ECONOMICS OF INTEGRATED BASIN SCALE MANAGEMENT IN THE PRESENCE OF DAM

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Introduction and Background

Source: Blueyurt Central Asia

Development of Water Resources Management in Central Asia

Soviet Union period (1924-1991)

- One integrated scheme
- Decision-making controlled by Moscow
- Upstream states of Tajikistan and Kyrgyzstan control water resources Amu Darya and Syr Darya Rivers, respectively. Water-abundant states with no own energy resources
- Downstream states of Uzbekistan, Turkmenistan and Kazakhstan have large agricultural land (cotton and wheat) but not enough water supplies. Water-deficit states with energy resources (oil and natural gas)
- Water for downstream states in irrigation period in exchange for energy supplies for upstream states in winter
- Ignore water claims of Afghanistan

Development of Water Resources Management (Cont.)

<u>Independent period (1991 to present)</u>

- Disputes because of the mode of operation of dams
- Agreement of February 19, 1992 "Cooperation in the Management, Utilization, and Protection of Water Resources of Interstate Sources"
- Interstate Commission for Water Coordination (ICWC) is established
- Water allocations in Amu Darya River basin (in percent of flow per year)
  - *Kyrgyzstan – 0.6% (0.4 km^3 or 0.1 mi^3)*
  - *Tajikistan – 15.4% (11.3 km^3 or 2.7 mi^3)*
  - *Turkmenistan – 35.8% (26.3 km^3 or 6.3 mi^3)*
  - *Uzbekistan – 48.2% (35.5 km^3 or 8.5 mi^3)*
- No agreement on provision of energy resources

Proposed Plans in Central Asia

New dams on Amu Darya River Basin:

- Dastijum Dam – agricultural and energy benefits for both Afghanistan and Tajikistan
- Rogun Dam - agricultural and energy benefits for Tajikistan

Design data: Rogun and Dastijum Reservoirs

Parameter	Units	Rogun	Dastijum
Height	m	335	320
Design capacity	cubic km	13.30	17.60
Active regulation storage	cubic km	8.60	10.20
Surface area	square km	170	135
Max depth	m	310	300
Hydropower capacity	MW	3,600	4,000
Long-term average annual hydropower production	TWh	14.50	15.60
Average cost of completion	million USD	2,800	3,200

Need for Integrated Analysis

Basin-scale analysis:

- Inform policy debates
- Better informed outcomes
- More efficient and sustainable economic benefits

Existing literature (Selected)

- Raskin et al. (1992) developed and applied a simulation model of water supply and demand for the entire Aral Sea Basin
- Cai et al. (2003) examined irrigation water management in entire Aral Sea Basin
- Glantz (2005) conducted a comprehensive analysis of water-climate-environment-demographic situation in Central Asia
- Schlüter et al. (2005) described optimization of long-term water allocation in the delta of Basin with an emphasis on ecological impact assessment
- Wegerich (2008) examined relations between water used for energy and agriculture production
- Schlüter and Herrfahrdt-Pähle (2011) analyzed water institutional resilience in the face of interdependent economic and ecological connections in the Basin

Gaps from previous work

- No analysis to date estimates consequences of the Dastijum Dam in place

- Previous models have not considered economic value of water allocation in the region

- A policy analytic model is needed that accounts for demands and possible future benefits of water developments for Afghanistan

Objectives

- Examine potential for mutually beneficial water development and allocation for sustainable development in the Amu Darya river basin to meet demands for water, food, and security.

- Develop policy-informing basin scale framework for 20-year horizon to analyze tradeoff between water, food, and energy.

- Examine economic feasibility of new irrigation developments in both Afghanistan and Tajikistan to reduce poverty and sustain economic benefits.

- Examine economic potential for hydro energy production in Afghanistan to achieve energy needs, revitalize local industry and promote exports.

Approach

Four policy options are examined:

1) With no dams
2) With both dams
3) With Rogun only
4) With Dastijum only

Under each of two water supply scenarios:

1) base
2) dry (50% of base)

With no dams: base water supply With no dams: dry water supply

With both dams: base water supply With both dams: dry water supply

With Rogun only: base water supply With Rogun only: dry water supply

With Dastijum only: base water supply With Dastijum only: dry water supply

Approach (cont.)

The model optimizes water distribution according to set objectives with the given constraints and available data in the entire modeled time period

Model reflects historical irrigated crop area in the basin (without Rogun and Dastijum Dams)

Important model dimensions:

- Water allocation
- Crop production
- Energy production
- Tradeoff between agriculture and energy production

Model Structure

- Crop mix: cotton, wheat, vegetables
- Irrigation season: Mar-Aug
- Second crop: June-August
- Hydropower demands: Sep-Feb
- Weak Afghan data: water, energy, crops, crop patterns
- No groundwater data

Model description

River and irrigation network is defined by:

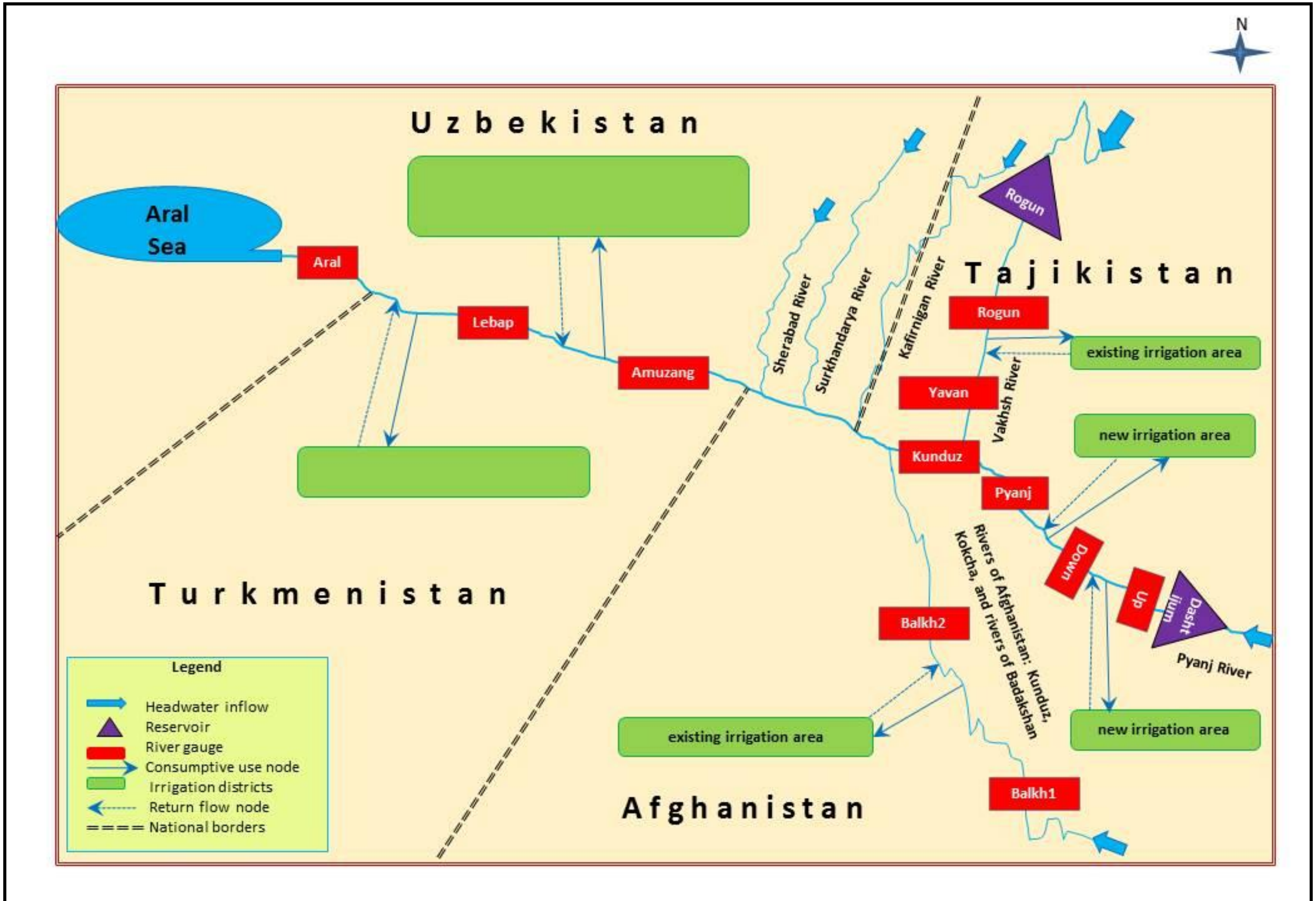
- Nodes: sources, diversions, users, return flows, irrigated areas, power production

- Gauges: account for monthly river flows

- Basin Schematic: consists of tributaries located in the upper stream: Vakhsh, Pyanj, Kafirnigan, Surkhandarya, Sherabad, and Kunduz rivers, two reservoirs (Dastijum and Rogun)

- Constrained optimization: maximizes net benefits from water allocated across users (countries)

Amu Darya Basin Schematic



Major equation and constraints

Objective Function

$$XBu = \sum_{u}\sum_{t}\sum_{m} AB_{utmhp} + \sum_{r}\sum_{t}\sum_{m} EB_{rtmhp}$$

AB_{utmhp} - ag benefits in *u* nodes in *m* month of year *t,* scenario *h* and policy *p*;
EB_{rtmhp} is energy benefits in *r* reservoir in *m* month of year *t,* scenario *h* and policy *p*

$$AB_{utmhp} = \sum_{j}\sum_{k}(P_{jtmhp}Y_{ujk} - C_{ujk})$$

P_{jtmhp} - price of each crop*,* Y_{ujk} crop yield in *u* node, and C_{ujk} cost of production in that node *u* per crop *j* in season *k*.

$$EB_{rtmhp} = EP_{tmhp} . P_{tmhp}$$

EB_{rtmhp} - energy benefits produced in *r* reservoir, in *m-th* month of year *t* in scenario *h* and policy *p*;
EP_{tmhp} is energy production in *r* reservoir in *m-th* month of year *t* scenario *h* and policy *p*
P_{tmhp} is electricity price which is fixed as P_{tmhp} = 0.02 (million of US dollars per GWH per month).

Political and Justice Constraints

Equity constraint

Ag land with dams > = Ag land without dams
Ag land with Dastijum Dam > = Ag land without dams
Ag land with Rogun Dam > = Ag land without dams

Hydrology constraint

Total Annual Water Used < = Mean Annual Discharge of Amu Darya

Data

- Headwater inflows
- Stochastic nature of inflows
- Reservoir storage capacity
- Reservoir energy production varies with height (head) and flow released through turbines
- Crop water requirements by crop and country
- Crop price
- Crop demand elasticity

Findings with Policy implications

- Development and operation of storage reservoirs offers opportunity for each basin country to be better off than without that storage.

- Total water-related economic benefits for entire basin with both dams are up to 44% higher than without the storage for both water supply scenarios (43% higher with Dastijum and 40% higher with Rogun).

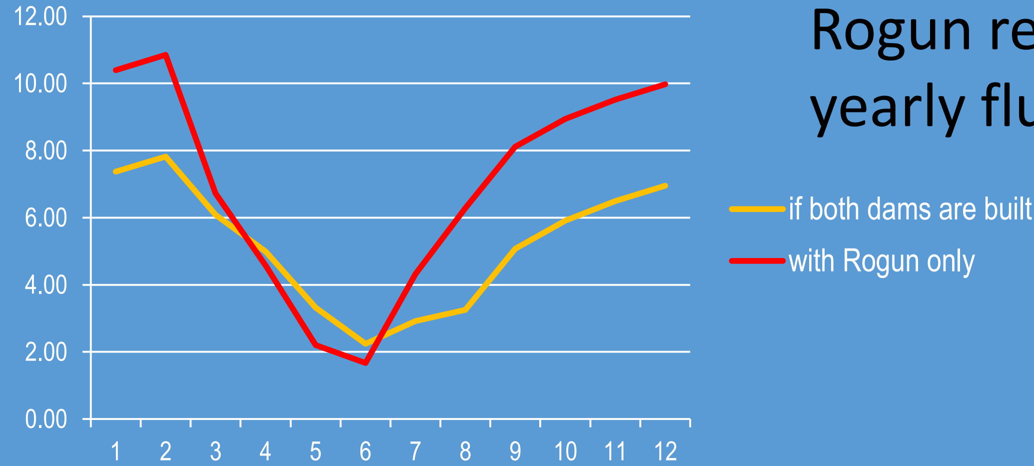
- Development and operation of each reservoir separately or both dams together the potential to increase both total irrigation land and farm income for both water supply scenarios (normal and drought).

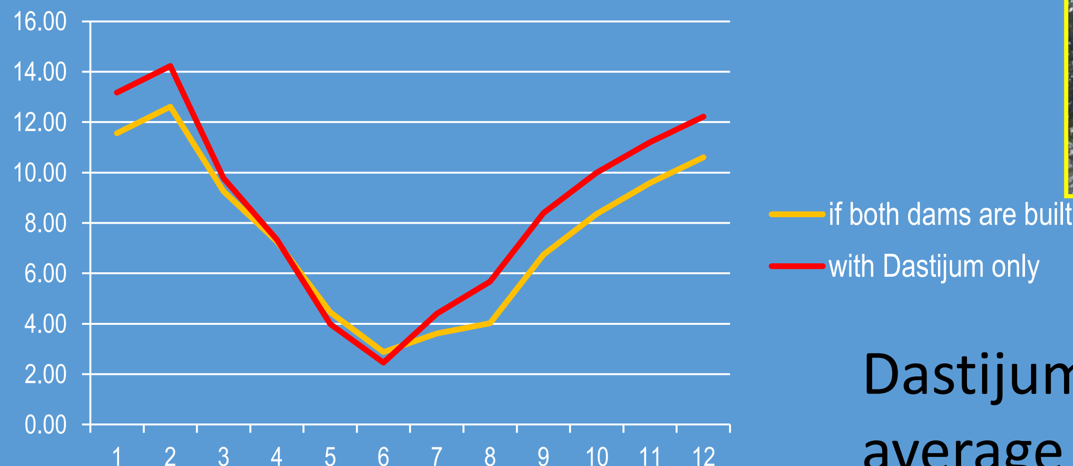
- With either or both dams, northern Afghanistan has potential to develop almost half of million hectares of new land.

- New land in Afghanistan could supply US$ 121 million in the base water scenario and US$ 98 million in 20 years (discounted at 5%).

Storage volume

Rogun reservoir average yearly fluctuations





Dastijum reservoir average yearly fluctuations

Farmland

- No reduction in farmland required from presence of dams
- Both Uzbekistan and Turkmenistan with reservoirs show little increase in total land in production (130% and 101%, respectively)
- However, Afghanistan and Tajikistan show large increase (508% and 196%, respectively) as Afghanistan will have 500,000 ha and Tajikistan – 300,000 ha.
- Cropping mix need not be affected much by reservoir development and operation

Food Production

- Agricultural output could increase in the case of the Dastijum and Rogun dams

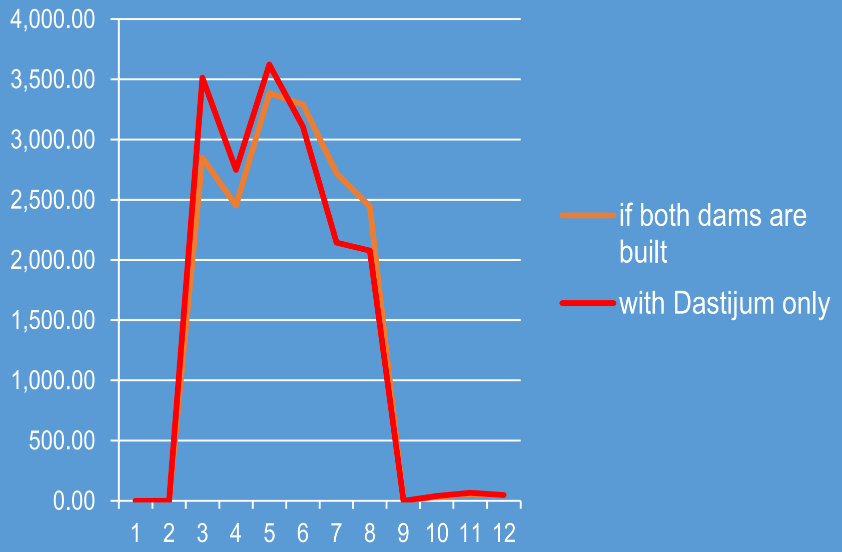
- Upstream countries will experience the highest growth

- Downstream countries could moderately increase their agricultural production

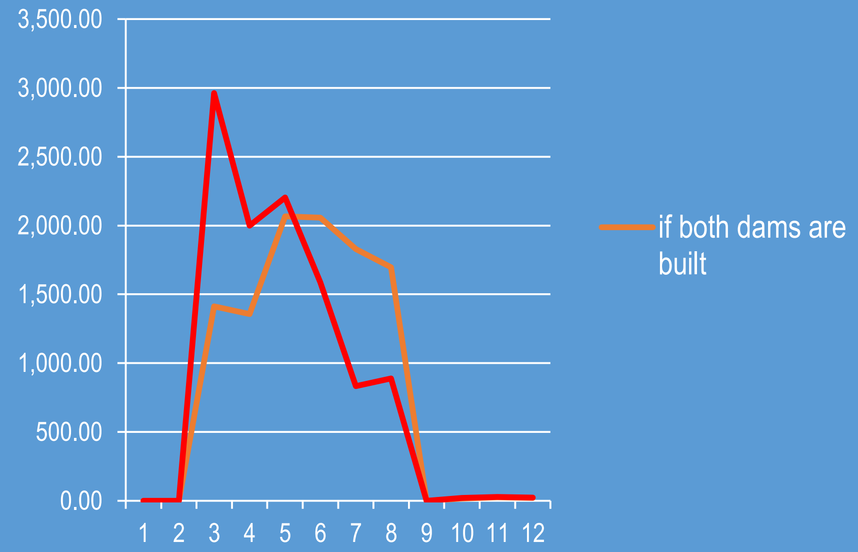
- As a result all of them could assure greater food security for continually growing population

Energy Production

Rogun



Dastijum



Electricity production

Year	Total energy production GWh/year	Note
Dastijum	17,000	Produced in nine months (except Sep, Jan, Feb) Maximum capacity of DR 15.6 TRh/year and RR 13.3 TRh/year
	7,000	
Rogun	10,000	
	4,000	

Conclusions

- Reservoirs could simultaneously serve energy requirements of Afghanistan and Tajikistan while increase food security for all riparian countries.

- All basin countries could be better off with dam than without dam: economic benefits to all countries could increase.

- Political negotiations needed to find policies to secure and sustained these benefits.