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Article

Alternative Water Allocation in Kyrgyzstan: Lessons from the Lower Colorado River Basin and New South Wales

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Abstract: Focus group discussions and a modeling approach were applied to determine policy and regulatory refinements for current water allocation practices in Kyrgyzstan. Lessons from the Lower Colorado River basin, Texas and New South Wales, Australia were taken into consideration. The paper analyzes the impact of adopting some of these interventions within the socio-environmental context that currently prevails in Kyrgyzstan. The optimization model for water distribution at the river-basin scale was developed using GAMS 2.25 software. Application of the model to the Akbura River basin indicated efficiencies in the proposed institutional rules especially in low water years.

Keywords: water allocation; modeling; water tariff; double cropping; Central Asia

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1. Introduction

Experience suggests that countries, especially those in transition, when seeking to reform their problem-stricken water-management sector try to embark on comprehensive water governance reforms turning to more user-driven and participatory models. As a result, several legal and policy innovations are introduced to establish an adequate enabling environment. However, such new environments, once created, are not sufficient to bring about intended changes on the ground. The major reason for this is that not all elements of institutional reforms are given adequate focus. According to [1], institutional change in the context of water is a function of the endogenous structure of water institutions and the endogenous environment surrounding them. While water institutional structures comprise water law, water policy and water administration components, the institutional environment implies a wider country-specific context providing an overall framework. Thus, appropriate institutional change on the ground can be expected if all basic elements of the water institutional structure are adequately reformed, realigned and readjusted. One such basic element of the water institutional structure that quite frequently lacks adequate consideration resulting from major legal and policy reform is water administration. This will assist in realigning water allocation in such a way that would ensure more efficient uses of this finite resource. This, in particular, requires adjusting and refining the principles of water allocation.

Kyrgyzstan is one of the countries under transition that has embarked on such water governance reforms. Its new Water Code, passed in 2004, creates conditions for effective water use and direct agreements between water organizations and water users [2]. However, despite this enabling legal environment, the relationships between the major actors are far from what they potentially could be. Since water service fees do not cover the operation and maintenance (O&M) costs of the delivery systems, water management organizations (WMOs) still have to rely heavily on state funding to support their operations. While water users associations (WUAs) purchase water on the volume of water delivered by the WMOs, farmers, in contrast, pay for water delivered by the WUAs on a per unit of area basis. This mixture of volumetric- and area-based payments for water limits the implementation of alternative approaches to improve current practices. Moreover, the availability of excessive water resources and low water charges for water delivery do not encourage water users to save water. These water relations become even more vulnerable in the context of transboundary small river basins shared by two or more countries. Such asymmetries between institutional (legal) environments and institutional arrangements in water management emphasize the need to improve water allocation principles.

Different water allocation case studies were reviewed in this assessment with the objective of identifying those approaches most suitable for possible water allocation improvements in one of the river basins in Kyrgyzstan: the Akbura River basin. This basin is located in the Osh province of Kyrgyzstan and has been the focus of various major project interventions by different aid agencies since early 2000. The two alternative case studies considered in this assessment are the Lower Colorado River basin in the United States and New South Wales in Australia. Findings from these cases were reviewed using focus group discussions held in 2008. The basic research question for this focus group exercise was to ascertain users' opinions on how water management could be improved.

This was then followed by a modeling exercise to see the efficiency of some of the proposed interventions.

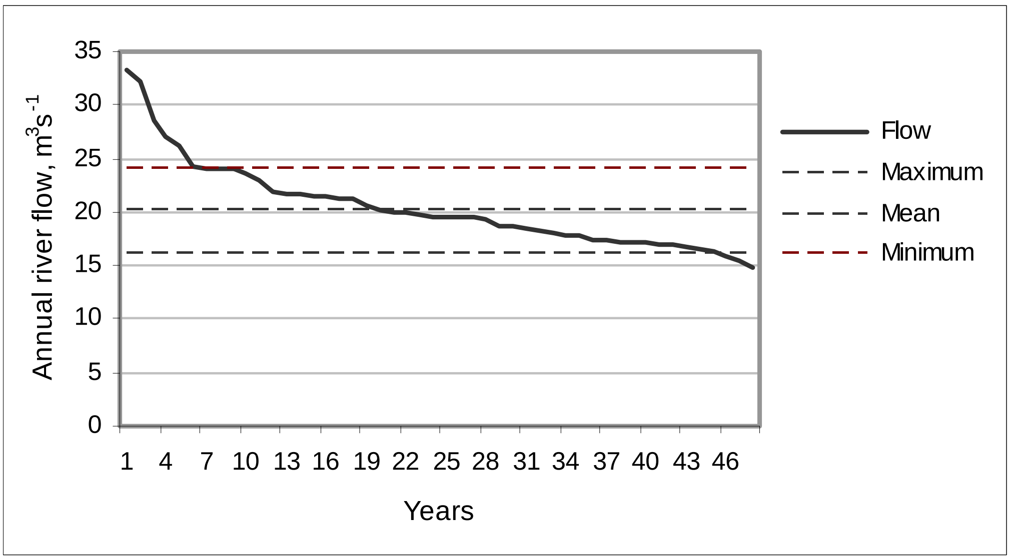
The first water allocation case study considered is from the Lower Colorado River basin, where the river authority has successfully contributed to 70 years of sustainable operations comprising water delivery and hydropower generation within the context of a free market framework [3,4]. Water users have rights that encourage effective water use based on the natural regime of the river runoff (run-of-river rights). Since water storage in the reservoir requires additional O&M costs, the delivery cost of such regulated water is higher than run-of-river flows.

Water relations in New South Wales, Australia provide an alternative approach to water allocation. The state applies an access license rule on regulated rivers which confers the right to annual water allocation only to the extent that water is actually available [5,6]. In contrast, in Kyrgyzstan, water use allotments are delimited on the basis of the prevailing water-shortage conditions.

As mentioned earlier, these alternative methods were tested through focus group discussions involving both water managers and water users. Overall, the discussions suggest that water users prefer simple rules in water management and are not supportive of more advanced and complicated refinements. At the discussions an important conclusion made was that participatory water management could be a key element for improving water allocation practices in Kyrgyzstan. This finding from the focus group discussions was verified through a modeling exercise aimed at determining the differences in water allocation between top-down and user-driven participatory approaches in water management.

Water allocation modeling was applied for the Akbura River basin. The Akbura River is one of the left-bank tributaries of the Syrdarya River with an average annual flow of 750 million m^3 (Mm^3). The river is a transboundary watercourse flowing through the territory of Kyrgyz Republic and Uzbekistan. According to the agreement between these two countries, Kyrgyzstan, being an upstream country, has the right to use the flow of the river up to a maximum of 70% in summer and 90% in winter. Natural flow of the river with high water in summer is suitable for irrigated agriculture. The long-term average river flow is 19.9 m^3/s (Figure 1).

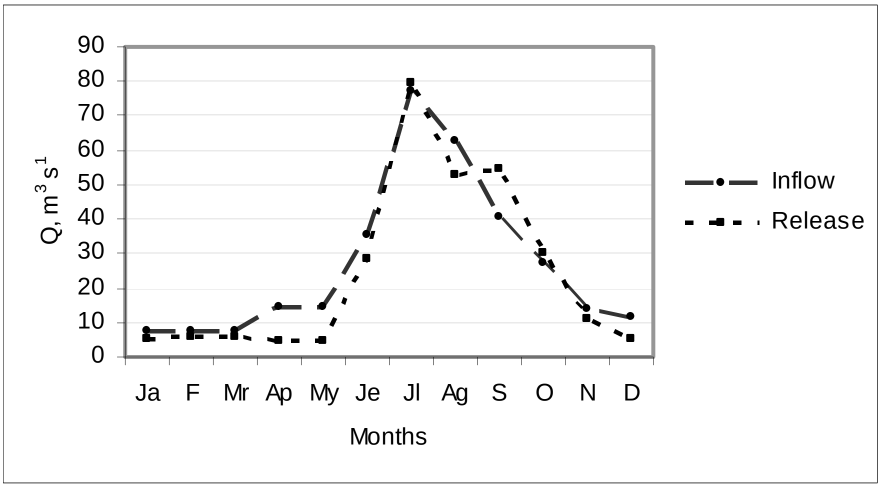
Figure 1. Flow probability curve for the Akbura River.



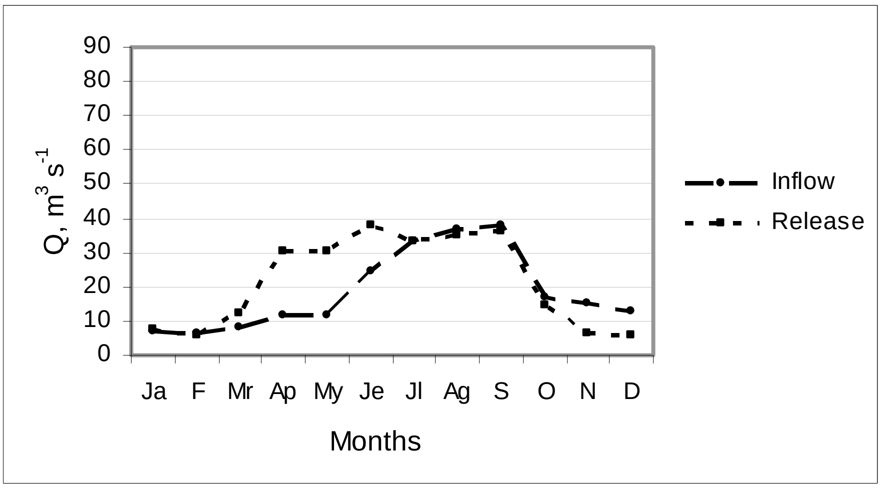
Since water shortage occurs in the lower reaches of the river basin on the territory of Uzbekistan, efficient water management in the upstream country will result in mutual benefits. The Papan Reservoir in the upstream with a net capacity of 250 Mm^3 allows seasonal flow regulation (Figure 2).

Comparison of the inflow and the outflow curves suggests that only 6% of the total water released from the reservoir in high water years is delivered during the summer season and 25% in low water years. In high water years, the irrigation season normally starts in late June due to heavy spring rainfall resulting in high soil moisture reserves. As a result, the farmers from the lower reaches of the basin have enough water to grow a second crop and the irrigation season lasts till the second half of October. In low water years, the irrigation season normally starts in April due to the dry spring and low soil moisture reserves. Water allocation for the second crop is restricted and the irrigation season ends in the second half of September.

Figure 2. Inflow to and outflow from the Papan Reservoir in (a) high and (b) low water years.



(a)



(b)

2. Methodology

Three complementary approaches were used to study options for improvement in water allocation practices in the Akbura River basin:

1 Two case studies, from Texas and Australia, were selected to study alternative water allocation procedures. The first case study concerns the Lower Colorado River basin (Texas, U.S.) operated by the Lower Colorado River Authority [3,4]. The second case study is from the state of New South Wales in Australia. which occupies a major part of the Murray-Darling River basin. Thus, interventions aimed at improving water allocation practices, both actual and suggested, are based on the lessons learned from the above two studies and the pertinent literature [6-8].

2 Focus group discussions were organized involving representatives of water organizations and water users. These were held first to identify issues existing in the current water allocation practices in Kyrgyzstan at the WUA and canal levels and second, to discuss the above two case study options for their applicability in the local setting.

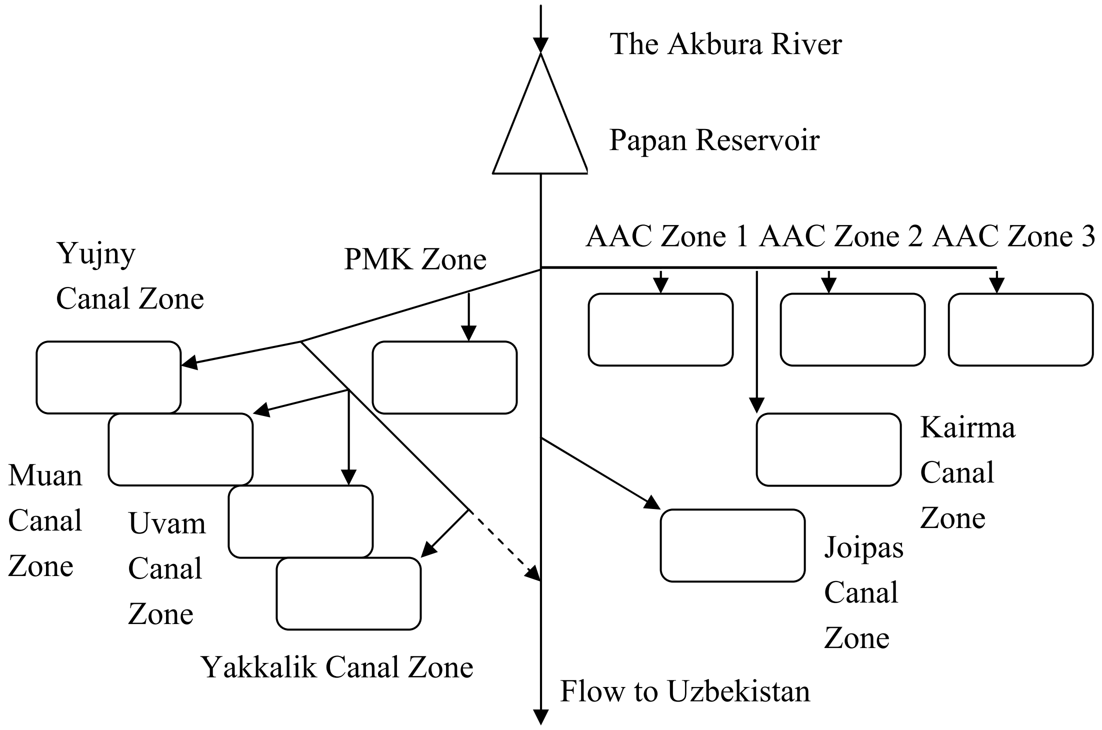
3 A modeling approach was applied to determine the efficiency of the proposed alternatives. Modeling platforms have been used to simulate water allocation decisions [9-21]. The impact of transition from a top-down to a user-based participatory water management approach on water use efficiency and the reallocation of saved water from the first to the second crop was analyzed for the Akbura River basin using a two-stage stochastic linear programming that takes into account the probabilistic water availability. For this, an optimization model of water distribution for river basin was developed using GAMS 2.25 software [22]. Details and formulation of the model of the Akbura River basin are presented below.

3. Optimization Model of the Akbura River

Linear two-stage stochastic programming was applied to analyze water allocations in the Akbura River basin (Figure 3). The algorithm developed by [17] was implemented to solve the stochastic problem. The main objective of the modeling was to simulate the river flow allocation between main canal command areas under different water management approaches, namely (1) a top-down approach and (2) a user-driven participatory approach. The model representing a simplified irrigation system version of the Akbura River basin can be used to operate the Papan Reservoir and perform seasonal water allocations. The basis of the solution is the efficient and commercial linear program solver GAMS2.25 software [22].

There are eight main canals in the river basin. They are: Aravan Akbura Canal (AAC), Kairma, Yujny, Joipas, Uvam, Ykkalik, Right Bank Canal (PMK) and Muan.

Figure 3. Simplified diagram of water distribution in the Akbura River basin.



The modeling considers probabilistic inflow to the reservoir [17]. River flow probability was calculated based on the time series of annual natural flow from 1935 to 1995. The time series show relatively low annual flow variability. Inflow probability values used in the modeling are presented in Table 1.

Table 1. Inflow probability into the Papan Reservoir.

Year	Relative value	Flow probability
High water	1.32	0.19
Mean	1.00	0.62
Low water	0.79	0.19

Irrigated agriculture is the main water user in the river basin. Irrigation water demands for the first cropping season are given in Table 2. The irrigation season for summer crops, such as cotton, vegetables, forages and orchards, is continuous from April to September, while that for winter wheat is continuous from October to November and then from March to May. In high water years, the area of the second crops increases by 20% when compared with the mean flow year. Farmers predominantly sow maize for fodder after harvesting winter wheat in July. The irrigation season of maize continues from July to September. However, in low water years, water allocation for the second crops is restricted. On average, the irrigation water demand in the Akbura River basin totals 10,666 m^3 ha^{-1} (Table 2).

Table 2. Irrigation water demands in the Akbura River basin in the mean water year.

No.	Command areas	Irrigated area	Irrigation water demand		Delivery efficiency
			October-March	April-September	
		ha	$m^3\ ha^{-1}$	$m^3\ ha^{-1}$	
	AAC Upper	1,195	493	11,153	0.81
1	AAC Middle	1,867	493	9,109	0.80
	AAC Lower	3,005	493	9,187	0.59
2	Kairma canal	1,406	493	11,153	0.60
3	Yujny canal	4,824	493	11,978	0.75
4	Muan canal	302	464	6,235	0.90
5	Uvam canal	6,164	668	9,527	0.77
6	Ykkalik canal	5,801	991	11,719	0.81
7	Joipas canal	680	464	9,109	0.80
8	PMK canal	79	464	11,978	0.90

The study suggests that farmers' decision with respect to the second crop in the Akbura River basin is dependent on the availability of water resources. In dry years, water management organizations do not release water for the second crop. Due to this, irrigation water demand in high water years is increased, on average, by 20%. The data on irrigation demand variability are available for all canals except AAC and Kairma where farmers normally do not cultivate a second crop due to relatively cooler weather conditions precluding the establishment of a further crop. Thus, demand variability depends on the probability of river flow.

Considering the above, water allocation in the Akbura River basin was modeled based on the following two scenarios:

Scenario 1: Water allocations under a top-down water management regime that focuses on minimizing water delivery costs, reducing water deficits, and accumulating water in the reservoir for allocations to the next season along with restrictions applied to double cropping in low water years.

Scenario 2: Water allocations under the user-driven participatory water management that aims at maximizing irrigation service fee collection and the accumulation of water in the reservoir for the next season, with no restrictions whatsoever on double cropping.

3.1. Scenario 1

Formulation of the model assumes that the river basin organization will annually attempt to minimize water delivery costs and accumulating water in the reservoir for the next season:

$$MINZ = \sum_{j=1}^{6}\sum_{i=1}^{n}(v * Sif_{ij}) + \sum_{j=7s}^{12s}\sum_{i=1}^{n}(v * (Sif_{ijs} + Sis_{ijs})) - \rho * W_s / Wcap \tag{1}$$

which is subject to the river flow budgeting:

$$Q_{ijs} = \sum (1 - a_i) * Q_{i-1\,js} - Qri_{i \in rjs} + Qro_{i \in rjs} - (Sif_{i \subset mjs} + Sis_{i \subset mjs} + Sni_{i \subset mj}) \tag{2}$$

Reservoir operation mode:

$$W_{js} * (1 - 0.5 * a_r) - W_{j-1} * (1 + 0.5 * a_r) - Qri_{js} + Qro_{js} = 0 \tag{3}$$

Demand-supply ratio for the first cropping:

$$\eta * Sif_{mjs} + Def_{mjs} = Dem_{mjs} \tag{4}$$

The irrigated area under the first cropping is permanent.
Demand-supply ratio for the second cropping:

$$\eta_m * Sis_{mjs} + Defs_{mjs} = Irs_{mj} * \omega s_m \tag{5}$$

The area under the second cropping is variable and limited by the area of land available after harvesting winter wheat in the middle of June.

The reservoir storage cannot exceed reservoir capacity:

$$Wjs <= Wcap \tag{6}$$

$$Wjs <= Wd \tag{7}$$

where, Q_{ijs} is river flow in month j at node i under scenario s; Qri_{js} is inflow in the reservoir in month j under scenario s; Qro_{js} is outflow from the reservoir in month j under scenario s; W_s is storage in the reservoir under scenario s to the end of the cropping season; $Wcap$ is full capacity of the reservoir; Wd is dead storage in the reservoir; W_{js} is storage of the reservoir in month j under scenario s; $Sif_{i \subset mjs}$ is irrigation water allocation for the first crops from river node i to zone m in month j under scenario s under run-of-river flow; $Sis_{i \subset mjs}$ is irrigation water allocation for the second crop from river node i to zone m in month j under scenario s; $Sni_{i \subset mjs}$ is water allocation for non-irrigation water uses from river node i to zone m in month j under scenario s; Dem_{mjs} is irrigation water demand in zone m; Def_{mjs} is deficit of irrigation water supply in zone m in month j under scenario s; Irs_{mj} is irrigation water requirements for the second crop per hectare in zone m in month j; ωs_m is the second cropping area in zone m and variable; a_i are losses of river flow from node i-1 to node i; a_r are losses of water from the reservoir; v is cost of delivery of irrigation water; p is penalty for free reservoir storages at the end of period, which is taken as 30% higher than the fees for irrigation water supply; η_m is delivery efficiency of the water-distributing system in irrigation zone m; s is the probabilistic scenario depending on the river flow variability (Table 1) and demand variability in low and high water years. Using the data given in Table 1, the model generates river inflow for different probabilistic scenarios of water supply [17].

3.2. Scenario 2

The user-driven participatory approach aims to maximize irrigation service fee collection and accumulate water in the reservoir for the following season:

$$MAXZ = \sum_{m}(Fees_{ms} - Debt_{ms}) - p * W_s / Wcap \tag{8}$$

In addition to the previous constraints, this scenario also considers the relations between yield and water supply. The relationships between relative yield (Y/Ym) and relative irrigation deficit for the first crop- growing period are taken as follows [23]:

$$Y_{mcrs} / Ym_{cr} = \kappa a * (1 - \kappa y_{cr}(1 - \sum_{j=1}^{n}[(Dem_{mj} - Def_{mjs}) / Dem_{mj}])) \tag{9}$$

The net profit from the first cropping is defined as follows:

$$\Pr_{mcrs} = (\alpha_{cr} Y_{mcrs} + \beta_{cr}) \omega f_{mcr} \tag{10}$$

The net profit from the second cropping is defined as follows:

$$\Pr s_{mcrs} = (\alpha_{cr} Y_{mcrs} + \beta_{cr}) \omega s_{mcrs} \tag{11}$$

The first cropping area is permanent and the second cropping area is variable and limited by the area made available after harvesting winter wheat. This constraint accounts current practices when farmers respond to water shortage by reducing the area of the second crops. The model also does not consider changes in crops as a result of water savings or technological change.

Irrigation service fees to be collected equal:

$$Fees_{ms} = v * \sum_{j}^{12}(Sif_{mjs} + Sis_{mjs}) / \eta_m \tag{12}$$

The amount of fees should not exceed the defined share (5%) of the total net profit of water users from crop production:

$$Fees_{ms} = 0.05(\Pr_{mcrs} + \Pr s_{mcrs}) + Debt_{ms} \tag{13}$$

where, Y_{mcrs} is the yield of crop cr in zone m under scenario s; Ym_{cr} is the maximum yield of crop cr; κy_{cr} is potential yield reduction due to water deficit for crop cr during the vegetation period, κa is coefficient of effect of farming practices other than water on crop yields, α_{cr} and β_{cr} are curve coefficients of relation of net profit ($\Pr_{mcrs}$) and yield (Y_{mcrs}); ωf_{mcr} is the first cropping area in zone m and is constant; $\Pr s_{mcrs}$ is net profit from the second cropping production in zone m under scenario s; $Fees_{ms}$ are the fees to be collected in zone m under scenario s; $Debt_{ms}$ is debt of water users to the water organization for water delivery services.

It was assumed that farmers were willing pay maximum of 5% of their net profit from crop production for water delivery services. Including the variable debt into the model allowed avoiding infeasible conditions.

The model required the following input data: probabilistic inflow to the reservoir; irrigation water demand summarized for each canal command area dependent on probabilistic inflow to the reservoir; water delivery efficiency for each canal; initial water storage in the reservoir; water storage efficiency in the reservoir; full capacity of the Papan Reservoir; and the dead storage level of the reservoir. The variables included monthly irrigation water allocation for each canal command area, monthly water storages in the reservoir and river flow diversions to the downstream country. The current cropping pattern according to the Osh Province Water Management Organization is presented in Table 3.

Table 3. Cropping pattern in the Akbura River basin.

Canal zone	Area Ha	Cotton %	Alfalfa %	Maize %	Wheat %	Fodder maize %	Orchard %
AAC1	1,195	10	10	20	50	25	10
AAC2	1,867	10	10	20	50	25	10
AAC3	3,005	30	10	20	30	25	10
Kairma	1,406	10	10	20	50	25	10
Uvam	6,164	40	10	20	20	25	10
Ykkalik	5,801	20	10	20	40	25	10
Yujny	4,824	40	10	20	20	25	10
Joipas	680	10	10	20	50	25	10
PMK	79	10	10	20	50	25	10
Muan	302	10	0	20	50	25	20
Total	25,323	28	10	20	32	25	10

Fodder maize is considered to be cultivated after winter wheat harvesting only. Crop water requirements are given in Table 4 according to the locally applied recommendations. The irrigation water requirements of the second crops are taken as for fodder maize.

Table 4. Crop irrigation water requirements.

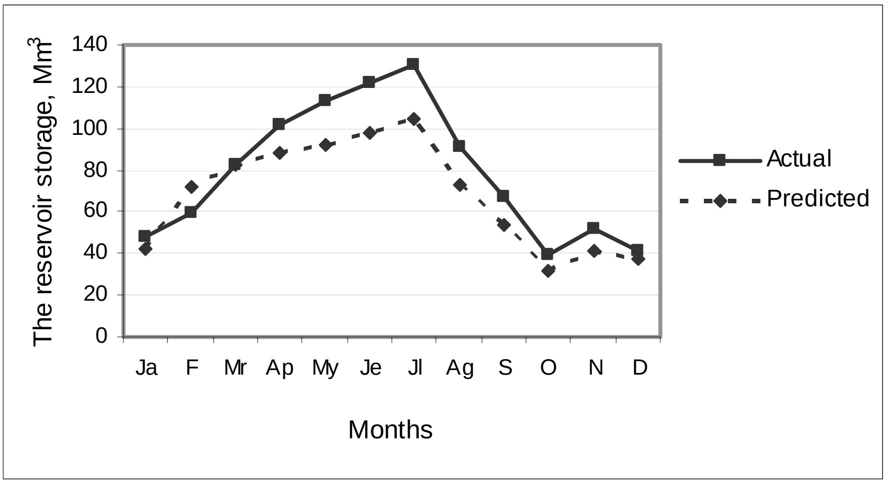
Crop	Oct.	Feb.	Mar.	Apr.	May $m^3\ ha^{-1}$	June	July	Aug.	Sept.
Cotton	0	113	1,587	0	623	2,427	2,750	2,500	0
Alfalfa	407	419	531	1,058	1,690	2,089	2,750	2,353	1,776
Maize	0	304	1,396	0	2,000	2,886	2,914	0	0
Fodder maize	1,350	0	0	0	0	338	1,004	2,482	2,477
Wheat	700	0	0	715	1,535	0	0	0	0
Orchard	0	1,417	283	0	1,200	1,625	2,001	2,590	0

Maximum crop yields Ym_{cr} in equation (9) were based on the yield level produced by farms that had applied best practices. Potential yield reduction due to water deficit (ky_{cr}) was taken from FAO studies [24]. Losses in the reservoir (a_r) based on the Papan Reservoir Operation Organization are taken as equal to 5% (Kadyr, personnel communication, 2008). Losses of the river flow (a_i) are taken as equal to 10% from node i-1 to node i. The delivery efficiency of the water-distributing system in irrigation zone m is given in Table 2.

4. Validation Approach

The model was validated based on water distribution data in the Akbura River basin in 2006. The model was run with a fixed monthly volume of water in the Papan Reservoir to fulfill the gaps in accounting of the actual water use by irrigation water users. The model was then run for 2007 and predicted values of monthly water storages in the Papan Reservoir were compared with actual data (Figure 4). A high degree of convergence between observed and predicted values was achieved for 2007.

Figure 4. Comparison of predicted and actual values of water storage in the Papan Reservoir, 2007.



The following section provides an overview of the lessons that could be learned from the experience of the Lower Colorado River Authority (LCRA) and the water organization practices of New South Wales, Australia. This is followed by the findings of the focus group discussions on the issues and adaptable alternatives to improve current water allocation practices in the Akbura River basin from the water users' point of view. The final section presents the results of the modeling exercise.

5. Case Study of the Lower Colorado River Basin

Water resources management in the Lower Colorado River basin is characterized by increasing demands and competition for renewable but limited water supplies. This specific challenge does not differ from that in Kyrgyzstan. The policy and regulatory arrangements in the basin that are thought to be of interest for the Kyrgyz case are as follows:

1 LCRA's four-fold mission: water, hydropower, conservation and land. This multipurpose mission is the basis for LCRA's more than 70-year long viability. In contrast, in Kyrgyzstan, in the Akbura River basin context, the local water management organization is only responsible for the delivery of water with no jurisdiction over the production of power. And, water marketing does not contradict the water law of Kyrgyzstan.

2 LCRA supplies water along two general categories of water demands: firm and interruptible. Firm water demands presently include the water for municipal, domestic, industrial, power generation, irrigation and in-stream flow maintenance purposes. Interruptible stored water is always used for agricultural irrigation. In the case of Kyrgyzstan, municipal and domestic water supply has a higher priority than irrigation.

3 Water supply to irrigation districts by LCRA is interruptible as water is supplied against contract and is subject to curtailment during shortages. It is distinguished from firm water supplies which should remain constant even during repeated critical droughts. In the case of Kyrgyzstan, irrigation demand of upstream and downstream water users is subject to curtailment at equal percentages based on the water supply level.

4 Lower reach irrigation water users in the Lower Colorado River basin have rights to consumptive water uses according to the natural regime of river runoff (run-of-river rights). Similar agreements exist between the upstream and downstream countries in the Akbura River basins.

Double-level tariffs are applied in the Lower Colorado River basin, with the first level applied to water delivered according to the natural run-of-river flow and the second level to the stored water. We hypothesized that the possible impact of the adoption of the double-level tariffs in Kyrgyzstan could be as follows: users' share in the water organization's budget will increase; water organizations will have incentives to improve water accounting; and WUAs will be encouraged indirectly to promote water saving. However, this intervention may not affect on-farm water use efficiency directly since currently farmers pay water charges on an area basis.

6. Case Study of New South Wales (Australia)

New South Wales currently faces a series of challenges in water resources management with the major challenge being the environmental consequences of excessive water extractions from the river systems. Further, there are a number of other water management issues that are not at all different from those in Kyrgyzstan. With this in mind, it can be said that the following are the key policy and regulatory innovations that could be considered for possible implementation in Kyrgyzstan:

1. Unbundling water rights including both surface water and groundwater, from land rights and specific uses. The pertinent Act distinguishes between water access license and water use approval. This is done to facilitate water trading. Thus, one's water entitlements can be traded separately from one's landholdings [25].
2. The allocation of water to access license holders varies between regulated and unregulated rivers. On regulated rivers, the access license confers the right for annual allocation of a volume of water but is confined to water that is actually available. The management of allocations is undertaken by an organization, State Water, which regularly calculates the percentage of allocation available by adding water to minimum expected inflows in storage and then subtracting system losses and environmental requirements. When this percentage is announced State Water also announces probabilities of the river flow within the next specified times [7,8]. This way, water resources allocated to a water user increase during the season from

the minimum available in the beginning to a certain quantity thanks to the river inflow. In contrast in Kyrgyzstan, as elsewhere in Central Asia, water use plans and schedules are subject to additional correction and elaboration in March each year, based on the volume of water in the reservoirs and river flow predictions for the following six months. Farmers are allowed a certain volume which is subject to curtailment during seasonal water shortages. This way, water users may receive less water than was scheduled in the beginning of the season.

3. Until recently in New South Wales, there were access licenses which specified the maximum area to be irrigated on unregulated rivers but the need for more intense management has created a continuing conversion to a volumetric basis of allocation [7].
4. There is a concept of *continuous accounting rule* in New South Wales, which allows individual water users to carry over some or all of their unused entitlement from one year to the next. They can then use this carryover in addition to any water they receive as part of the annual allocation for the next season. The continuous accounting rule is a market-based water efficiency compliance instrument that emerged in Australia to complement traditional ‘command and control’ systems. The ‘command and control’ approach would be to impose some form of absolute or relative water efficiency target on identified liable entities; and permit these entities to meet their compliance targets either by undertaking water efficiency actions within their own operations or by purchasing the benefit of water efficiency actions of others. One of the variations of the market-based instruments is the concept of ‘Saved water certificate,’ by which investors in water saving activities are rewarded with an instrument redeemable for a defined entitlement of water. Farmers adopting water saving technologies have preferential access to water [8,26].

7. Results and Discussion

Focus Group Discussions on Water Allocation

Consultations with key water use stakeholders were held in the Akbura River basin to discuss water allocation issues and available options to improve the current situation. The aims of the consultations were to: (1) identify problems in existing water allocation structures; (2) identify possible ways to improve current practices; and (3) encourage the participants to discuss new alternatives for water allocation based on their expectations.

Two groups of key stakeholders were approached for this purpose, namely water users and water managers. Those representing water users included local farmers, leaders of WUAs and representatives of the Union of WUAs. Water managers were represented by the leading specialists of local canal and basin water management organizations. Each consultation was in the form of focus group discussions with seven to ten participants per group. Each group discussion had five rounds. First, the aims of the consultation were explained to the participants. Second, participants were asked to identify priority issues concerning legal, economic and technical matters of their current water allocation practices, especially, in low-water years. In doing so, the participants were encouraged to use charts, diagramming and/or drawing to present their group findings on the issue. This allowed setting the context for further diagnosis, analysis and interpretation of the issues under discussion.

Third, group participants were asked to come up with alternative solutions for the top two priority issues as earlier identified. Fourth, the participants were given a detailed presentation of the two alternative water allocation case studies outlined earlier. Finally, they were encouraged to reflect on the usefulness and adaptability of the two case study options presented. The intention was to obtain feedback from group participants with regard to the two case studies as potential innovations for adoption within the pilot canal areas.

With each focus group coming up with its own insights and suggestions on the issues discussed, overall, the group of water users showed more responsiveness and openness to innovations, while the group of water management specialists was more pragmatic, basing their judgments on a thorough knowledge of water planning issues. Overall, issues in the entire water allocation chain were found to be mostly concentrated at the below-WUA level. In particular, the problem of irrigation service fee recovery was found to significantly constrain the viability of both state-run water management organizations and community-based water users associations. Low service fee recovery was largely attributed to low profitability of smallholder farming in Kyrgyzstan varying in range of 0.3 to 5 ha, as a result of land reforms after 1990. Among the factors contributing to low profitability of current farming practices, both water users and water managers referred to restrictions on double cropping that are frequently imposed due to water shortages in low water years. Further, the group discussions indicated that there was a need for direct incentives to save water in order to encourage WUAs and farmers to reduce their excessive water use practices. However, major malfunctions and problems restricting possible improvements in current water allocation and water management as a whole were attributed by the participants of both focus groups to the fragmentation of the former large-size collective farm system into multiple smallholder farming entities as well as poor water accounting [27]. As a possible solution to the problems faced, both water users and water managers emphasized the role of designing proper incentives to encourage water saving at all levels from water users to water management organizations, which would hopefully also allow avoiding restrictions for double cropping.

Following this, both groups of the key stakeholders discussed the experiences of the Lower Colorado River Authority and New South Wales for their relevance and adaptability to the Kyrgyz context. Both groups revealed that they would rather go for simple solutions than for complicated innovations. The participants' feelings and attitudes towards the usefulness of case-study-based innovations to the local context that emerged from the discussion can be summarized as follows:

- Participants were not supportive of the double-level water tariffs as a water saving method or of the current practices of forced water saving through restricted water supply. The overall attitude towards double-level water tariffs was that they were too complicated for the local context.
- At the same time, group participants supported the idea of granting preferential access to water and land for those water users who would like to invest in water saving technologies. They were also supportive of the current water tariffs in Kyrgyzstan that are based on specific irrigation water requirements for different crops.
- It was clear from group discussions that restricted double cropping was one of the reasons impeding the collection of water fees, for it had significantly affected farmers' incomes.

- All the participants wanted their water supply to be as reliable as possible. That is why they have supported water use planning based on available water resources.

Implications of adopting the innovative institutional arrangements to the Akbura River basin as suggested by the above two case studies and as discussed in two focus groups of the key stakeholders of the basin are summarized in Table 5. The findings of the case studies suggest that successful adoption of the identified innovations requires a proper institutional setup of water management. Adoption of the innovations under the current water management based on a top-down approach may, in cases of water shortage, increase the risk of conflicts between water users and water organizations. Therefore, participatory water management was indicated as a base for successful adoption of the potential innovations. The participants of the discussion hypothesized that an involvement of the water users in the water management will both reduce risks of conflicts and ensure equitable water allocations. In this paper, we have examined this hypothesis through the modeling approach and compared centralized state-driven water management and user-driven participatory scenarios.

Table 5. Implications of adopting innovations suggested by two case studies to water allocation in Kyrgyzstan.

Innovations	**Current instrument**	**Benefits**	**Risks**
Right for water use in extent of run-of-river flow.	Water use permit system; water right for water use is under adoption.	Equitable water allocation between upper and lower sub-basins; incentives for increasing efficiency of water use and decreasing water losses.	Water charges based on irrigated area do not permit implementing this rule at the on-farm level in most of the cases in Kyrgyzstan.
Right for beneficial water use.	Water right for water use is under adoption. Transboundary state right for water use in extent of run-of-river flow for small transboundary rivers.	The state may use water losses beneficially in future; secured future and environmental needs; improved access to water and water accounting by water organizations; improved viability of, and incentive for water saving by water user organizations. May produce new benefits for small transboundary river basins.	Proper water accounting is required at all levels starting from the basin to farm gates. Upstream/downstream conflicts may arise under water shortage conditions.
Double-level water tariffs.	One-level water tariff, area based, depends on irrigation requirements of different crops.	Improved water accounting; improved viability of water organizations; improved water supply.	Conflict between WOs and WUAs under poor water accounting conditions; full access to river flow data to be provided to WUAs
Access license.	Permits for limited water use under water shortage.	Facilitates water trading; provides secured water supply;	Is to be tested, yet unknown

Table 5. *Cont.*

Continuous accounting rule.	None.	Facilitates water trading; improved water accounting.	Guaranteed access to storages is required for water users; the state may reallocate the stored water for other needs.
Market-based water efficiency compliance instrument.	Command and control.	Creates incentives for water saving; facilitates saved water trade; applicable even in water pricing based on irrigated area.	Conflict between different farmers may arise on preferential access to water.

The specific conditions to define scenario 1 (top-down) comprised minimizing the costs of water delivery, reducing water deficit, accumulating water in the reservoir for the next season, and restricting double cropping in low water years. The specific conditions to define scenario 2 (user-based) comprised maximizing collection of irrigation service fee, accumulating water in the reservoir for the following season and not restricting double cropping. It was assumed under scenario 2 that farmers can practice double cropping even in low water years and water management organizations are free to reallocate irrigation water from the first to the second cropping.

With this in mind, the next section compares the efficiencies of the top-down approach *versus* the user-driven participatory approach as outlined above.

8. Optimal Water Allocation in the Akbura River Basin

The run simulations indicated different levels of water fee collection under the top-down (scenario 1) and the user participatory approaches to water management across all main canal systems of the Akbura River basin (scenario 2) (Figure 5).

Overall, under scenario 2, the collection of water service fees was 25% higher than under scenario 1 where no access to water for the second crop in low water years was assumed. As for the reallocation of part of the irrigation water from the first to the second crop, scenario 2 was more efficient than scenario 1 (Table 6).

Figure 5. Fee collection under top-down and user participatory water management.

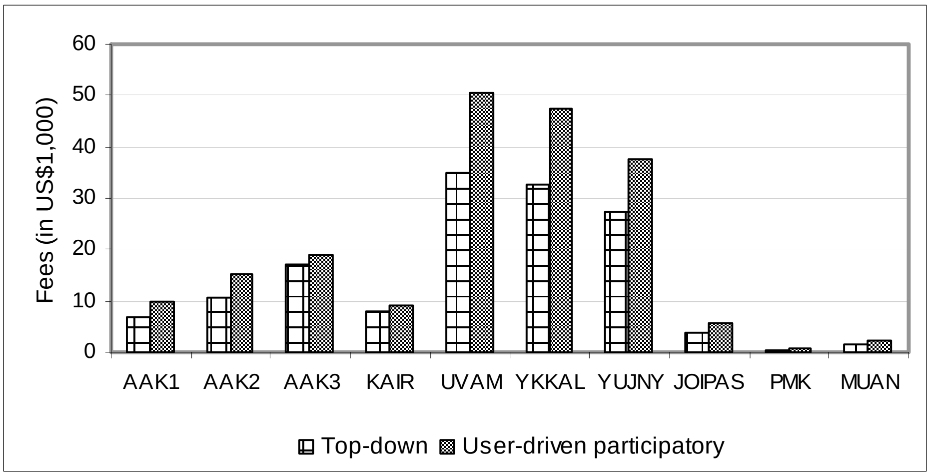


Table 6. Simulation of first and second cropping areas under user participatory water management.

Sub-commands of the Akbura River basin	First crop		Second crop	
	Area ha	**Water deficit Tm^3**	**Area ha**	**Water deficit Tm^3**
AAC Upper	1,195	0	598	0
AAC Middle	1,867	0	934	0
AAC Lower	3,005	1,735	1,503	4,487
Kairma canal	1,406	868	703	1741
Yujny canal	4,824	2,511	3,082	0
Muan canal	302	0	2,901	0
Uvam canal	6,164	0	2,412	0
Ykkalik canal	5,801	0	340	0
Joipas canal	680	0	40	0
PMK canal	79	0	151	0

Note: $Tm^3 = 1,000\ m^3$

Under scenario 1, irrigation water was applied to the first crop only. The simulations suggest that production of the second crops under scenario 2 was efficient on 12,664 ha (or 50% of the total irrigated area) after harvesting winter wheat.

Clearly, the effects of transition from top-down to user participatory approach were the following implications: profits of water organizations increased, while water user demands were better met owing to adoption of water saving technologies by water users and reallocation of water from the first to the second crop. Excluding restrictions on the second crop under scenario 2 stimulated the application of deficit irrigation and allowed reallocation of the water saved. Farmers were interested in gaining more crops with less water, while water organization benefited from increased fee collections. The results of the modeling studies indicated the importance of introducing effective penalties for debts of the water users to water organizations and for free storage of the reservoir under the user participatory water management. In this study, the penalty for debts was equal and for free storage of the reservoir it was 30% higher than for the fees for irrigation water supply.

Conclusions

Under the top-down water management approach farmers have no incentives to save irrigation water due to low tariffs for irrigation water delivery and water restrictions imposed on a second crop. Under user participatory water management, the double cropping strategy increases farmers' benefits and improves irrigation service fee collection both by WUAs and water management organizations. The user participatory approach in water management allows maximizing profits to farmers and the collection of water fees to water organizations.

Preliminary findings from the comparative analysis presented in this paper suggest that the benefits from a transition to user participatory water management in Kyrgyzstan can be more significant when supported by proper arrangements in current water allocations. The findings of model simulations also suggest that farmers can achieve higher profits by reallocating a part of their irrigation water allowance from the first to the second crop. As a result, incomes of water organizations are increased due to higher cropping intensities. The studies indicated the importance of establishing effective penalties for debts of water users to water organizations for water delivery services and for free storage of the reservoirs.

Other specific conditions emerging from the two case studies reviewed in this paper (*i.e.*, those from Texas and New South Wales) that could lay the basis for testing future scenarios may include: (a) preferential access to water for water users investing in water saving technologies; (b) water allocation planning based on available water resources; and (c) rights for beneficial water use. Further modeling studies are required to examine the proposed regulatory interventions under different policies and ecological environments of Kyrgyzstan and other neighboring Central Asian countries at the basin, sub-basin and WUA levels.

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