Appendix A

Article Title: Enhancing streamflow projections under climate change using optimized machine learning: A comparative study in the Babolrood River Basin, Iran

Journal Name: Iranian Journal of Science and Technology, Transactions of Civil Engineering

Authors: Ali Akbar Eatesam[1], Khosrow Hosseini[1] and Hojat Karami[1]

[1]Department of Water Engineering and Hydraulic Structures, Faculty of Civil Engineering, Semnan University, Semnan, Iran

Corresponding Author: Khosrow Hosseini

Corresponding author's email: khhoseini@semnan.ac.ir

To enhance the clarity and readability of the main manuscript, detailed performance data for the machine learning models used in this study are provided in Supplementary Table S1. The table presents the results for seven different input data models during the training and testing phases, covering both their standalone performance and their performance when optimized by the PSO and FDA algorithms.

Table S1: Comparison of machine learning model performance in independent and optimized states during training and testing phases.

Model	Train					Test				
M_1	RMSE	MAE	NSE	KGE	R	RMSE	MAE	NSE	KGE	R
KNN	-	-	-	-	-	18.45	9.76	0.55	0.65	0.75
KNN-FDA	-	-	-	-	-	17.25	7.88	0.64	0.68	0.82
KNN-PSO	-	-	-	-	-	17.07	7.88	0.63	0.65	0.84
SVR	14.36	6.32	0.76	0.76	0.87	30.02	18.03	0.00	0.37	0.06
SVR-FDA	11.73	5.24	0.84	0.87	0.92	15.13	7.94	0.63	0.60	0.80
SVR-PSO	13.94	6.15	0.77	0.78	0.88	16.84	7.66	0.70	0.70	0.84
LSTM	22.49	13.85	0.43	0.41	0.63	23.27	15.46	0.49	0.60	0.70
LSTM-FDA	13.99	7.76	0.79	0.73	0.89	14.42	8.03	0.75	0.63	0.83
LSTM-PSO	14.60	7.73	0.76	0.77	0.88	13.62	7.59	0.70	0.75	0.84
RF	25.95	15.11	0.24	0.16	0.56	21.70	13.83	0.24	0.17	0.55
RF-FDA	8.87	4.16	0.91	0.86	0.96	13.38	7.13	0.79	0.82	0.86
RF-PSO	9.68	4.34	0.89	0.84	0.95	15.01	7.54	0.68	0.75	0.82
XGBoost	0.71	20.48	11.10	0.50	0.71	21.77	11.42	0.54	0.63	0.73
XGBoost-FDA	2.58	1.76	0.99	0.98	0.99	16.97	8.30	0.73	0.73	0.86
XGBoost-PSO	4.30	2.91	0.98	0.96	0.99	18.75	8.92	0.68	0.72	0.82

Continued Table S1: Comparison of machine learning model performance in independent and optimized states during training and testing phases.

Model	Train					Test				
M_2	RMSE	MAE	NSE	KGE	R	RMSE	MAE	NSE	KGE	R
KNN	-	-	-	-	-	24.26	9.76	0.55	0.65	0.75
KNN-FDA	-	-	-	-	-	19.56	9.82	0.45	0.66	0.76
KNN-PSO	-	-	-	-	-	18.17	9.51	0.53	0.56	0.73
SVR	14.54	6.03	0.76	0.02	0.87	28.82	17.69	0.02	0.24	0.15
SVR-FDA	16.94	7.72	0.66	0.68	0.82	19.22	9.12	0.65	0.58	0.81
SVR-PSO	18.13	8.18	0.61	0.61	0.80	20.65	9.40	0.54	0.52	0.76
LSTM	24.88	13.03	0.41	0.21	0.64	29.50	14.27	0.38	0.40	062
LSTM-FDA	19.86	11.19	0.64	0.47	0.80	18.70	11.42	0.48	0.33	0.69
LSTM-PSO	13.67	8.26	0.77	0.79	0.73	23.28	11.22	0.53	0.67	0.73
RF	26.76	15.36	0.19	0.10	0.59	23.31	14.67	0.12	0.01	0.41
RF-FDA	11.60	5.54	0.85	0.82	0.93	17.68	9.75	0.50	0.56	0.72
RF-PSO	11.80	5.76	0.84	0.80	0.92	19.35	10.01	0.56	0.71	0.76
XGBoost	20.44	11.25	0.50	0.61	0.71	23.79	11.99	0.42	0.51	0.65
XGBoost-FDA	11.32	6.52	0.83	0.83	0.91	16.97	8.30	0.73	0.73	0.86
XGBoost-PSO	10.59	6.31	0.87	0.87	0.94	19.45	10.27	0.49	0.63	0.70
M_3	RMSE	MAE	NSE	KGE	R	RMSE	MAE	NSE	KGE	R
KNN	-	-	-	-	-	23.21	11.50	0.32	0.58	0.61
KNN-FDA	-	-	-	-	-	19.87	9.34	0.55	0.65	0.74
KNN-PSO	-	-	-	-	-	21.07	9.51	0.53	0.56	0.73
SVR	15.64	6.25	0.74	0.74	0.87	23.98	16.48	0.02	0.20	0.20
SVR-FDA	17.97	7.70	0.64	0.68	0.80	17.32	8.56	0.52	0.51	0.72
SVR-PSO	19.34	8.34	0.57	0.57	0.77	18.36	8.83	0.60	0.62	0.79
LSTM	24.50	19.09	0.50	0.35	0.71	25.65	19.37	0.41	0.53	0.64
LSTM-FDA	20.04	10.18	0.55	0.55	0.74	16.87	9.76	0.54	0.50	0.74
LSTM-PSO	17.57	9.25	0.62	0.66	0.79	21.35	10.64	0.58	0.50	0.80
RF	24.72	14.45	0.29	0.21	0.65	24.58	14.19	0.28	0.20	0.62
RF-FDA	12.40	5.82	0.83	0.78	0.92	16.00	8.77	0.52	0.58	0.74
RF-PSO	12.13	6.37	0.84	0.76	0.93	14.10	8.44	0.61	0.65	0.79
XGBoost	21.59	11.48	0.48	0.65	0.70	22.34	11.41	0.21	0.50	0.54
XGBoost-FDA	10.90	6.00	0.86	0.85	0.93	20.62	10.36	0.45	0.62	0.68
XGBoost-PSO	10.18	5.77	0.88	0.87	0.94	20.43	10.58	0.49	0.58	0.70
M_4	RMSE	MAE	NSE	KGE	R	RMSE	MAE	NSE	KGE	R
KNN	-	-	-	-	-	24.21	11.38	0.52	0.57	0.73
KNN-FDA	-	-	-	-	-	22.77	10.52	0.50	0.61	0.74
KNN-PSO	-	-	-	-	-	19.78	9.32	0.52	0.56	0.74
SVR	14.32	6.19	0.78	0.77	0.89	25.04	16.48	0.01	0.34	0.10
SVR-FDA	11.47	5.14	0.84	0.86	0.92	22.49	9.42	0.60	0.52	0.82
SVR-PSO	15.20	6.63	0.73	0.72	0.86	17.83	8.28	0.61	0.66	0.78
LSTM	29.62	16.60	0.02	0.01	0.58	29.63	15.86	0.03	0.35	0.60
LSTM-FDA	14.51	8.50	0.79	0.71	0.89	15.82	9.11	0.60	0.52	0.77
LSTM-PSO	15.04	8.33	0.75	0.77	0.86	13.85	7.94	0.70	0.83	0.83
RF	25.41	14.97	0.23	0.15	0.57	28.26	15.32	0.23	0.14	0.59
RF-FDA	9.94	4.71	0.88	0.83	0.94	19.58	8.24	0.66	0.55	0.83
RF-PSO	10.03	4.49	0.89	0.82	0.95	16.78	7.62	0.58	0.63	0.76
XGBoost	20.80	11.39	0.52	0.66	0.73	20.17	11.60	0.29	0.55	0.59
XGBoost-FDA	7.02	4.44	0.94	0.93	0.97	17.75	8.82	0.70	0.70	0.84
XGBoost-PSO	3.44	2.36	0.99	0.97	0.99	18.82	8.96	0.66	0.71	0.81

Continued Table S1: Comparison of machine learning model performance in independent and optimized states during training and testing phases.

Model	Train					Test				
M_5	RMSE	MAE	NSE	KGE	R	RMSE	MAE	NSE	KGE	R
KNN	-	-	-	-	-	21.77	10.04	0.42	0.53	0.66
KNN-FDA	-	-	-	-	-	19.88	7.76	0.56	0.51	0.75
KNN-PSO	-	-	-	-	-	24.36	10.70	0.52	0.46	0.77
SVR	13.89	6.26	0.78	0.78	0.89	27.46	17.74	0.00	0.35	0.08
SVR-FDA	13.18	5.95	0.80	0.81	0.90	14.38	7.54	0.67	0.58	0.82
SVR-PSO	14.33	6.49	0.76	0.76	0.88	17.74	7.79	0.63	0.68	0.79
LSTM	18.52	10.80	0.67	0.32	0.82	20.63	11.98	0.57	0.38	0.76
LSTM-FDA	23.77	13.48	0.50	0.23	0.71	27.30	14.50	0.48	0.20	0.69
LSTM-PSO	16.21	9.43	0.70	067	0.86	17.01	10.05	0.60	0.66	0.79
RF	25.29	16.55	0.24	016	0.59	28.75	16.55	0.20	0.11	0.54
RF-FDA	10.50	4.91	0.88	0.83	0.94	14.35	7.54	0.67	0.61	0.82
RF-PSO	9.71	4.47	0.88	0.83	0.95	15.19	7.61	0.66	0.73	0.81
XGBoost	20.49	11.14	0.51	0.63	0.71	22.01	10.85	0.47	0.58	0.68
XGBoost-FDA	3.62	2.44	0.98	0.97	0.99	21.36	9.92	0.63	0.64	0.80
XGBoost-PSO	5.38	3.50	0.97	0.95	0.98	19.15	9.16	0.62	0.69	0.79
M_6	RMSE	MAE	NSE	KGE	R	RMSE	MAE	NSE	KGE	R
KNN	-	-	-	-	-	29.58	15.87	0.34	0.40	0.59
KNN-FDA	-	-	-	-	-	19.88	7.76	0.56	0.45	0.55
KNN-PSO	-	-	-	-	-	23.10	13.19	0.37	0.35	0.63
SVR	13.31	6.22	0.80	0.79	0.90	28.36	18.04	0.00	0.35	0.08
SVR-FDA	18.61	9.86	0.61	0.67	0.79	19.68	12.41	0.38	0.46	0.64
SVR-PSO	22.70	12.09	0.43	0.41	0.69	18.68	11.46	0.50	0.52	0.72
LSTM	26.61	14.29	0.10	0.05	0.49	33.95	17.05	0.21	0.36	0.62
LSTM-FDA	22.05	13.50	0.47	0.46	0.68	20.80	13.35	0.30	0.31	0.55
LSTM-PSO	19.94	13.11	0.56	0.55	0.76	19.51	13.07	0.39	0.40	0.63
RF	26.43	15.69	0.21	0.12	0.56	23.95	14.29	0.09	0.04	0.30
RF-FDA	13.63	9.30	0.79	0.75	0.90	19.93	13.31	0.41	0.40	0.65
RF-PSO	13.78	7.61	0.79	0.71	0.91	18.73	12.50	0.44	0.55	0.66
XGBoost	23.65	14.38	0.37	0.49	0.61	23.27	14.68	0.19	0.44	0.50
XGBoost-FDA	14.28	10.01	0.77	0.76	0.99	22.13	13.22	0.33	0.59	0.62
XGBoost-PSO	13.30	9.36	0.80	0.79	0.90	22.10	13.63	0.40	0.51	0.63
M_7	RMSE	MAE	NSE	KGE	R	RMSE	MAE	NSE	KGE	R
KNN	-	-	-	-	-	18.65	9.89	0.41	0.61	0.69
KNN-FDA	-	-	-	-	-	17.89	8.80	0.57	0.64	0.78
KNN-PSO	-	-	-	-	-	23.82	10.43	0.47	0.45	0.72
SVR	10.91	5.94	0.86	0.82	0.94	27.35	17.83	0.00	0.30	0.11
SVR-FDA	13.02	5.89	0.81	0.83	0.90	17.55	8.20	0.81	0.59	0.76
SVR-PSO	15.41	6.93	0.74	0.73	0.87	14.47	7.41	0.66	0.72	0.82
LSTM	27.11	14.60	0.16	0.15	0.59	25.65	14.14	0.09	0.44	0.58
LSTM-FDA	20.69	10.44	0.58	0.47	0.76	13.89	8.78	0.67	0.47	0.82
LSTM-PSO	14.96	7.85	0.73	0.75	0.86	17.40	8.56	0.70	0.66	0.83
RF	25.76	14.46	0.26	0.17	0.66	21.32	14.10	0.27	0.18	0.64
RF-FDA	9.73	4.43	0.89	0.85	0.95	17.17	8.03	0.58	0.51	0.77
RF-PSO	10.30	4.63	0.88	0.81	0.94	15.42	7.84	0.64	0.74	0.80
XGBoost	20.56	11.22	0.50	0.64	0.71	23.11	12.17	0.42	0.57	0.65
XGBoost-FDA	12.50	7.05	0.80	0.82	0.90	19.58	9.55	0.68	0.70	0.83
XGBoost-PSO	9.00	5.38	0.89	0.88	0.95	21.50	9.55	0.68	0.61	0.80