central Asia were inherited from the Soviet system, which were used for centralized agricultural production systems when the state was responsible for all inputs, including water. It does not take into account the growing role of individual farmers in the production system.

The planning is based on the zonation (mapping) of the irrigated territories by climatic, soil, depth of the groundwater table and assignment of irrigation norms for different crops. The system is called hydromodule zoning. Hydromodule zones are territories with identical groundwater depth, soil and climatic conditions. A hydromodule zone is a taxonometric unit with differentiated irrigation regimes (optimal number of irrigations, their appropriate distribution with respect to crop development stages, irrigation norms for a predetermined set of environmental conditions) for specified crops. This system of aggregated soil-meliorative and meteorological zonation was proposed by the leading research institute of the Soviet Union – Sredazgipro-vodkhlopok (Shreder et al., 1969) and later updated by the Cotton Institute – SouyzNIKhI (Legostaev and Mednis, 1971). The approach to determine seasonal water requirements of crops is based on long-term research (field) experience on crop water requirements for given soil, climatic and groundwater conditions. The basis for the calculation and zonation of irrigation norms of crops, is embedded in the correlation between the evapotranspiration and potential evaporation (evaporation from the water surface), e.g. discharge of water from the field follows the physical laws of evaporation, its intensity is determined by the meteorological factors (temperature and humidity), and irrigation technologies (Shreder et al., 1969). Morozov (1997), in his review of the local crop water requirement calculation methods, refers to G.M. Hasankhanova and states that according to her comparisons the differences between internationally recognized methods, for example Penman–Monteith and Soviet methods, are trivial. However, the static and aggregated zonation of the large territories with irrigation norms was inconsistent with the dynamic nature of irrigation activities and natural processes, especially climatic conditions, groundwater regimes and changes in irrigation practices that are not reflected in the methodology. During the 1970s and 1980s these zones were reviewed when additional research information became available and new zonation maps and irrigation norms were established. Usually the *rayvodkhozes* (district water management organizations) calculate irrigation demands for large collective farms with the irrigation infrastructure designed to supply the required water for these large-scale irrigation schemes.

The mapping (zonation) of crop water requirements was prepared for the soil, climate and meliorative conditions of the 1970s and 1980s and fixed territories of irrigated lands specified by the Land Cadastre (State Land Inventory Department) at that time. However, expansion of irrigated land and cropping patterns, changes in the attributes of soils, climate, ameliorative conditions (salinity, groundwater levels), deterioration of the irrigation infrastructure (losses) and drainage systems (not operational), recent post independence reforms: transfer from collective to private smallholder ownership – all have contributed to the questioning of existing norms and irrigation regimes that are currently being used in the region.

Recent studies of the current groundwater conditions in the Uzbek part of the Ferghana Valley indicate the dramatic change in watertable depth. In places where it was deeper than 5 m in 2001, it has been reported to be 0.5 m and less in 2005 (Mukhamdejanov, 2008; Stulina et al., 2007). This would suggest that groundwater conditions may vary over the time and that there is a need for constant review of the hydromodule zones under varying conditions, which require significant human and financial resources, while there are other options for demand-oriented calculations of irrigation requirements. Further, the irrigation performances of the WUA were evaluated by assessing the actual water deliveries against required amounts that were based on FAO method.

3.3. *Evaluation of performance indicators*

The A_{WD} values show no significant difference across WUAs (multiple regression: $F_{1,18} = 36.7$; $p = 0.000016$ and $R = 0.82$). The other three indicators (EF_{WD}, EQ_{WD} and D_{WD}) were not considered because they represent different derivational forms of the A_{WD}.

A_{WD} values for all four WUAs for the period between 2003 and 2007 are summarized in Table 7. For Japalak, the A_{WD} is within the acceptable limits and shows adequate water delivery compare to irrigation demand with average performance of 0.96. Jani-Arik and Isan demonstrated declining trends of A_{WD}: from 1.67 (2003) to 0.88 (2007) and from 1.56 (2003) to 1.25 (2007), respectively. These values ranged from "fair" (0.80–0.89) to "good" (0.90–1.00) performance. Consistently higher A_{WD} values, judged as 'good' performance according to Molden and Gates (1990), for all three aforementioned WUAs during 2003–2007 are related to the project interventions within the scope of IWRM Ferghana project. These interventions include activation of WUA governing bodies, introduction of transparent water distribution, awareness building activities among water users and formation of water users groups at the tertiary canals using comprehensive participatory and

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Table 7
Summary of calculated performance indicators.

Performance indicators	Years of observation					Average	StDev[a]	C_v[b]
	2003	2004	2005	2006	2007			
WUA Japalak								
A_{WD}[c]	0.97	1.15	0.89	0.92	0.89	0.96	0.10	0.10
EF_{WD}[d]	1.03	0.87	1.12	1.09	1.12	1.05	0.09	0.09
D_{WD}[e]	0.82	0.60	0.62	0.42	1.23	0.74	0.27	0.37
EQ_{WD}[f]	1.17	1.17	1.03	0.98	0.99	1.07	0.08	0.08
WUA Jani-Arik								
A_{WD}	1.67	1.87	1.34	1.08	0.88	1.37	0.36	0.27
EF_{WD}	0.60	0.53	0.75	0.93	1.14	0.79	0.22	0.28
D_{WD}	0.82	1.31	0.57	0.56	0.69	0.79	0.28	0.35
EQ_{WD}	1.18	1.17	1.12	1.36	1.26	1.22	0.08	0.07
WUA Isan								
A_{WD}	1.56	1.44	1.45	1.14	1.25	1.37	0.15	0.11
EF_{WD}	0.64	0.69	0.69	0.88	0.80	0.74	0.09	0.12
D_{WD}	0.65	0.56	0.55	0.66	1.42	0.77	0.33	0.43
EQ_{WD}	2.24	2.42	2.16	1.96	2.38	2.23	0.16	0.07
WUA Murza-Aji								
A_{WD}	2.64	2.26	2.03	2.03	2.11	2.21	0.23	0.10
EF_{WD}	0.38	0.44	0.49	0.49	0.47	0.46	0.04	0.09
D_{WD}	0.88	0.52	0.71	0.48	0.98	0.71	0.20	0.27
EQ_{WD}	0.11	0.20	0.01	0.01	0.30	0.12	0.11	0.91

[a] StDev stands for standard deviation.
[b] C_v stands for coefficient of variation.
[c] A_{WD} is referred to adequacy.
[d] EF_{WD} is referred to efficiency.
[e] D_{WD} is referred to dependability.
[f] EQ_{WD} is referred to equity.

bottom up social mobilization approach (Yakubov and Ul Hassan, 2007; Kazbekov and Abdullaev, 2006; Abdullaev et al., 2006). However, this did not occur in Murza-Aji. Murza-Aji provided water with exceptional A_{WD} (average was 2.23) due to a number of reasons: (i) the secondary outlets WUA flows through Osh City before reaching farmers, which makes water management difficult, (ii) the earthen outlets are 2–3 km long and to compensate for delivery losses Murza-Aji tended to request more water than needed and (iii) farmers in Murza-Aji grow cotton and onions, which require greater and more frequent irrigations. When the delivery matches water needs, A_{WD} is one. However, when supply surpasses the demand, A_{WD} is less than 1. Hence, where A_{WD} is greater than 1 the water delivered is in surplus of that required and should be considered as a non-beneficial use of the resource.

Efficient water delivery was achieved in Japalak where the average EF_{WD} value remained at the acceptable limit of 1.05 (ranging from 0.87 to 1.12) (Table 7). The reason for this excellent performance is that for Japalak inter-farm irrigation systems were rehabilitated and supported by the WUA Support Unit of the Osh Province initiated by the Ministry of Agriculture, Water and Processing Industry, the World Bank (Johnson and Stoutjesdijk, 2008) and exceptional WUA leadership that actively involved water users in the WUA management resulting in transparent decisions. A lower average, 0.74, but improving EF_{WD} was observed for Isan, where EF_{WD} increased from 0.64 (2003) to 0.80 (2007). The fair to good performance in Isan is attributed to operational and leadership deficiencies caused by the frequent change in the WUA management due to the lower salaries and accumulating debt of the Association, weakness of the governing body (WUA Council) and inactiveness and non-participation of water users in WUA management. To address this issue, since 2004, the social mobilization activities (IWRM[3] project) supported the establishment of 20 WUGs along tertiary outlets of the six secondary canals. In 2005, the WUA Council in agreement with local elders hired a new Director, who had an appropriate background and started to take advantage of the WUGs. The new Director has utilized the WUGs: (i) to collect service fees, (ii) to collect more accurate cropping pattern information, (iii) undertake the distribution of water amongst farmers of outlets and (iv) to represent farmers of outlets in the WUA Council. Thus, the change in governance structure has allowed for the active participation of water users from end-tail.

The rapid improvement of EF_{WD} in Jani-Arik, from 0.60 (in 2003) to 1.14 (in 2007), was attributed to the strong WUA leadership, active user participation and good service fee collection rates. In 2004–2005, Jani-Arik was able to rehabilitate its in-system outlets through the On-Farm Irrigation program of the World Bank (Johnson and Stoutjesdijk, 2008).

In contrast, the EF_{WD} was poor in Murza-Aji, ranging from 0.38 to 0.49 in 2003–2007. The location of the Murza-Aji at the point of water intake from the Aravan Akbura Main Canal, length of the secondary water delivery system canals (KD and Kayirma outlets with length of 14 and 9 km, respectively), and limited discharge capacity of the canals are the factors contributing to the “inefficient use” of water. Yakubov and Ul Hassan (2007) have shown that the over-supply of water in this area is due to infrastructure problems. Losses are due to excess water supply to secondary canals to balance conveyance losses compared to demand. As a result, adequate water supply is achieved by a substantial over-supply of water.

The calculated values of D_{WD} for Japalak, Jani-Arik, Isan and Murza-Aji ranged from 0.42 to 1.42, which fall outside the upper limits accounting for “poor” performance (>0.20 for D_{WD}) (Table 7). The highest D_{WD} observed during 2003, which was characterized as a water abundant year; indicates that water deliveries were not uniform in terms of temporal variability in accordance with demand. All four WUAs showed improved D_{WD} values (ranged from 0.42 to 0.71) during 2004–2006 periods,

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[3] The SDC supported project titled Integrated Water Resources Management in the Ferghana Valley is implemented by the consortium of partners – IWMI and SIC since 2002.

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except in Jani-Arik (1.31 in 2004), where preparation activities for rehabilitation resulted in higher variability of D_{WD}. The highest D_{WD} values are observed in 2007: Japalak (1.23), Jani-Arik (0.69), Isan (1.42) and Murza-Aji (0.98). This was probably due to low water availability during 2007, which affected releases from the Papan reservoir. Comparison of 5-year average D_{WD} values (from 0.71 to 0.79) indicates that temporal uniformity in water distribution gradually improved after the project interventions started in 2003 and are still ongoing. D_{WD} of Murza-Aji compared to other three WUAs did not deviate, suggesting that the distance from the water source and length of the canal does not influence dependability. Nevertheless, since A_{WD} is maintained in all WUAs throughout the study period, indications of poor D_{WD} do not indicate that water supply is unreliable but rather suggests a measure of temporal variability in over-supply, especially in case of Murza-Aji. Notwithstanding this, considerable work is needed to improve D_{WD} to ensure temporal uniformity in water distribution requiring careful planning of irrigation demands and making proper requests to release water from the main canal.

The results of EQ_{WD} calculations are presented in Table 7. The EQ_{WD} values remained much higher than accepted limits of 0.10. EQ_{WQ} values were highest in three WUAs, Japalak, Jani-Arik and Isan (averages are 1.07, 1.21 and 2.23, respectively), indicating that the performance of these WUAs was very poor in maintaining EQ_{WD} in water distribution. Contrasting this, since A_{WD} is maintained as outstanding throughout the study period, EQ_{WD} does not necessarily mean unfair water distribution but suggests spatial variability with respect to excess delivery of water.

Under the circumstances, Murza-Aji performed exceptionally well during 2003–2007 with average and improving EQ_{WD} of 0.12. However, slightly higher EQ_{WD} values during 2007 suggest that drought conditions have less of an impact on EQ_{WD} as long as a participatory rotational water distribution system in place. The introduction of a participatory rotational water distribution system under the IWRM Ferghana project allowed farmers involved in this scheme to be always aware of their specific time schedules including when to irrigate their fields and for how long. This alone led to large savings in time for farmers when waiting for their turn to irrigate and a more equitable water distribution. This has also allowed those at the tail end to increase crop yields and net incomes, resulting in better irrigation service fee collection. Further, there has been a positive change in the nature and pattern of water disputes. Disputes among farmers over water volumes and irrigation turns in 2004 have decreased by 24% and 69%, respectively (Abdullaev et al., 2006).

4. Conclusions

The premise of this study was to analyze the current planning methods and evaluate the irrigation performance of four WUAs in Kyrgyzstan using A_{WD}, EF_{WD}, D_{WD} and EQ_{WD} indicators. These indicators confirm the operational performance of WUAs in relation to water delivery according to set targets. Nevertheless, the comparison of planned, required and actually delivered water volumes showed that the currently practiced planning method, which was based on hydromodule zonation, significantly over-estimates irrigation demands. Consequently, evaluation of the performance was undertaken by comparing amounts of actually delivered and calculated irrigation requirements based on the FAO method. The overall purpose of these analyses was to present a general view of the impact of the IWRM Ferghana project, especially its institutional interventions implemented to improve water allocation and distribution to a large number of fragmented farmers organized into WUAs in Kyrgyzstan. In order to improve the operational performance, WUAs should pay more attention to the development of accurate water use plans. This will require the collection of accurate information on crops that are planned to be grown; moving from supply oriented hydro-module planning methods to more demand oriented approaches; improving the skills of WUA managers in the use of modern techniques for calculating actual crop water requirements; and real-time monitoring of flows and requests during any given irrigation season.

Although the irrigation performance of WUAs is dependent on the state of the irrigation network and technical skills of the WUA staff, it is also contingent on WUA's leadership concept, e.g. ability of WUA managers to involve its users by effective communication, bringing transparency and sharing the management of water, which is essential for the water planning and distribution. The strong leadership in Japalak and Jani-Arik has contributed to the relatively better performance of these WAUs when compared to Isan and Murza-Aji.

The results indicate that adequacy of water delivery was appropriate for all WUAs. In the case of Murza-Aji the analysis indicated more than adequate supply due to over-request to cover the conveyance losses in the system. For effective water control, the following institutional innovations are proposed: establishing effective WUGs; introducing rotational schedules with leaders elected by water users; facilitate infrastructure improvements through collective action, locally known as "*hashars*"; and train WUG leaders on crop water requirements.

EF_{WD} was in line with the acceptable limits for all WUAs, except Murza-Aji due to an over-supply. To improve this, water saving incentives such as the introduction of volumetric water payment, rather than area based payment, should be introduced through facilitation of WUGs in installation of water measuring and regulating devices at the head of the tertiary canals.

D_{WD} values show improvement with the establishment of WUAs but are still far from ensuring uniformity. This was similar in the case of EQ_{WD} values, which shows large variations. In order to improve the indicator of dependability, water supply periods from WUAs should coincide with the period when water is actually needed. It is not an easy task in Kyrgyzstan where WUAs deals with thousands of water users. To ensure acceptable A_{WD}, delivery of water to WUAs must be carried out taking into consideration predicted water requirements by WUAs in their general irrigation plan for the growing season. The conveyance losses in the system should also be taken into account when deciding water releases for a certain WUA. If the supply is matched with the predicted demands of the seasonal water use plans of WUAs, adequacy and efficiency of water delivery will also improve. Although, the study gives insights into the performance of WUAs in Central Asia, the methodology applied in this study is of use in irrigated areas of arid and semi arid zones. Viable and simple performance assessment tools are a pre-requisite for the development of operational WUAs universally. This study fills a gap in the literature on evaluation of planning and distribution of water resources within WUAs.

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