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Addressing Water Resources Regulations Policy in Zeravshan River Basin

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Synopsis

Water resources security and efficient usage is the main source of conflict over transboundary rivers. Zeravshan a transboundary river in Central Asia is a snow-glacier fed river originating in Tajikistan that use only 4% of its resources and further flows to Uzbekistan, who fully utilize river resources for irrigation. Such disparity in river usage causes Tajikistan to consider heavy investments in hydropower dams that will increase social and political tension between counterparts. The distribution of the available lands for irrigation and income is high in downstream, while upstream argues to have right over water to generate own benefits in producing energy.

In this research we analyze impacts of the future dam construction in the middle stream of the Zeravshan river basin through framework of several models to address future policy on the water resources regulation. To balance usage of the water resources between participators to reach a better economic outcomes between argues.

Keywords: SiBUC, water resources policy, water management, Zeravshan river basin

1. Introduction

Balancing water demand for the whole basin efficiency is priority task in the world. This is especially true in the arid regions with the limited resources, where water resources is linked to the main income source agriculture. Central Asia is one of such regions with conflicts over water sharing of the transboundary river basins. Here are two groups of countries with opposite interests, the first upstream countries, being origin and source of the river flow mostly mountainous regions interested in hydropower generation, and the second who utilize the most of the flow for irrigation in agriculture. The distribution of the available lands for irrigation and income is high in downstream, while upstream argues to have right over water to generate own benefits in producing energy. The balanced usage of the water between participators to reach the most outcome from available resources could ease tension and provide a better economic outcomes between argues. In this research we address this problem through implementation of the framework to assess water resources distribution policy over dam operation in the upstream.

Zeravshan river basin a transboundary river shared by Tajikistan in upstream and Uzbekistan downstream is chosen for the investigation (fig. 1). Previously, one of tributary to Aral Sea is now reverted in the fields for irrigation, although 20% of return water is reused again it is still not enough to cover irrigation needs. Today Tajikistan uses only 4% of the river flow, while for the Uzbekistan it is a very important water source fully utilized for irrigation. Such disparity in river usage causes Tajikistan to consider heavy investments in hydropower dams that possibly will increase social and political tension between counterparts. The

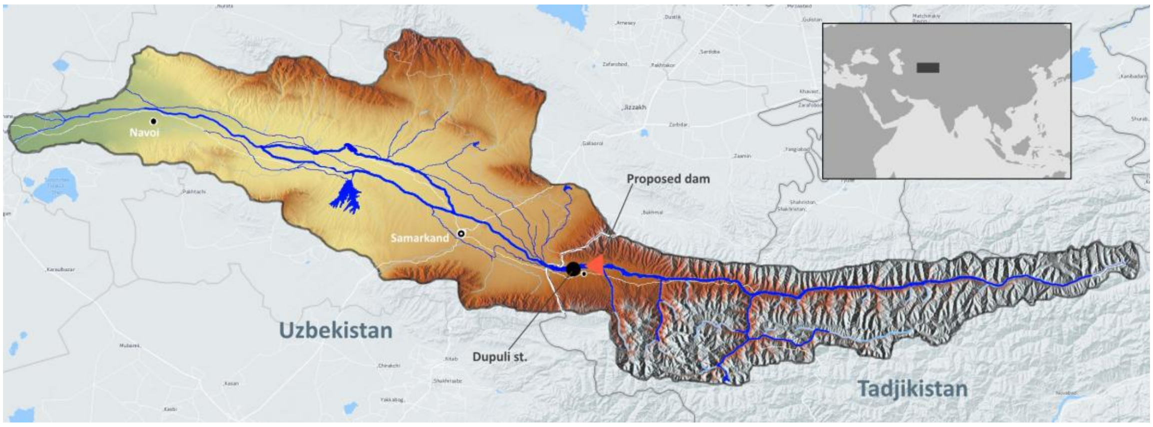


Fig. 1 Zeravshan river basin study area

dam planned in the middle stream of the Zeravshan River Basin were chosen to analyze possible scenarios of dam operation versus agriculture irrigation.

Zeravshan river basin relies on conventional flooding irrigation practices and soil leaching that requires large amounts of water. On the other hand, traditional irrigation under extreme arid climate conditions and huge diversion of the water resources causes high rates of water losses in infiltration and evapotranspiration leading in many cases to land salinization that further require more water for cleaning (Toderich et al, 2005). These processes may be intensified by climate change under less water availability and frequent droughts in Central Asia directly impacting human wellbeing (Toderich et al, 2010). The major challenge, especially in dry season is as reports indicate above average temperature increasing trend equal to 1.2-2.1°C, which doubles global average of 0.5°C (IPCC, 2007). Such warming poses a threat to the glaciers and snow storage that currently provides over 98% of the water for irrigation in summer season in Zeravshan (Hagg et al., 2007, Olsson et al., 2010). Observation of the glaciers over the last decades has already shown high recession rates (Aizen et al. 1997). Bernauer and Siegfried (2012) suggest the major implications of the predicted climatic change scenarios will be changes in seasonality of the runoff, mild winters, hot and more dry summers with less amounts of available water. Such climate change is accepted to have great impact not only to agriculture due to water availability and quality deterioration caused by lesser water availability but also cattle breeding in directly affecting forage availability and other spheres of human activities in region. Thus defining current state of the *status quo* in the Zeravshan River basin as well as analyze strategies for water resources usage is important.

Arguments over increasing water use by upstream to the water demand in downstream and analysis of the possible water resources distribution were analyzed. Through optimization framework including multi objectives impacts on the dam operation, irrigation demands, social and urban demands were used. The framework includes model to analyze available water resources and assessment of the whole basin efficiency including dam operation and irrigation demand. Our main goals were to define optimal solution to achieve nexus on water resources distribution between counterparts and discuss possible impacts for the future climate change impacts investigations.

2. Methodology

2.1 Framework setup

The framework to analyze impacts of the water recourses redistribution includes 3 main blocks (fig. 2): land-surface model - SiBUC block to calculate water balance in the basin as well as available river flow; simple Dam operation model block that addresses operation options to maximize hydropower output or irrigation; Policy analysis block focuses on calculation of available options to maximize hydropower and irrigation output based on observed discharge data from past to project it for future runs. First results of the SiBUC model output - available water resources are transferred to

Dam model, in the second phase Dam model calculates output of the discharge on the Dupuli station (on the border of Uzbekistan and Tajikistan), based on this results policy for the dam operation and irrigation needs are addressed in the Policy Analysis model.

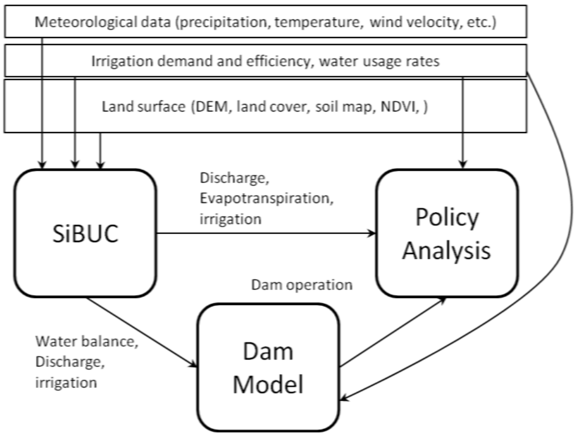


Fig. 2 Framework for policy analysis.

2.2 SiBUC model set up and datasets

To address climate change impact and assess water balance of the basin we applied Simple Biosphere model including Urban Canopy (SiBUC) land surface model (Tanaka et al, 2004). The model use "mosaic" approach to incorporate all kind of land-use into land surface model including irrigation schemes that takes into account main flooding practices used in the region (Touge et al, 2015).

In this study data from SRTM30 digital elevation data of CGIAR-CSI (Consultative Group for International Agriculture Research-Consortium for Spatial Information) was used (http://srtm.csi.cgiar.org). The data were analyzed from 250m resolution originally, additionally upscaled dataset of 1 km were used. Land use data of GLCC ver. 2 (global land cover characterization) by USGS grouped to 24 types were applied. We also obtained official irrigation area data from the Ministry of Melioration and Water Resources of Uzbekistan (MAWR). Spot Percentage of the land use area was calculated in each grid of 5km grid to re-classify the definition of land use in SiBUC in respect to non-irrigated area. EcoCliMap data needed for processing of the land surface process such as soil data rate, the number of leaf area, green leaves amount and others (http://www.cnrm.meteo.fr/gmme/PROJECTS/ECOCLIMAP/page_ecoclimap.hrm) also were used. Meteorological forcing dataset from Hirabayashi (H08) available for global use were chosen in this research. H08 dataset is weather data of 0.5° global by Hirabayashi et al. (2008) for 1948 to 2006 years provided for each day. In addition to meteorological data that has been forced from the observational data, we also corrected coverage of the rain gauge data using the wind speed data in H08 in Central Asia due to dependency to water source in snowfall in areas of high altitude. Additionally data from JRA-25 (http://jra.kishou.go.jp/JRA-25/index.html) to supply atmospheric pressure and wind velocity missed in H08 were analyzed. Hydrological observed daily dataset from Meteorological Agency of Uzbekistan collected from 1959 to 1999 of the river discharge were used to check river flow historically and calibrate river flow output in Dupuli station (fig. 1).

Outputs of the SiBUC are essentially calculated via simple Dam operation model, that takes to account dam level operation needs, irrigation demands to calculate simple water balance based on inflow from SiBUC to the monthly output passed to the Policy Analysis calculations.

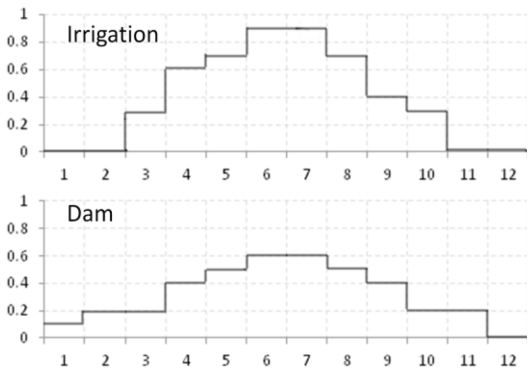


Fig. 3 Water resources demand of each objective in time scale (%, from total)

2.3. Policy analysis and dam operation

For policy analysis the emphasis was given to the maximization of the hydropower output and irrigation. Figure 3 shows that current demand of the irrigation and dam operation are in correspondence with each other, while the maximum output are on opposite sides. Irrigation is mostly needed in summer, while hydropower generation benefit is in winter. In this case keeping dam level within season of the irrigation could become the main sources of negotiations of the dam operation. To address such questions, simple calculations of the current flow with an effect of the dam operation and other components of the river are presented on the figure 4. In this research Reservoir 2 was omitted due to limited data.

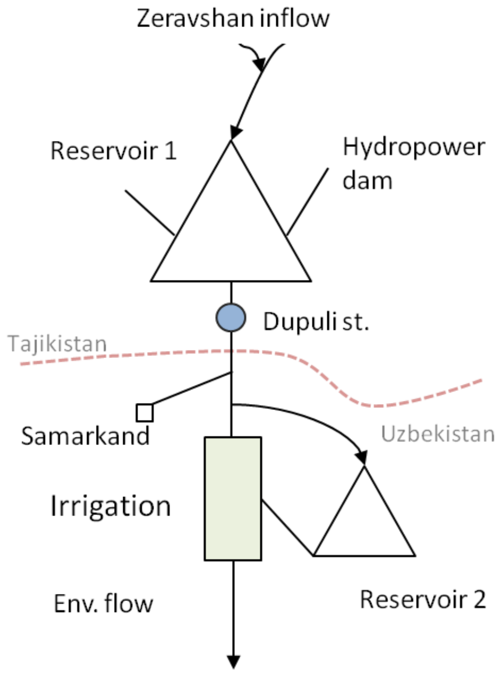


Fig. 4 Scheme of the main components described in the policy model

The analysis model is based on the mass balance equation of the water volume available s_t in Reservoir 1 through identification of the multi-objectives dynamics in Zeravshan river basin (1).

$$s_{t+1} = s_t + q_{t+1} - I_{t+1} - e_{t+1} - r_{t+1} \qquad (1)$$

where s_t water volume change between t and t+1 time; q_{t+1} - inflow to the dam calculated by SiBUC output on the Dupuli station point; I_{t+1} - irrigation demand based on the calculations needed for current agricultural needs downstream; e_{t+1} - environmental flow, defined as a minimum flow needed; r_{t+1} is release decision for dam operation, based on maximization of the hydropower generation, irrigation supply and environmental flow. To simplify output, hydropower generation is optimization of the outflow - high discharge provides high energy outcome. Decision time step is adopted on daily basis, based on the inflow to the reservoir and its current level.

The highest priority was given to the irrigation, as it provides highest benefit per person, hydropower energy generation is second in rank and had to be adjusted to the seasonality of the energy needs compared to when it will provide most.

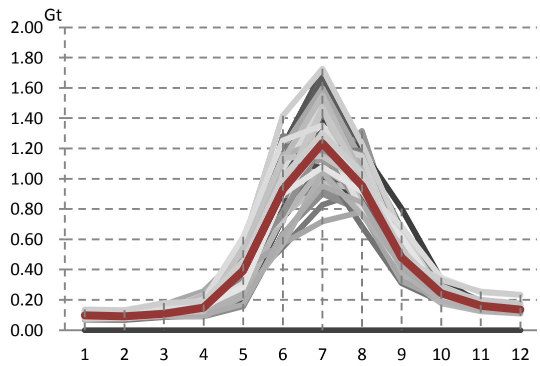


Fig. 5 Average water balance for whole year ensemble (1972-2000)

3. Results and discussion

3.1 Simulation inputs

First simulation of the land surface model were conducted, to check output results and address quantity of available water resources. After results were obtained it was compared to the historic observation. The simulation in the upstream by SiBUC supported to have difficulties in the mountainous area and glacier feed river. Due to absence of the recent classified glacier data, high elevation over 4500m were proposed to have glacier coverage. This assumption further was checked by glacier coverage map available in the basin by Meteorological Agency of Uzbekistan for the year 2000. GCM datasets were subjected to BIAS correction for the area. The basin was divided to 2 areas: upstream - mountainous areas, irrigated areas in downstream. Correcting coefficient were used to match observed datasets in 1972-2000 years. The impact of the flow were analyzed compared to the data on Dupuli station in the upstream.

Although compared to the average annual discharge results are not significantly different from observed (fig. 5). We concluded that total available water flow stays reasonably close to observed data to make further flow estimations (Khujanazarov et al, 2014).

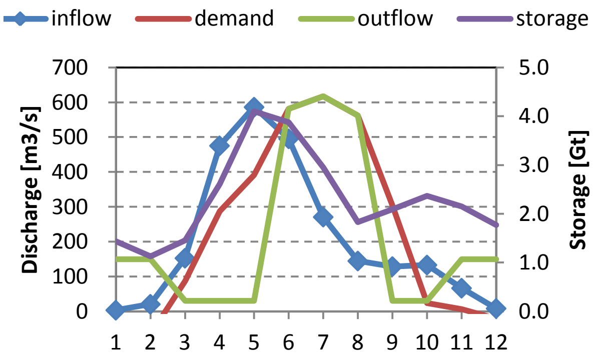
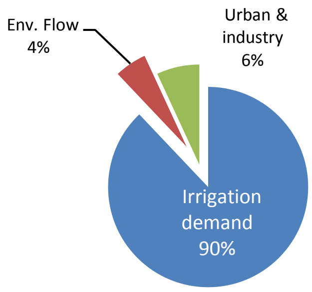
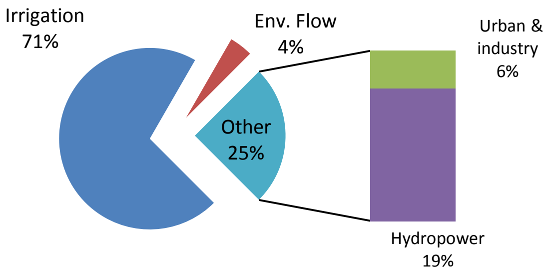


Fig. 6 Dam operation to the average of 30 years flow (1975-2000)



a)



b)

Fig. 7 Average water balance for whole year ensemble (1975-2000)

In the second phase results were input to the dam operation model and divided to 2 scenarios in policy analysis: a) irrigation benefit, b) energy generation with the balance to irrigation.

Dam operation, showed overall decrease in the discharge to 15% compared to the average flow, which will cost significant decrease in irrigated area downstream, even without reservoir filling time. On the other hand, dam operation provides option to control flow with specific timing while providing more smooth releasing curve (fig. 6). Additionally, it has to be noted, that evaporation rates, which are high in this region should also be included in the model operation to contribute to the reservoir level. Overall results from the policy analysis however, show different outcomes in 2 selected scenarios (fig. 7). Results show that water discharge in the scenario a) will be decreased for 10% than current discharge, as from released flow only 90% will be available for irrigation even it will be totally committed to irrigation. While environmental flow could be considered within available flow, some of it will be discharged in the autumn-winter months, when water is not used for irrigation. On the other case, this flow could be considered as stable within variations of wet and dry years, providing certain amount of water within several seasons. In the second scenario b), considered as optimization for irrigation with dam operation in winter, decrease is more significant and holds for 20% low than available flow for irrigation on average. In this case however, discharge through period of energy generation was highest in non-vegetation periods, thus decreasing available resources. It is also important to note that such operation can have severe impact in the downstream that has 7 times high population compared to upstream.

4. Conclusions

In this research we could assess the impact of the dam operation in the upstream of the Zeravshan River through framework including several models simulation. Using land surface model SiBUC shown good results in calculating available water resources in the arid climate, while early peaks of hydrograph remains to be solved in future.

Results show how dam operation can benefit energy output while having positive impact on irrigation, however still can't compensate the needs of energy in winter months. Although, availability of the water resources in dry and wet years could show positive impact on planning crops and outcomes in future. In case of the energy production cooperation of the both sides are required to address such changes in river flow as interest lies on opposite side. Dam operation rules in dry years with limited discharge as well as access to control flow of the water should be taken to account. Both sides should cooperate to increase Zeravshan River basin efficiency through increasing irrigation efficiency or even re-using water resources. Combination of dam operation for energy production and increasing irrigation efficiency additionally by using return waters can provide a beneficial scenario for the region under future climate change. However, it will require strong political will to address energy swap interexchange and social impact on population with decreased water flow. Our main goals were to define optimal solution to achieve nexus on water resources distribution between counterparts.

SiBUC performance has shown good results in reproduce water balance in the region. It is important to address earlier water peaks on the river with further analysis of the glacier melting and river basin topography for altitude dependant correction proved to be one of main factor in the simulation overestimation. Dam operation model, should also be improved considering reservoir filling, and more advanced operation rules should be implied, that could control flow more efficiently on the monthly basis. Policy analysis should include additional scenarios for dry and wet years, while considering economic impacts of hydropower generation and irrigation benefits. This should be addressed in future research and to re-estimate water resources in the basin.

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