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Comparative Analysis of Projected and Actual (Observed over Past Decade) Water-Availability in the Syr Darya and Amu Darya River Basins

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INTRODUCTION

This policy brief analyzes the accuracy and effectiveness of growing-season river runoff forecasts for five key sections of the Aral Sea basin: the Naryn, Karadarya, Chirchik, and Vakhsh rivers, and the Amu Darya at the Kelif settlement (nominal Kerki gauging section). Prepared annually as of April 1st for the 2015-2024 period, these forecasts utilize the analogue-year method. This analysis evaluates the methodology's performance to determine its reliability for water management.

FORECASTING AND EVALUATION METHODOLOGY

Forecasting Methodology

The assessment of potential river runoff was conducted using the analogue-year method. This approach identifies two historical years that most closely resemble the hydrological conditions of the current year as of 1 April.

Analogue years are selected from the SIC ICWC database, which contains runoff records dating back to 1911. The selection process is governed by two primary statistical criteria. Criterion 1 implies minimal deviations between the integral curves of key hydrological parameters for the

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current year and the potential analogue year. Criterion 2 suggests minimal deviations in the sum of monthly variation modules. By identifying historical hydrological series with the highest similarity to the current year at the time of forecasting, the observed runoff from those analogues serves as the basis for the upcoming growing season's forecast. To account for natural variability, the results in this dataset are presented as interval ranges (minimum–maximum).

Forecast Verification

Forecast accuracy was evaluated using a strict verification protocol. A forecast is considered verified[1] (labeled as 'Correct') if the actual observed runoff value falls within the predicted interval (between the minimum and maximum values).

A forecast is classified as overestimated, if the actual runoff was lower than the minimum projected value. This indicates that the actual runoff was below even the most pessimistic forecast estimate.

A forecast was classified as underestimated, if the actual runoff exceeded the maximum projected value. This indicates that the actual runoff was higher than the most optimistic forecast estimate.

ANALYSIS

Based on the analysis of decadal data (2015–2024, total 50 forecasts), the following conclusions can be drawn.

Overall Forecast Correctness

The overall forecast correctness rate is **44%**, with 22 out of 50 forecasts classified as correct. These results indicate satisfactory performance of the analogue-year method when averaged across all selected rivers. However, forecast performance varies substantially between rivers. On average, every second forecast is inaccurate, which represents a significant risk for operational water management.

A total of 13 underestimated forecasts (46%) were identified, in which observed runoff exceeded the maximum forecast value. This type of error poses the greatest risk in terms of flood safety.

Additionally, there were 15 overestimated forecasts (54%), where observed runoff failed to reach the minimum forecast value. Such errors are particularly critical for crop irrigation and energy planning, as they may result in overestimation of available water resources and subsequent shortages during the growing season.

Analysis by Rivers

For the Naryn River, the forecast correctness rate is 50% (5 out of 10 years). The analogue-year method demonstrates relatively high reliability for this river.

Errors due to forecast overestimation or underestimation are nearly balanced, with two cases of overestimation and three cases of underestimation (Table 1).

For the Karadarya River, the forecast correctness rate is 40% (4 out of 10 years) and is con-sidered the least reliable among the analyzed forecasts. Overestimation and underestimation errors are equal, with three cases of each (Table 1).

[1] Table 1 marks a verified forecast as 'Correct', overestimation as 'Over' and underestimation as 'Under'

Table 1

Comparison of forecasts for the growing season with actual data for 2015-2024 (as of April 1) in the Syr Darya Basin

Year	Naryn river – inflow to the Toktogul reservoir				Karadarya river – inflow to the Andijan river				Chirchik river – inflow to the Charvak reservoir			
	Forecast		Actual	Forecast correctness	Forecast		Actual	Forecast correctness	Forecast		Actual	Forecast correctness
	min	max			min	max			min	max		
2015	*9,221*	*13,229*	*10,407*	*Correct*	*1,716*	*2,340*	*2,778*	*Under*	*5,811*	*6,201*	*5,348*	*Больше*
2016	*7,970*	*12,187*	*12,095*	*Correct*	*1,625*	*4,066*	*2,277*	*Correct*	*4,453*	*6,289*	*6,145*	*Correct*
2017	*10,349*	*11,332*	*13,383*	*Under*	*1,791*	*2,170*	*4,132*	*Under*	*5,545*	*6,359*	*8,694*	*Under*
2018	*9,888*	*12,179*	*9,853*	*Over*	*1,752*	*3,758*	*2,491*	*Correct*	*4,108*	*5,625*	*4,673*	*Correct*
2019	*12,095*	*12,187*	*8,806*	*Over*	*2,372*	*2,976*	*1,945*	*Over*	*4,990*	*5,719*	*6,241*	*Under*
2020	*7,188*	*10,640*	*8,679*	*Correct*	*2,084*	*2,420*	*1,200*	*Over*	*4,681*	*6,116*	*4,399*	*Over*
2021	*7,188*	*10,640*	*8,762*	*Correct*	*2,084*	*2,420*	*1,719*	*Over*	*3,921*	*4,681*	*3,863*	*Over*
2022	*7,371*	*8,521*	*10,429*	*Under*	*2,080*	*2,778*	*3,014*	*Under*	*5,601*	*6,243*	*4,572*	*Over*
2023	*7,970*	*13,559*	*9,178*	*Correct*	*1,549*	*2,463*	*2,072*	*Correct*	*5,012*	*5,783*	*4,209*	*Over*
2024	*8,679*	*10,640*	*10,693*	*Under*	*2,080*	*3,014*	*2,465*	*Correct*	*5,012*	*5,130*	*5,071*	*Correct*

For the Chirchik River, the forecast correctness rate is 30% (3 out of 10 years), with overestimation errors predominating. In 5 out of 7 unverified cases, the observed runoff was lower than the projected values, indicating that the method more frequently overestimates runoff for the Chirchik River (Table 1).

For the Vakhsh River, the forecast correctness rate reaches 50% (5 out of 10 years), reflecting an average level of accuracy. However, a tendency towards underestimation is evident: in 4 out of 5 unverified cases, the observed runoff exceeded the projected values. This suggests insufficient estimation of high-water years for this river (Table 2).

For the Amu Darya River (at the nominal Kelif gauging station), the forecast correctness rate is also 50% (5 out of 10 years). In this case, a clear tendency towards overestimation is observed, with four cases of overestimation compared to one case of underestimation (Table 2).

Table 2

Comparison of forecasts for the growing season with actual data for 2015-2024 (as of April 1) in the Amu Darya Basin

Year	Vaksh river – inflow to the Nurek reservoir				Amu Darya River – Kelif section			
	Forecast		Actual	Forecast correctness	Forecast		Actual	Forecast correctness
	min	max			min	max		
2015	*16,070*	*16,422*	*19,343*	*Under*	*36,204*	*54,429*	*47,101*	*Correct*
2016	*11,503*	*16,819*	*17,205*	*Under*	*45,524*	*46,997*	*35,926*	*Over*
2017	*15,094*	*18,346*	*21,887*	*Under*	*22,484*	*43,120*	*46,466*	*Under*
2018	*16,765*	*17,742*	*16,244*	*Over*	*42,596*	*52,209*	*33,281*	*Over*
2019	*15,386*	*17,167*	*17,439*	*Under*	*26,852*	*46,260*	*42,804*	*Correct*
2020	*13,222*	*18,869*	*13,298*	*Correct*	*40,678*	*64,834*	*33,551*	*Over*
2021	*13,313*	*19,196*	*15,465*	*Correct*	*26,852*	*42,804*	*36,965*	*Correct*
2022	*15,353*	*18,519*	*16,403*	*Correct*	*43,120*	*43,662*	*37,281*	*Over*
2023	*15,094*	*18,346*	*16,789*	*Correct*	*37,175*	*54,429*	*39,330*	*Correct*
2024	*13,222*	*18,869*	*16,388*	*Correct*	*36,204*	*47,101*	*39,566*	*Correct*

Conclusions on Methodological Effectiveness

The analogue-year method demonstrates moderate effectiveness; however, its accuracy significantly depends on individual river basin. The errors identified for the Karadarya and Chirchik rivers indicate that, for these basins, the method requires further refinement. This is associated with high runoff variability and a strong dependence on storm rainfall and glacier melt, which are not always fully accounted for during analogue selection. A key limitation of the method is its inability to reliably account for anomalous or extreme hydrometeorological conditions, which become increasingly frequent in the context of climate change.

RECOMMENDATIONS

To improve the accuracy of forecasts, particularly for rivers exhibiting low forecast correctness rates (e.g., the Karadarya and Chirchik rivers), it is recommended to supplement or modernize the analogue-year method.

The most promising directions for methodological improvement include the integration of hydrological models (e.g., *ModSnow*) and application of machine-learning approaches.