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Supplement of

Can causal discovery lead to a more robust prediction model for runoff signatures?

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The results of feature selection, correlation analysis, variable importance, PC algorithm, and models' performances for each signature are as follows:

S1 Correlation Analysis of Runoff Signatures with Catchment and Climate Attributes in CAMELS Datasets

S1.1 Correlation analysis for Baseflow Index (baseflow_index)

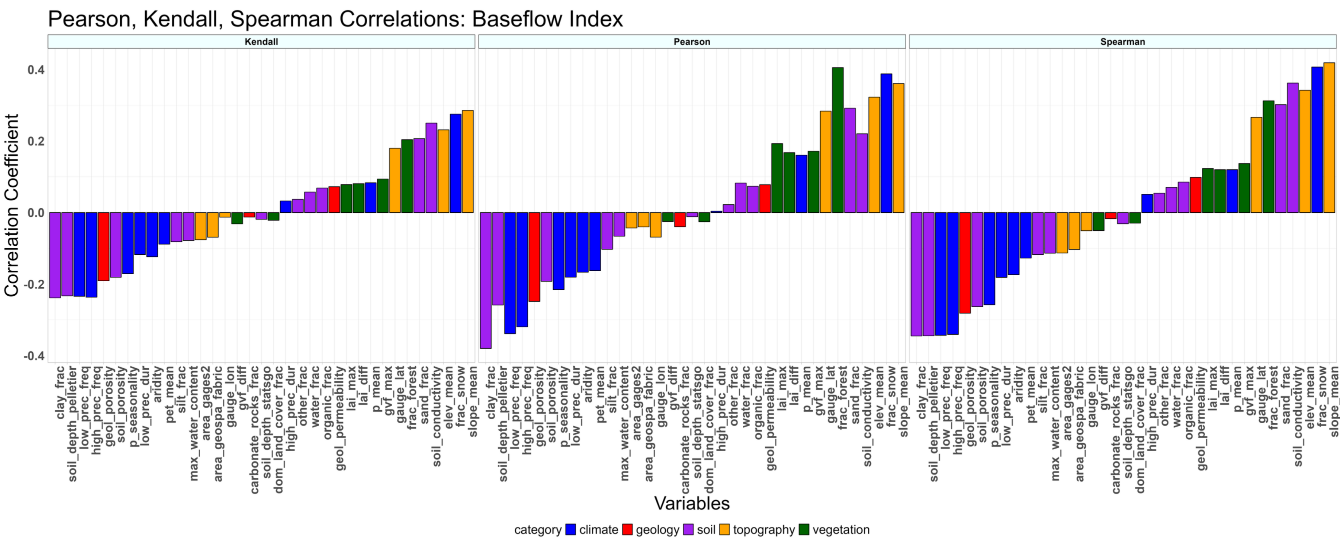

Fig. S1. Correlation analysis between catchment and climate attributes and baseflow index

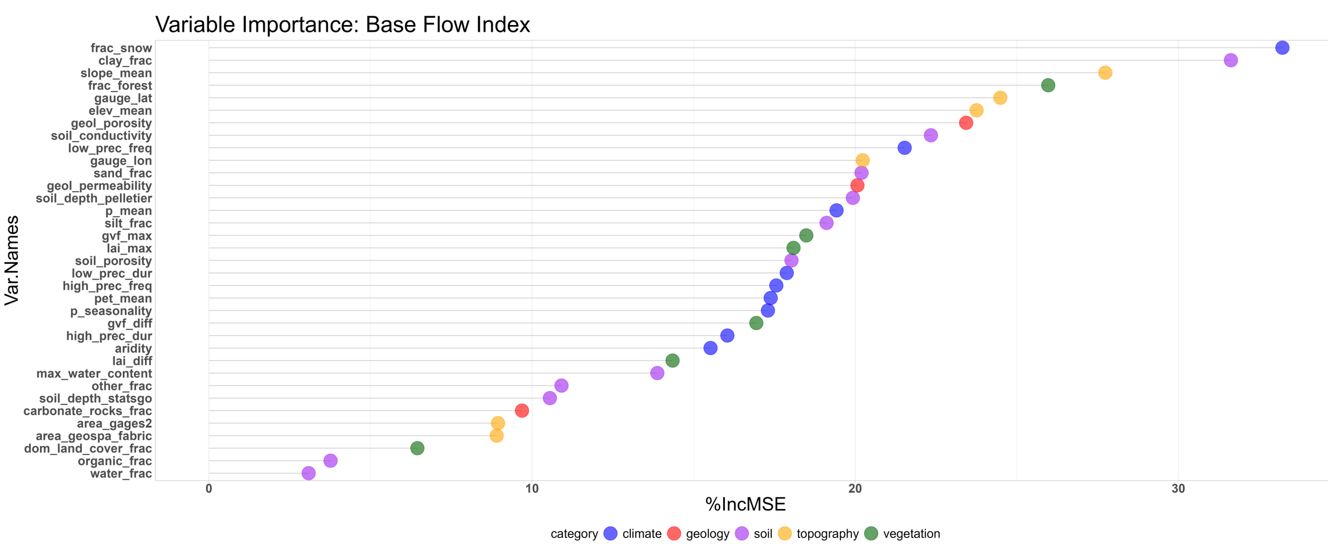

Fig. S2. Random forest variable importance analysis between catchment and climate attributes and baseflow index

S1.2 Correlation analysis for High Flow Duration (high_q_dur)

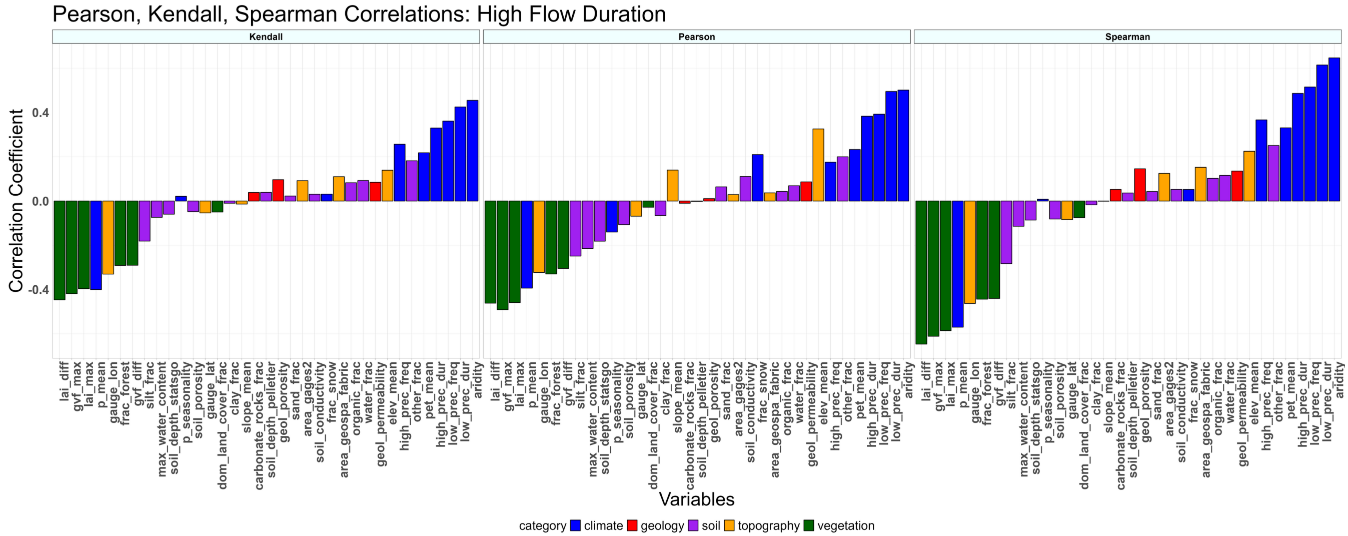

Fig. S3. Correlation analysis between catchment and climate attributes and high flow duration

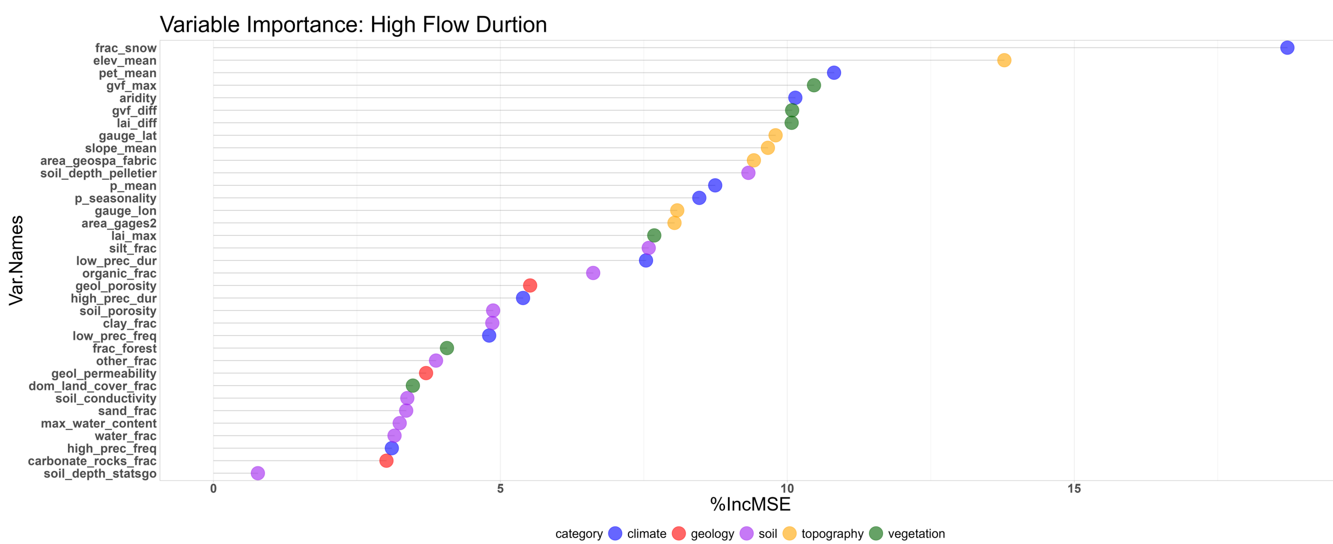

Fig. S4. Random forest variable importance analysis between catchment and climate attributes and high flow duration

S1.3 Correlation analysis for High Flow Frequency (high_q_freq)

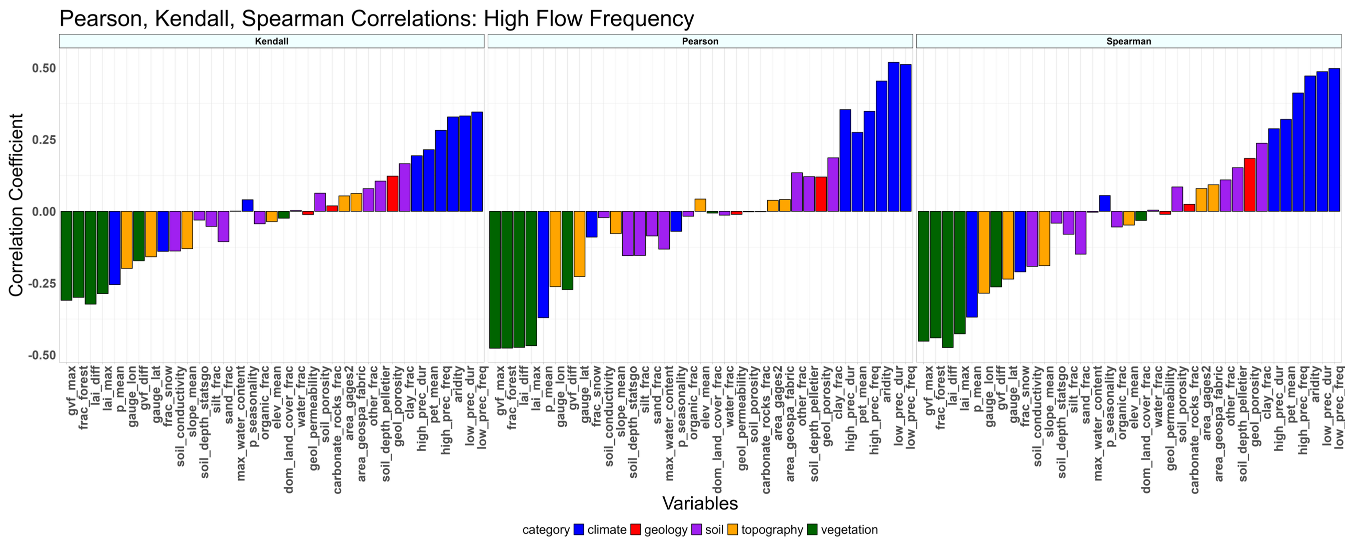

Fig. S5. Correlation analysis between catchment and climate attributes and high flow frequency

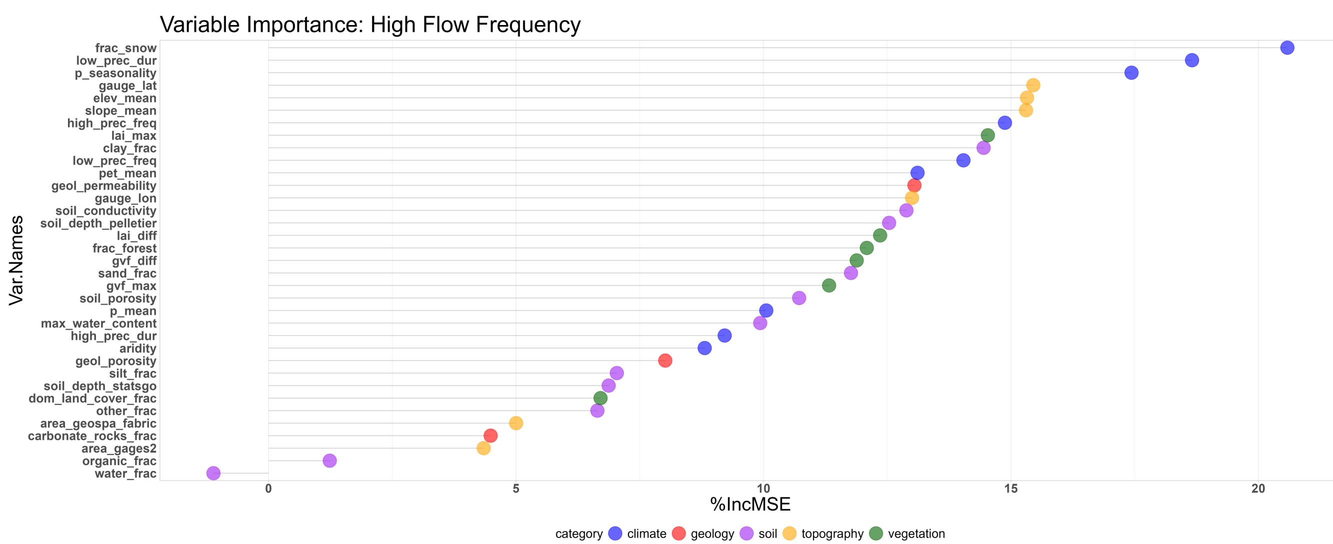

Fig. S6. Random forest variable importance analysis between catchment and climate attributes and high flow frequency

S1.4 Correlation analysis for Low Flow Duration (low_q_dur)

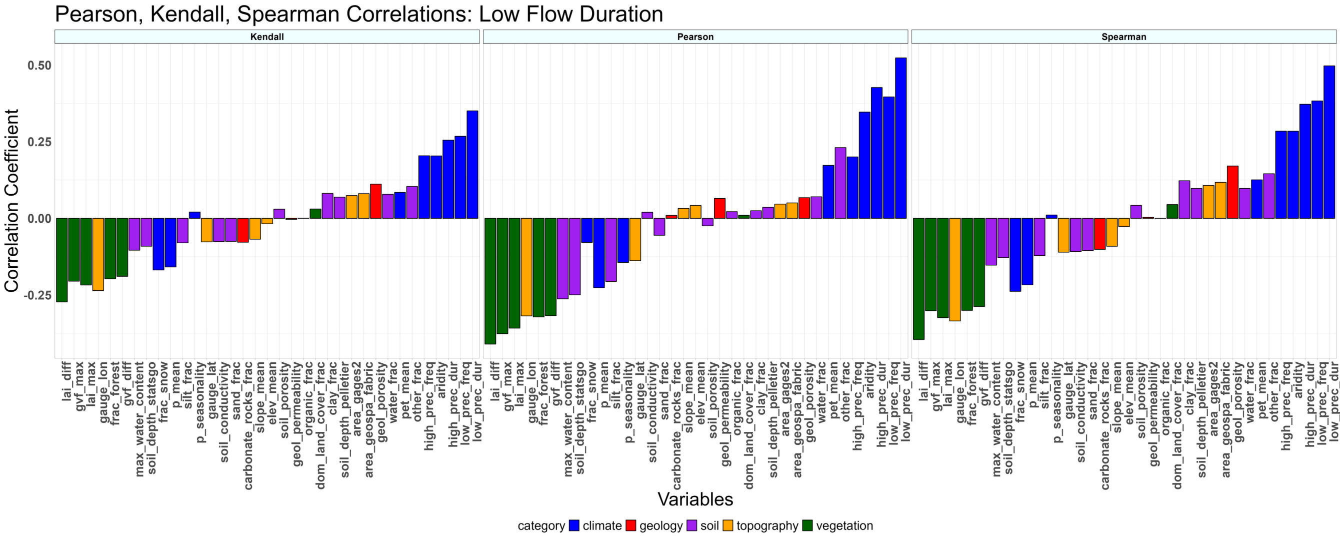

Fig. S7. Correlation analysis between catchment and climate attributes and low flow duration

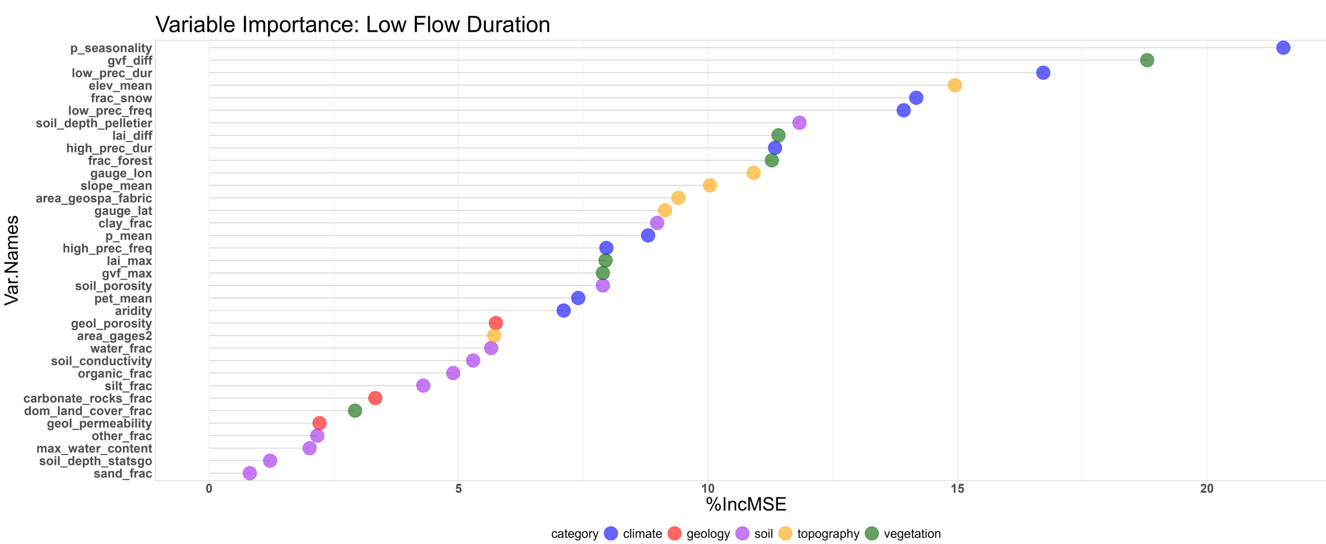

Fig. S8. Random forest variable importance analysis between catchment and climate attributes and low flow duration

S1.5 Correlation analysis for Low Flow Frequency (low_q_freq)

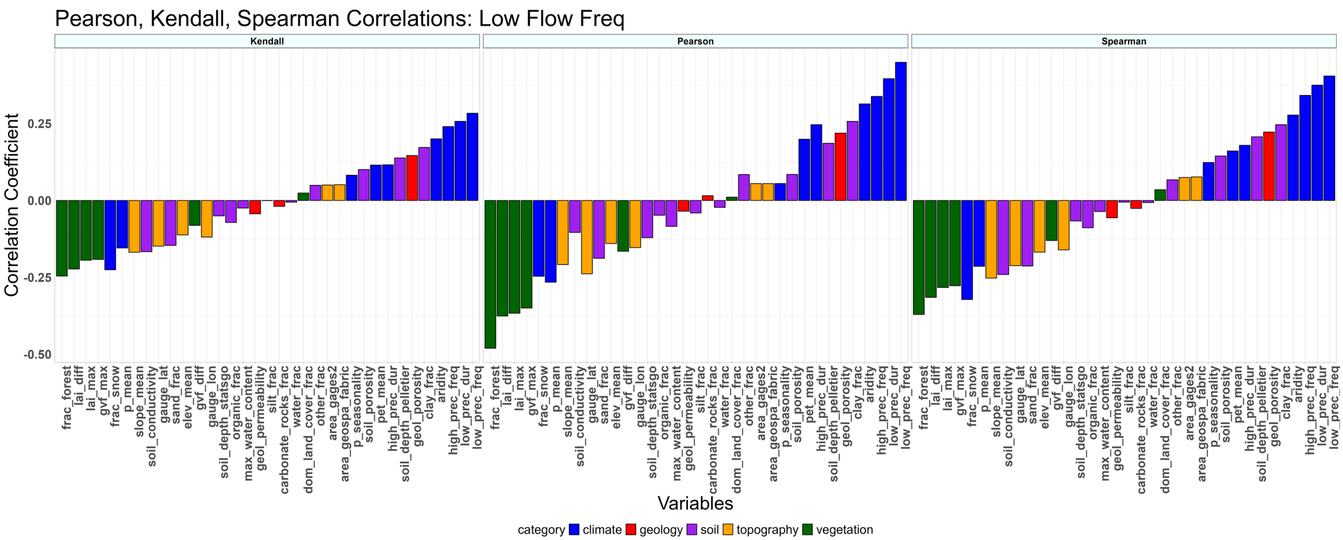

Fig. S9. Correlation analysis between catchment and climate attributes and low flow frequency

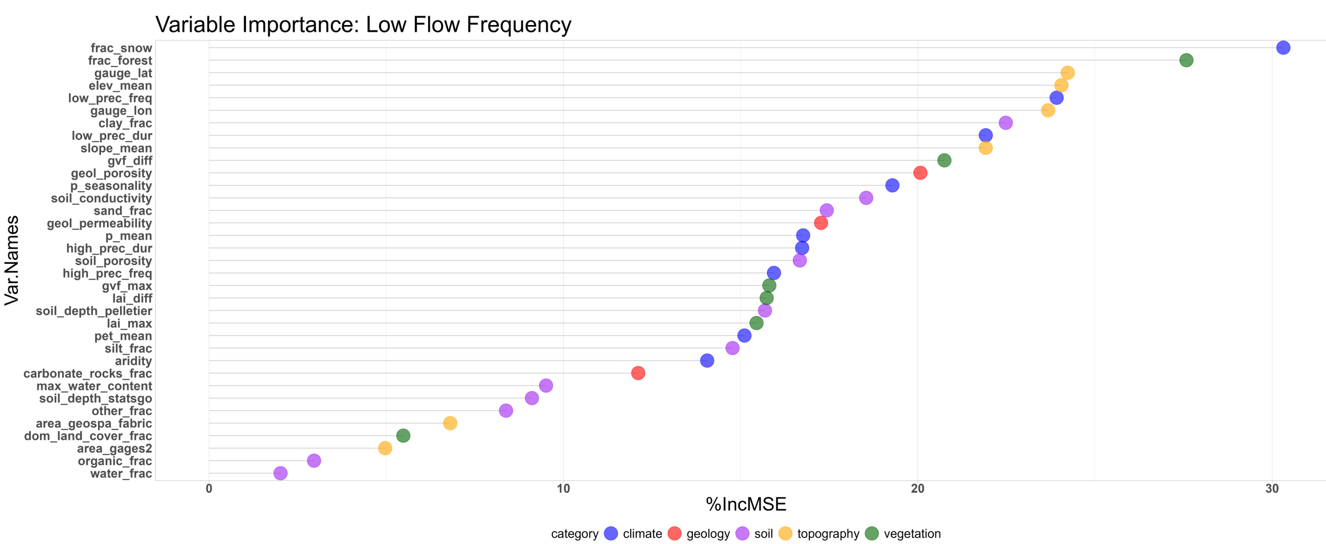

Fig. S10. Random forest variable importance analysis between catchment and climate attributes and low flow frequency

S1.6 Correlation analysis for Mean Daily Discharge (q_mean)

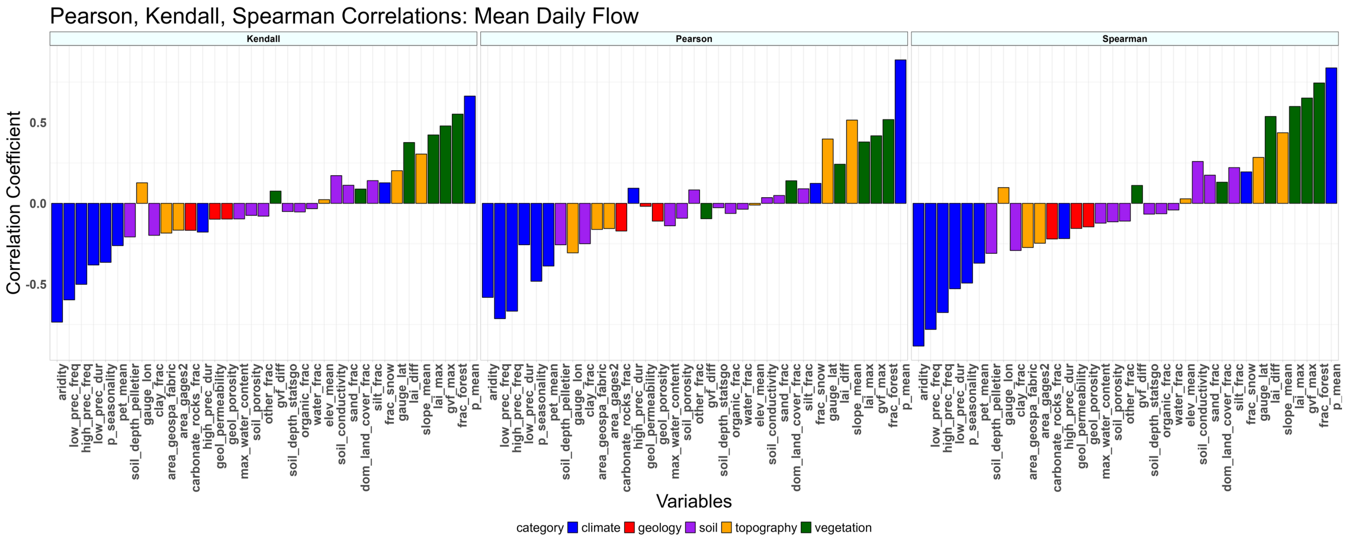

Fig. S11. Correlation analysis between catchment and climate attributes and mean daily flow

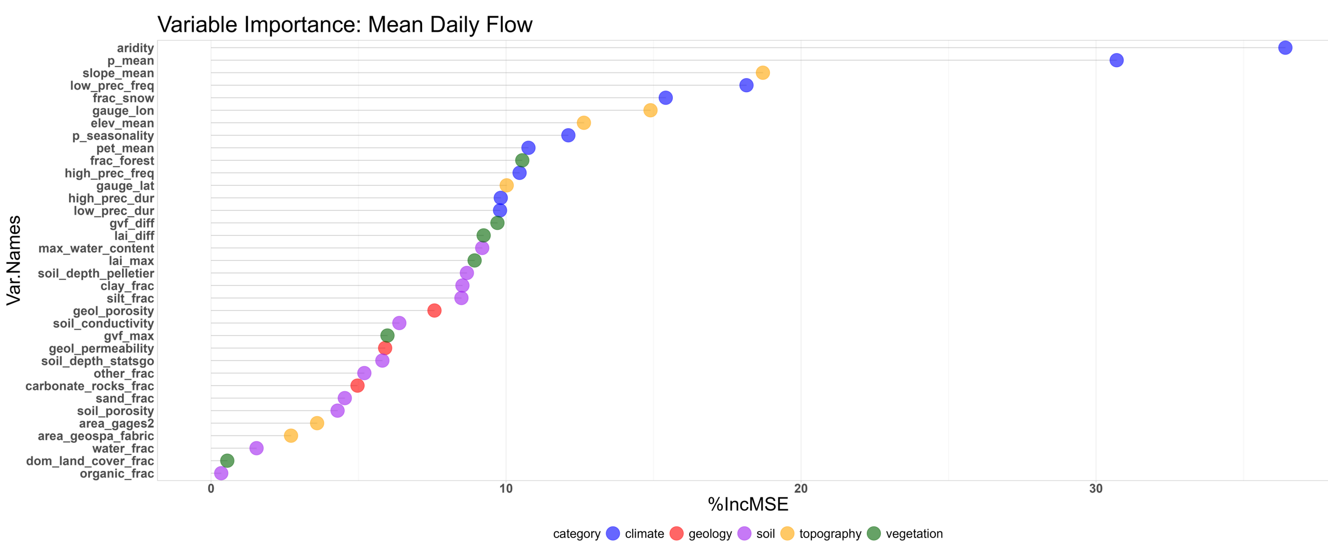

Fig. S12. Random forest variable importance analysis between catchment and climate attributes and mean daily flow

S1.7 Correlation analysis for Low Flow (q5)

The figure has been updated for the new set of variables.

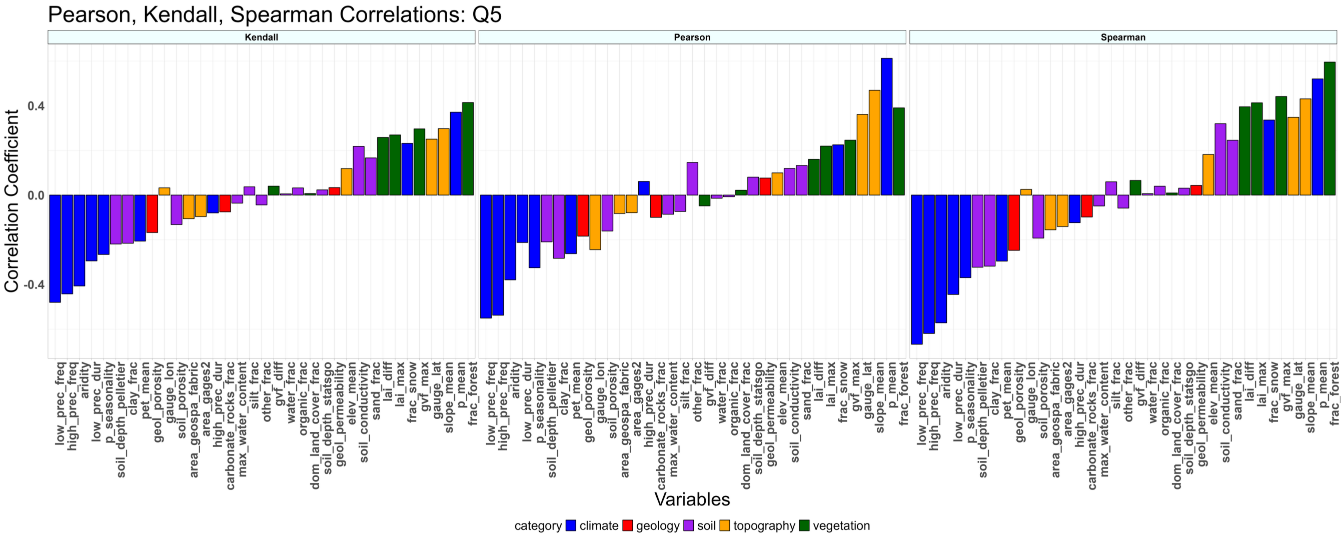

Fig. S13. Correlation analysis between catchment and climate attributes and low flow

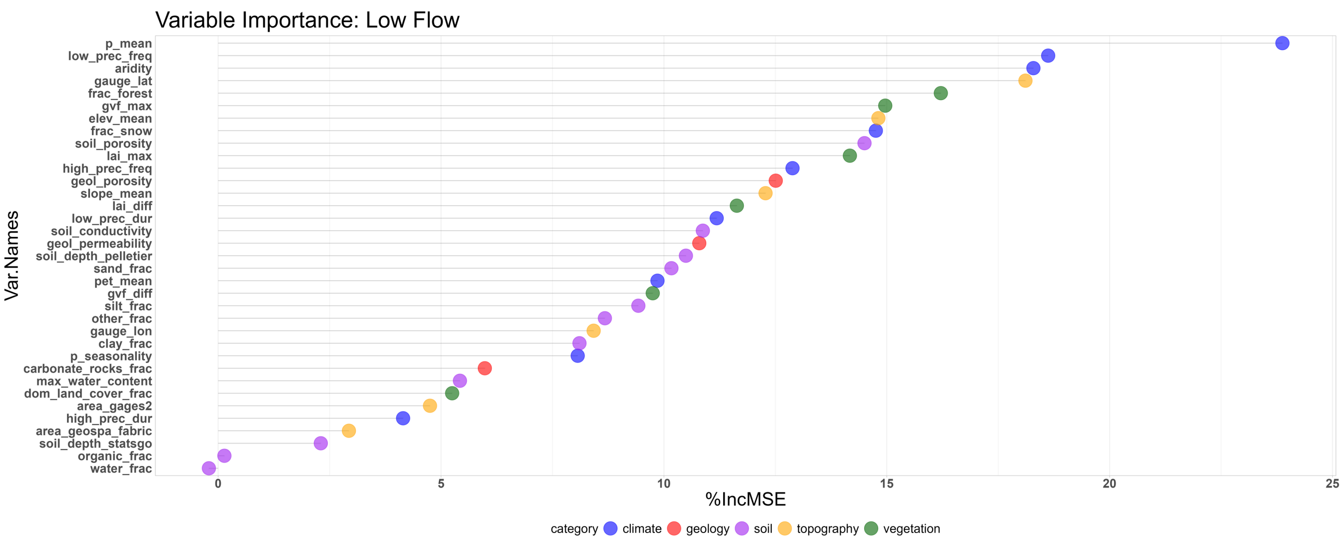

Fig. S14. Random forest variable importance analysis between catchment and climate attributes and low flow

S1.8 Correlation analysis for High Flow (q95)

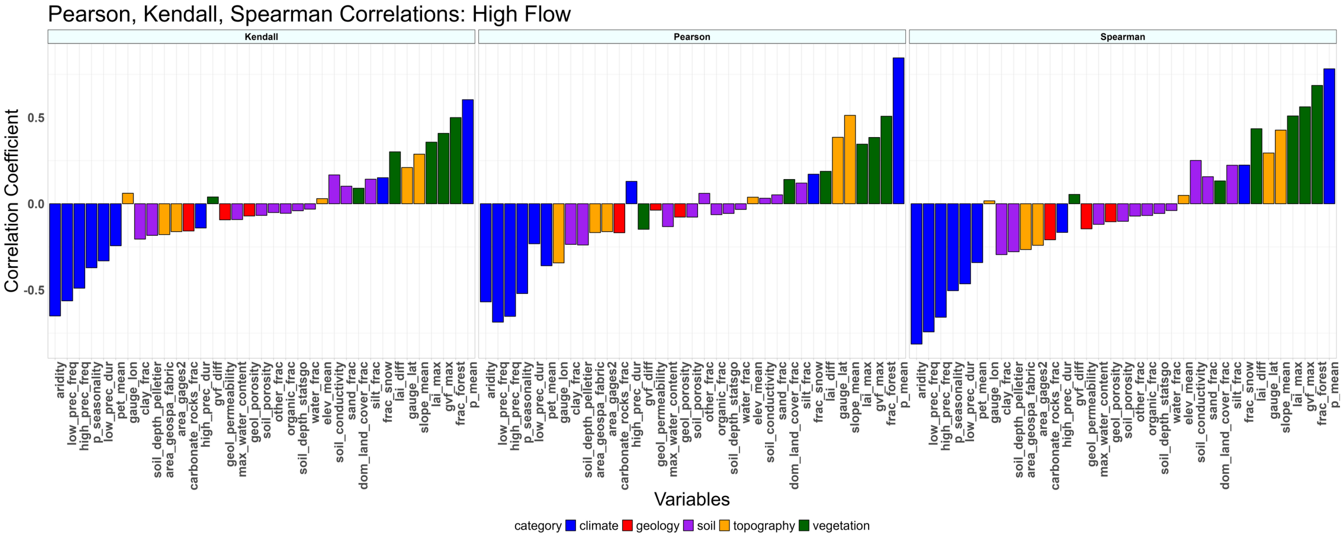

Fig. S15. Correlation analysis between catchment and climate attributes and high flow

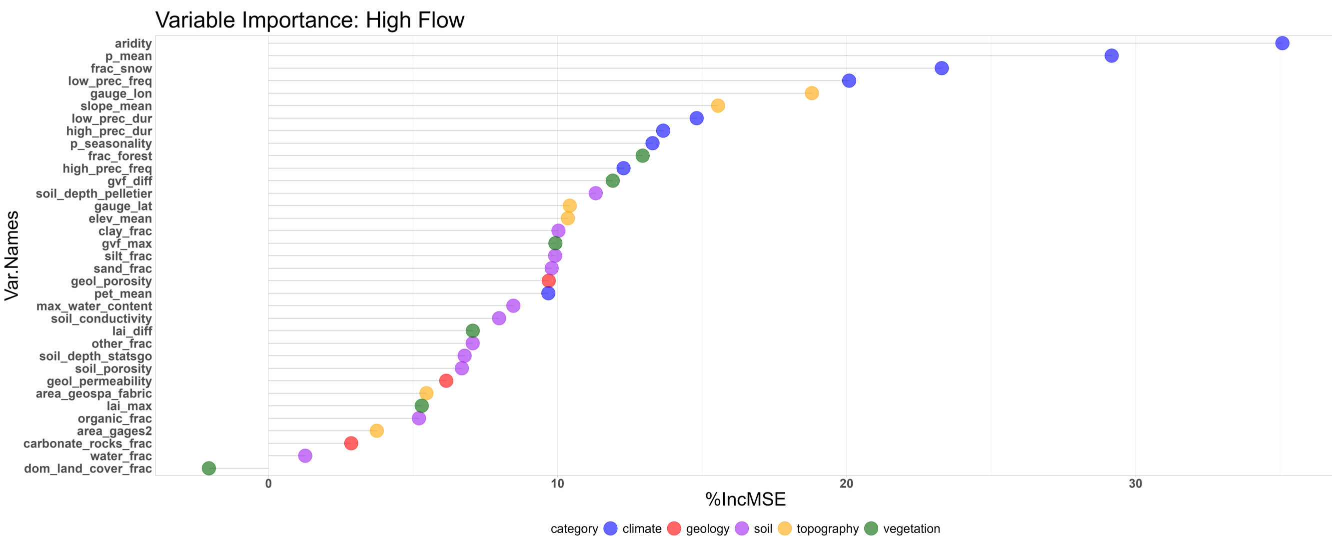

Fig. S16. Random forest variable importance analysis between catchment and climate attributes and high flow

S1.9 Correlation analysis for Runoff Ratio (runoff_ratio)

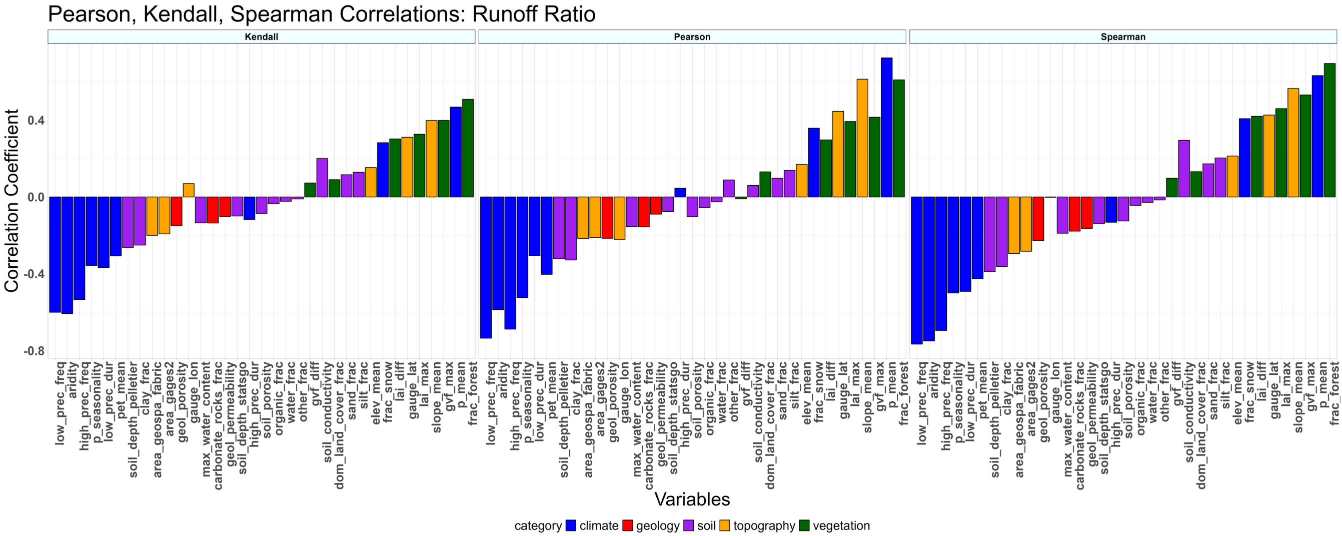

Fig. S17. Correlation analysis between catchment and climate attributes and runoff ratio

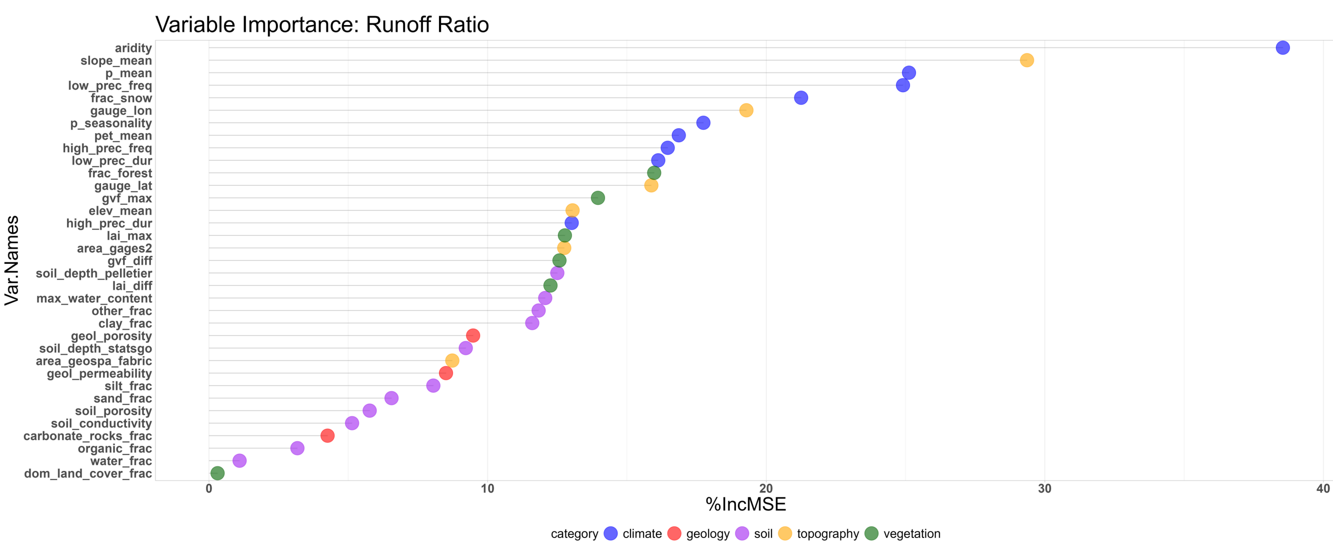

Fig. S18. Random forest variable importance analysis between catchment and climate attributes and runoff ratio

S1.10 Correlation analysis for Slope of Flow Duration Curve (slope_FDC)

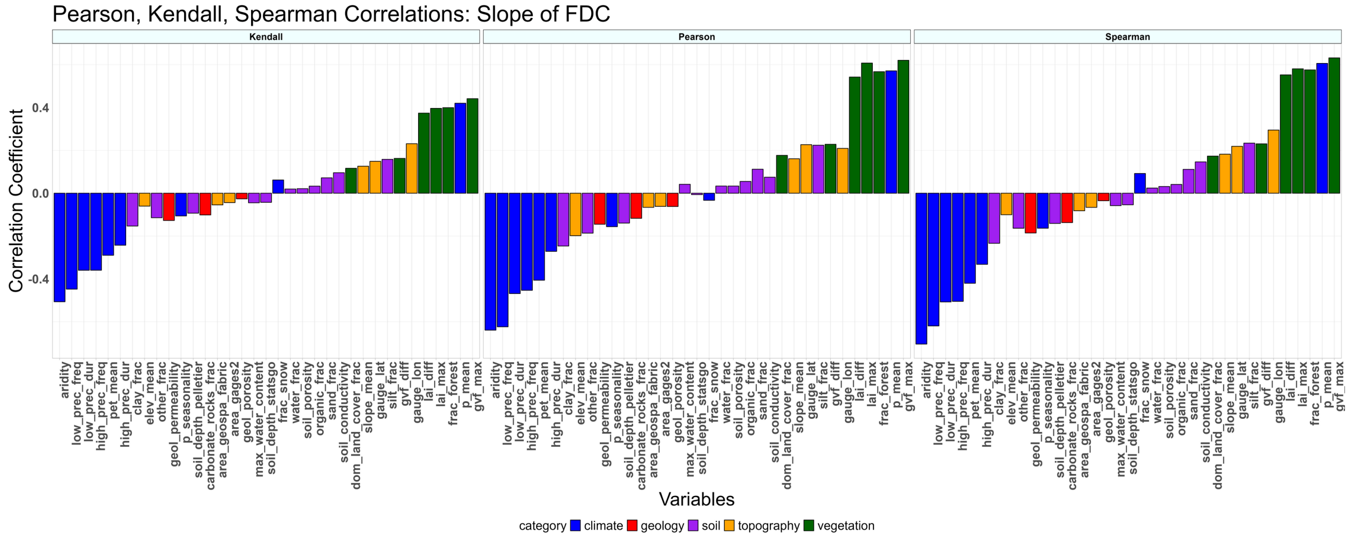

Fig. S19. Correlation analysis between catchment and climate attributes and the slope of flow duration curve

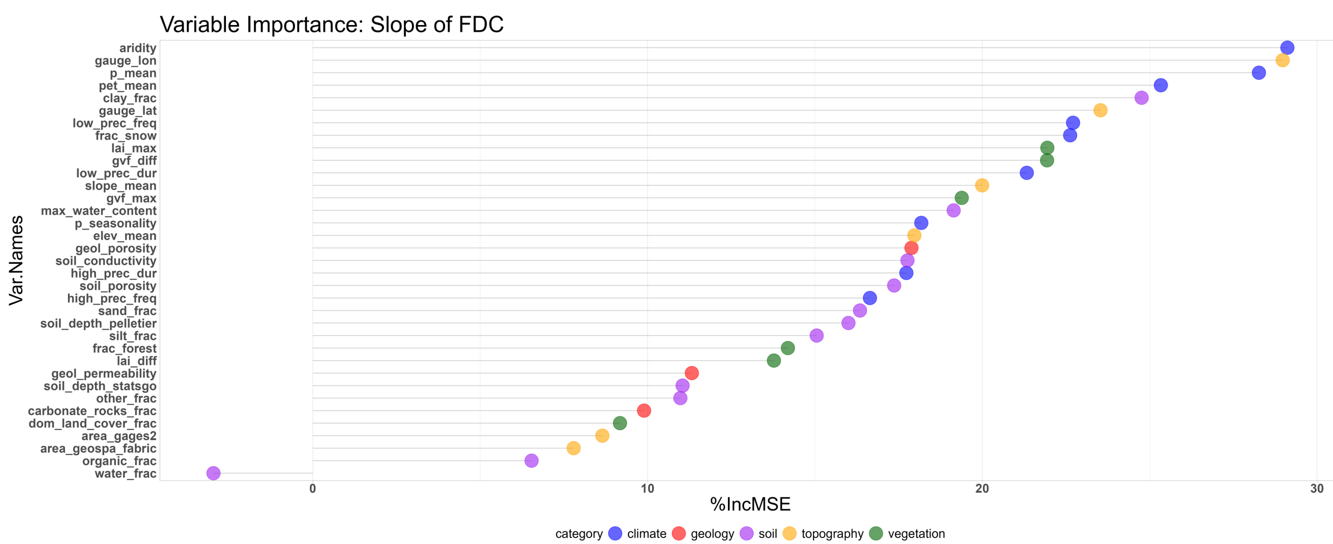

Fig. S20. Random forest variable importance analysis between catchment and climate attributes and the slope of flow duration curve

S1.11 Correlation analysis for Streamflow Elasticity (stream_elast)

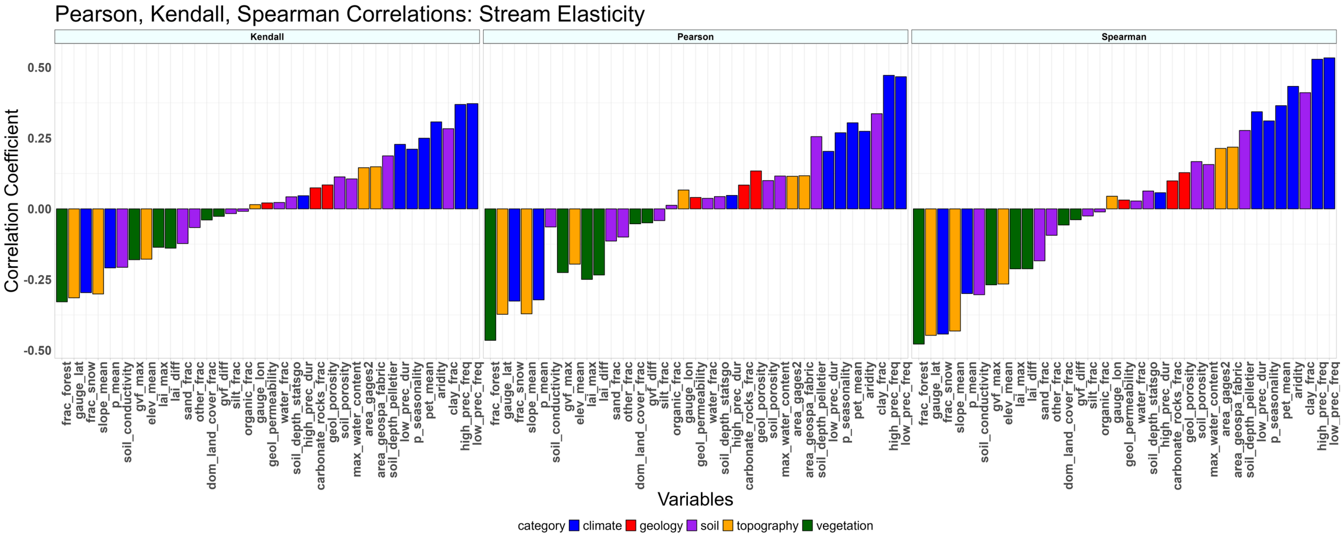

Fig. S21. Correlation analysis between catchment and climate attributes and streamflow elasticity

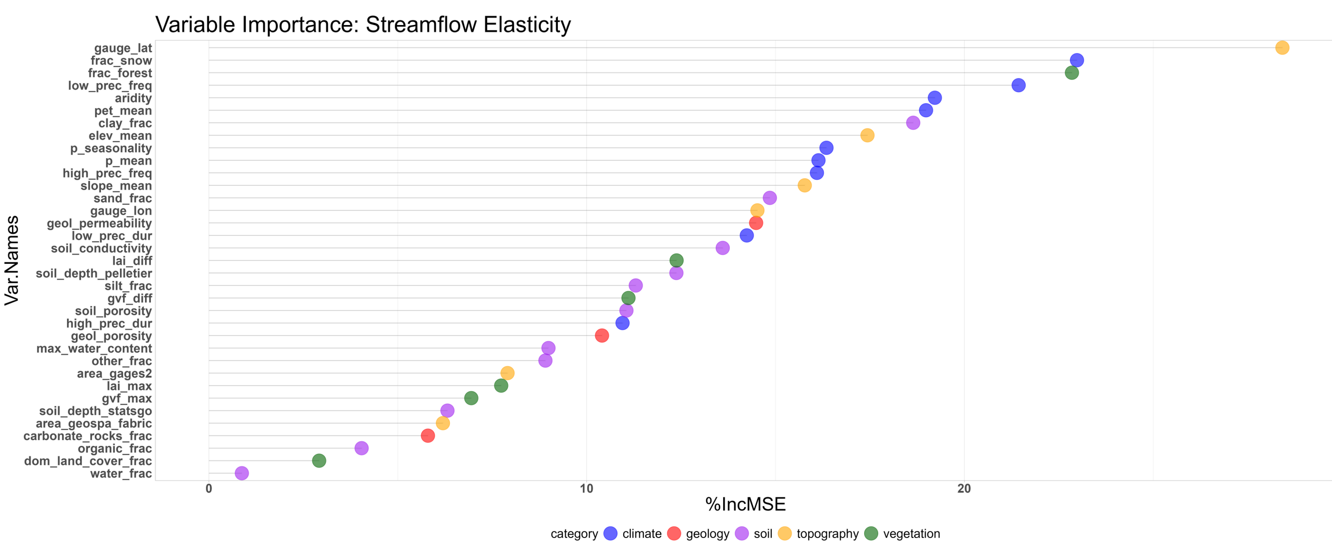

Fig. S22. Random forest variable importance analysis between catchment and climate attributes and streamflow elasticity

S2 Causal discovery and prediction results

S2.1 Recovered causal structure and prediction results for the Baseflow Index (baseflow_index)

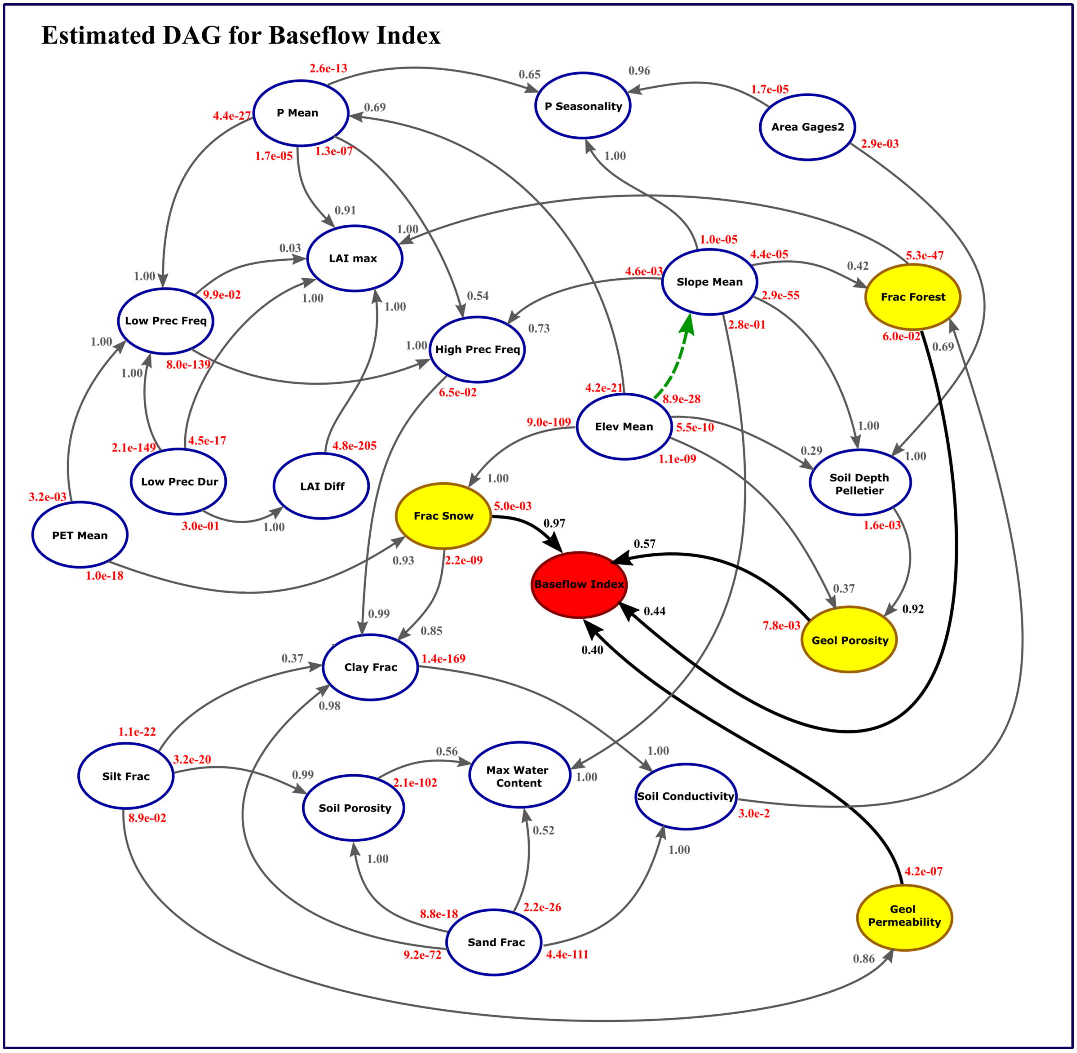

Fig. S23. Directed Acyclic Graph (DAG) for the Baseflow Index. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

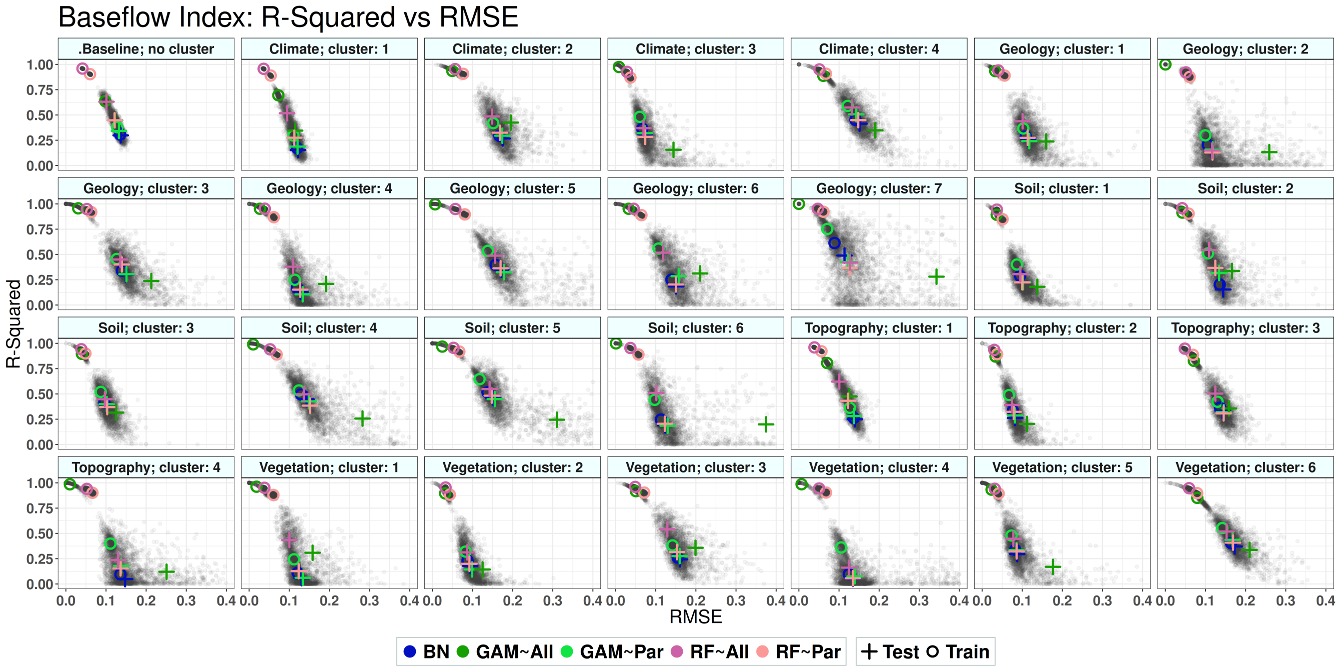

Fig. S24. R-squared vs RMSE in each cluster for all models for baseflow index.

S2.2 Recovered causal structure and prediction results for the High Flow Duration (high_q_dur)

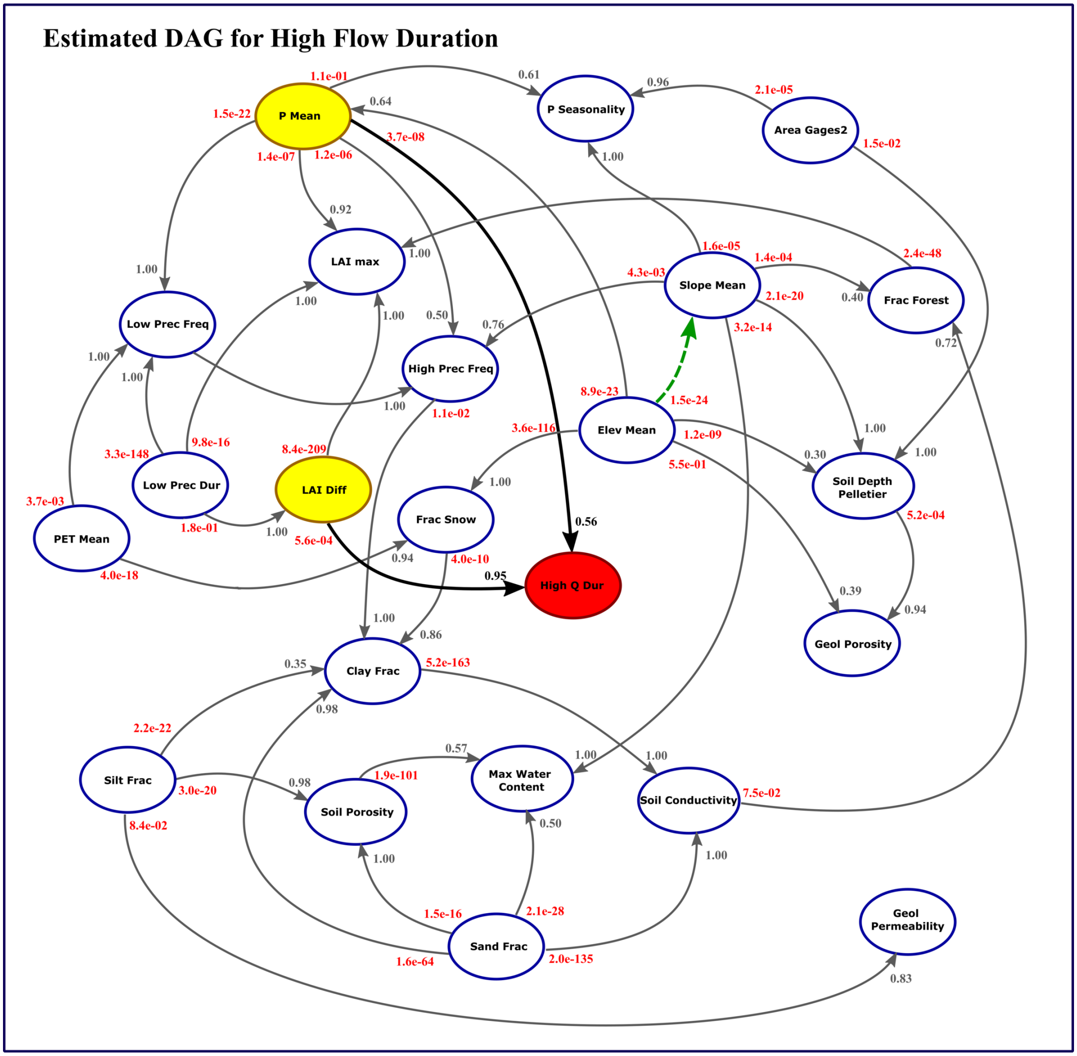

Fig. S25. Directed Acyclic Graph (DAG) for the High Flow Duration. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

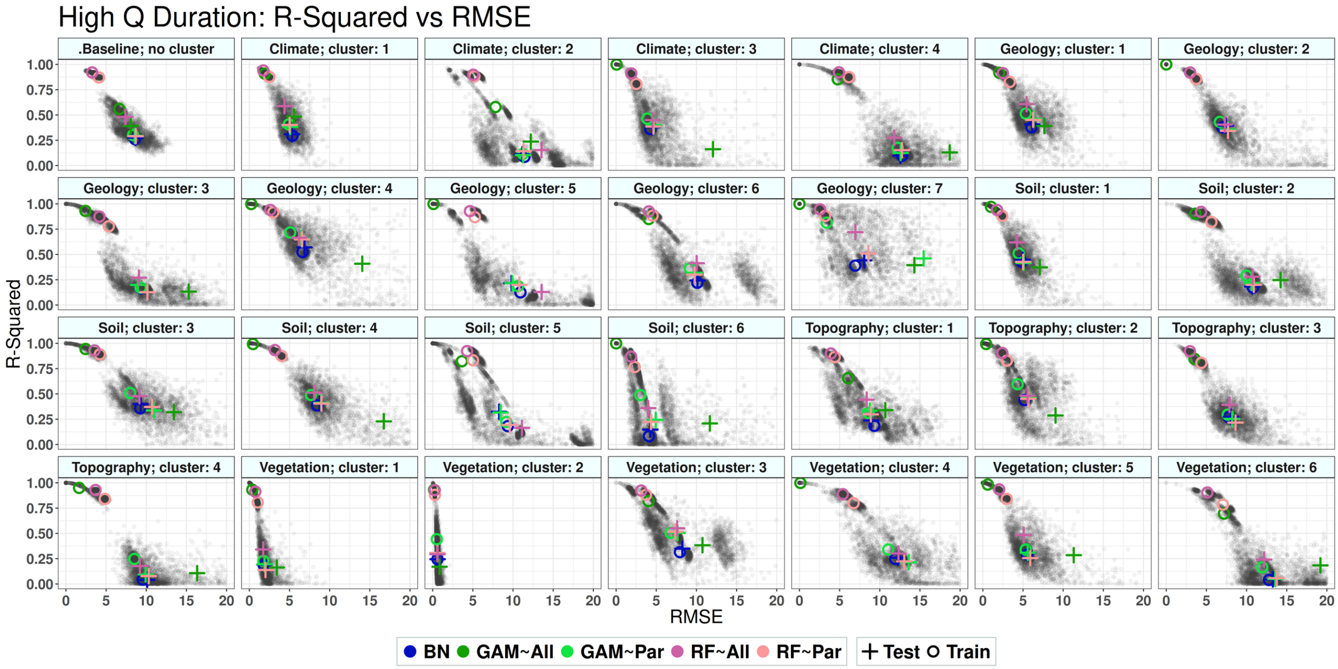

Fig. S26. R-squared vs RMSE in each cluster for all models for high flow duration.

S2.3 Recovered causal structure and prediction results for the High Flow Frequency (high_q_freq)

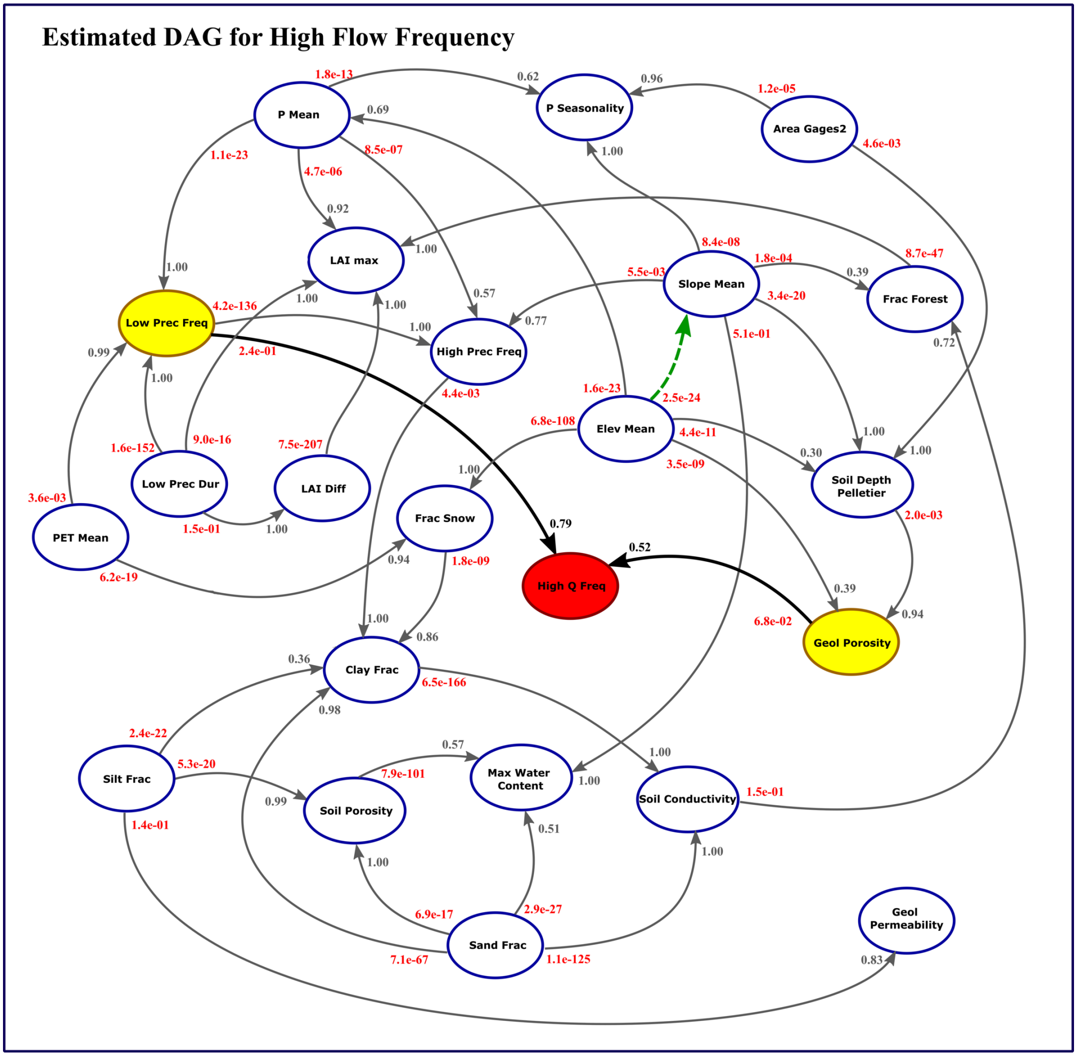

Fig. S27. Directed Acyclic Graph (DAG) for the High Flow Frequency. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

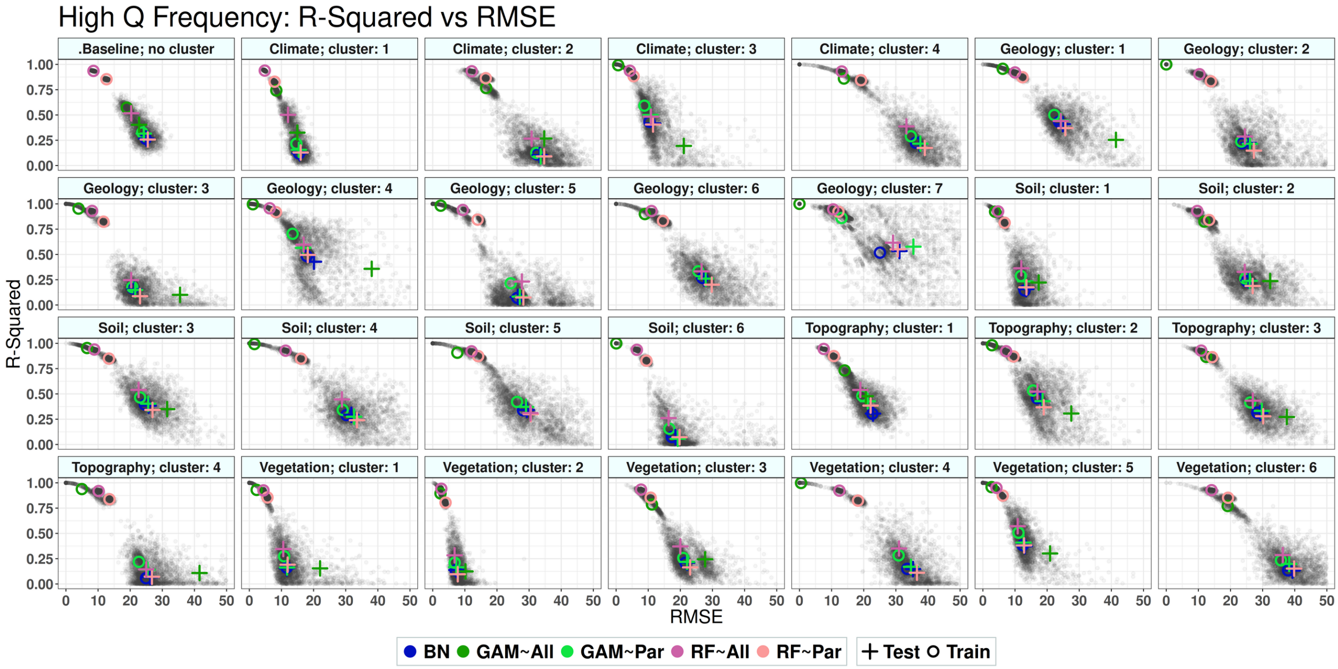

Fig. S28. R-squared vs RMSE in each cluster for all models for high flow frequency.

S2.4 Recovered causal structure and prediction results for the Low Flow Dur (low_q_dur)

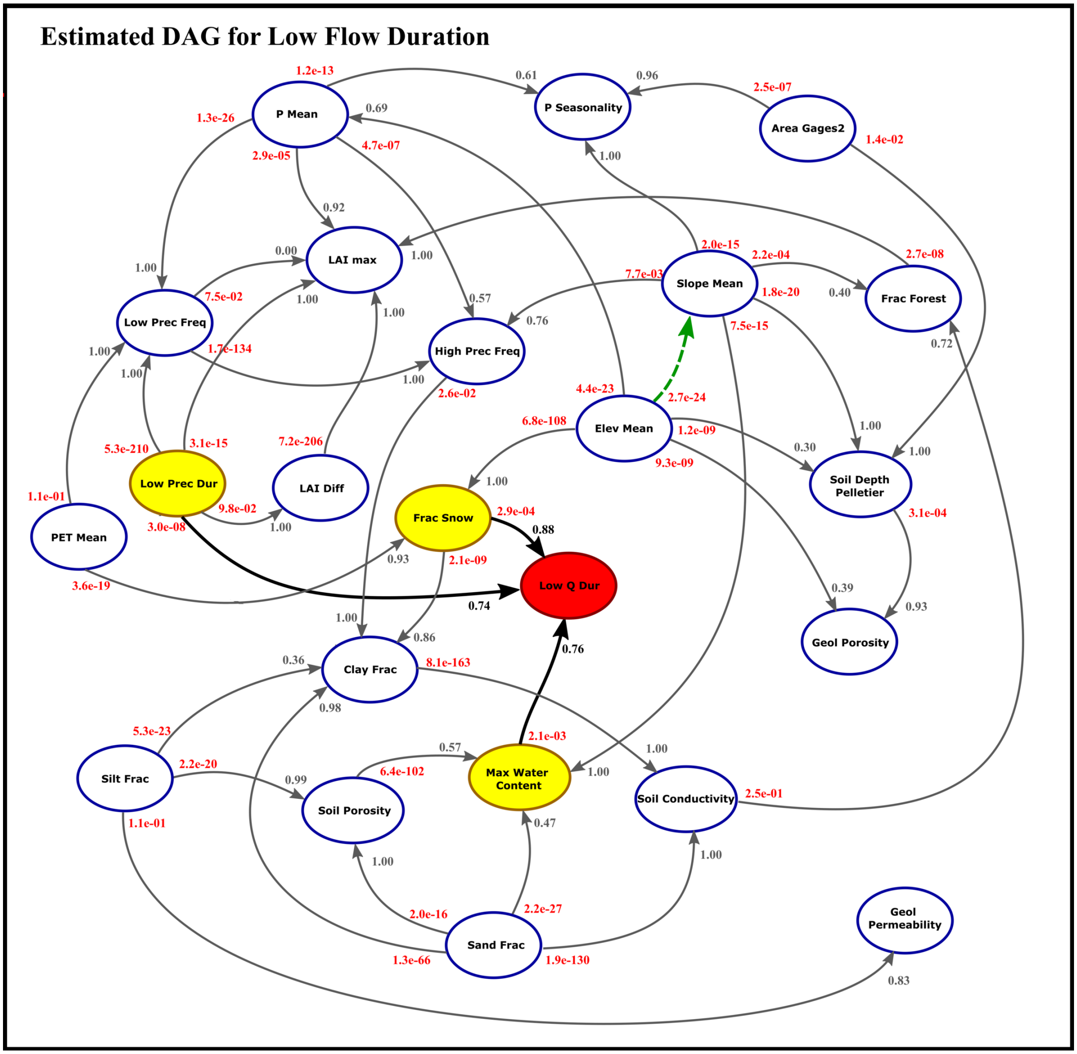

Fig. S29. Directed Acyclic Graph (DAG) for the Low Flow Duration. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

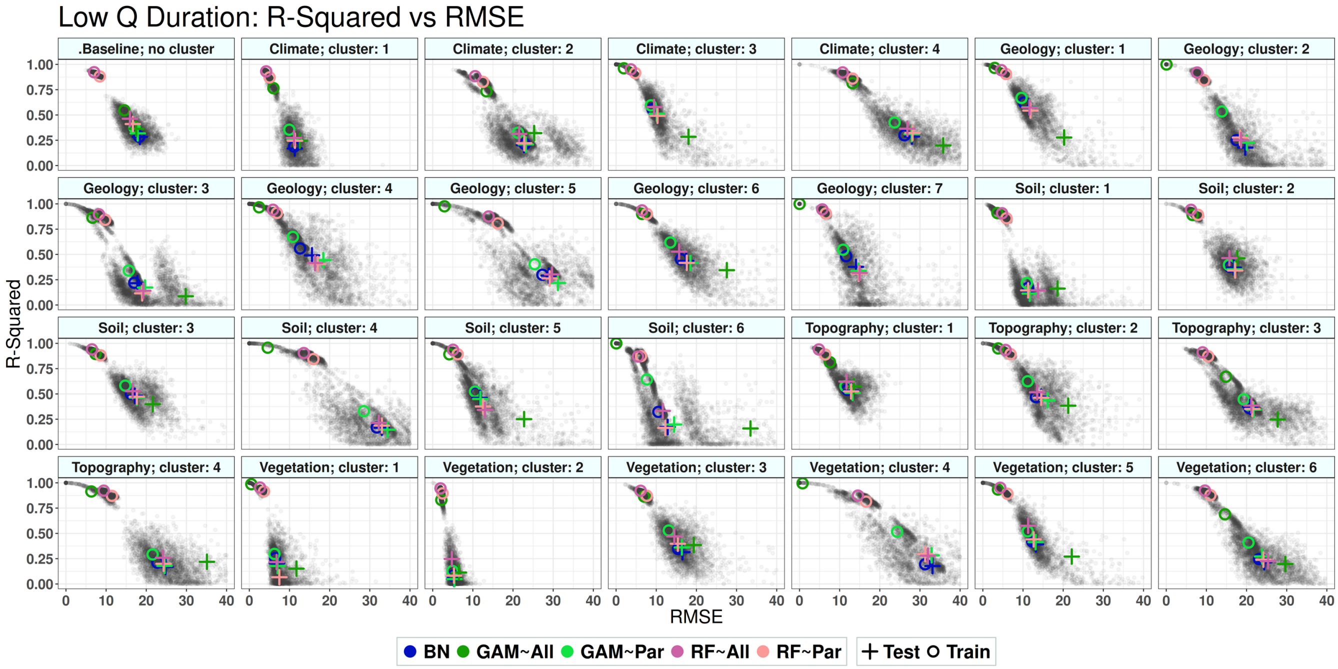

Fig. S30. R-squared vs RMSE in each cluster for all models for low flow duration.

20
S2.5 Recovered causal structure and prediction results for the Low Flow Frequency (low_q_freq)

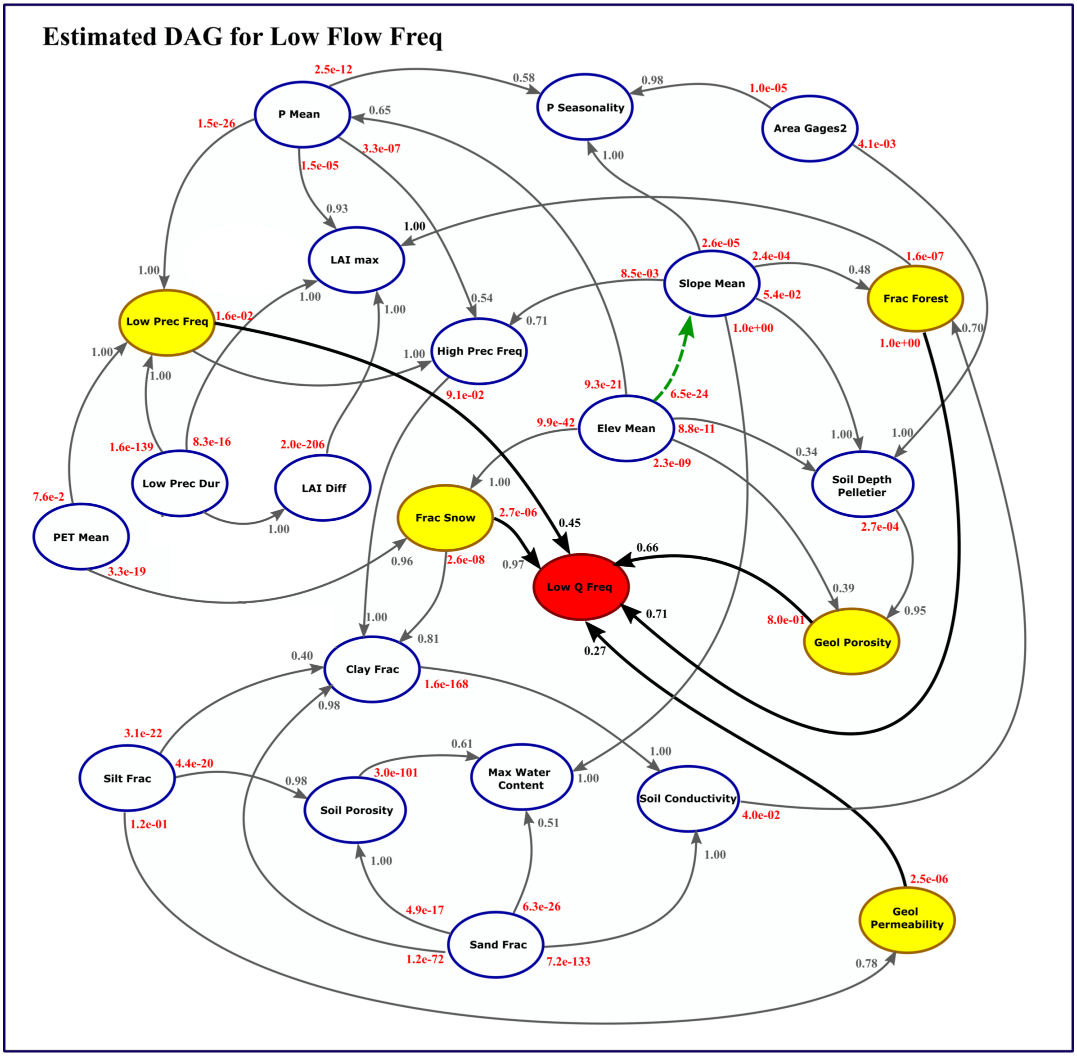

Fig. S31. Directed Acyclic Graph (DAG) for the High Flow Frequency. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

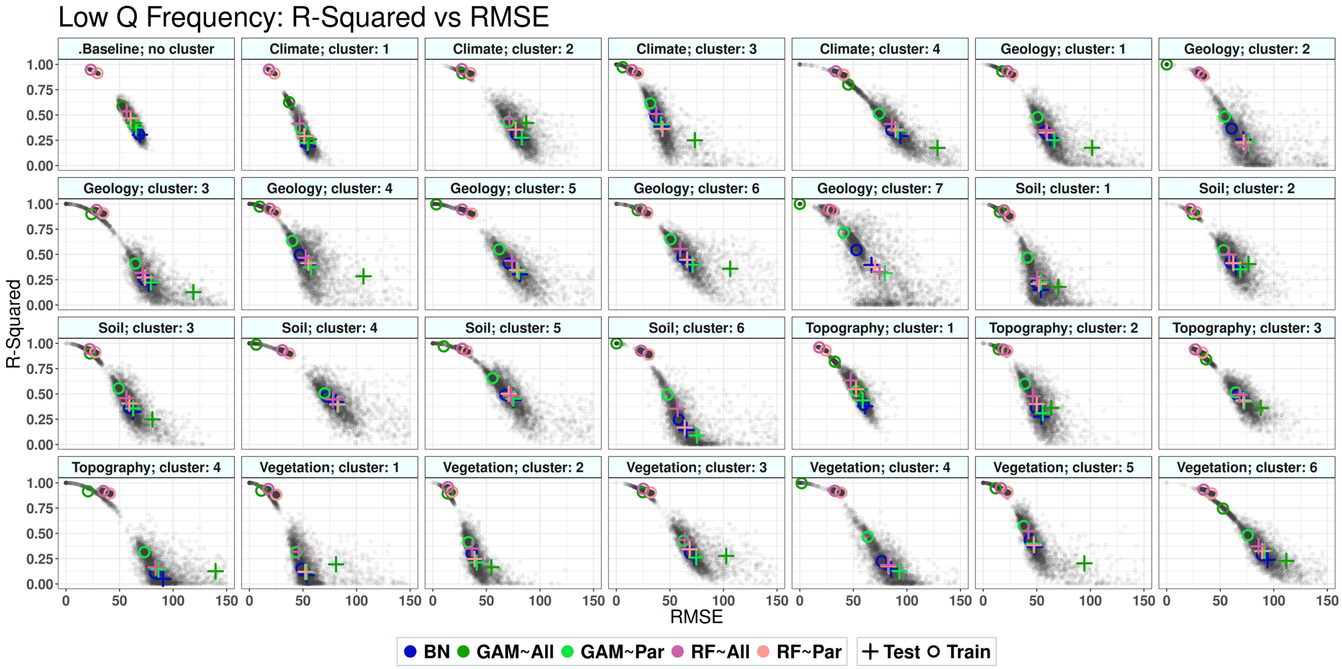

Fig. S32. R-squared vs RMSE in each cluster for all models for low flow frequency.

S2.6 Recovered causal structure and prediction results for the Mean Flow (q_mean)

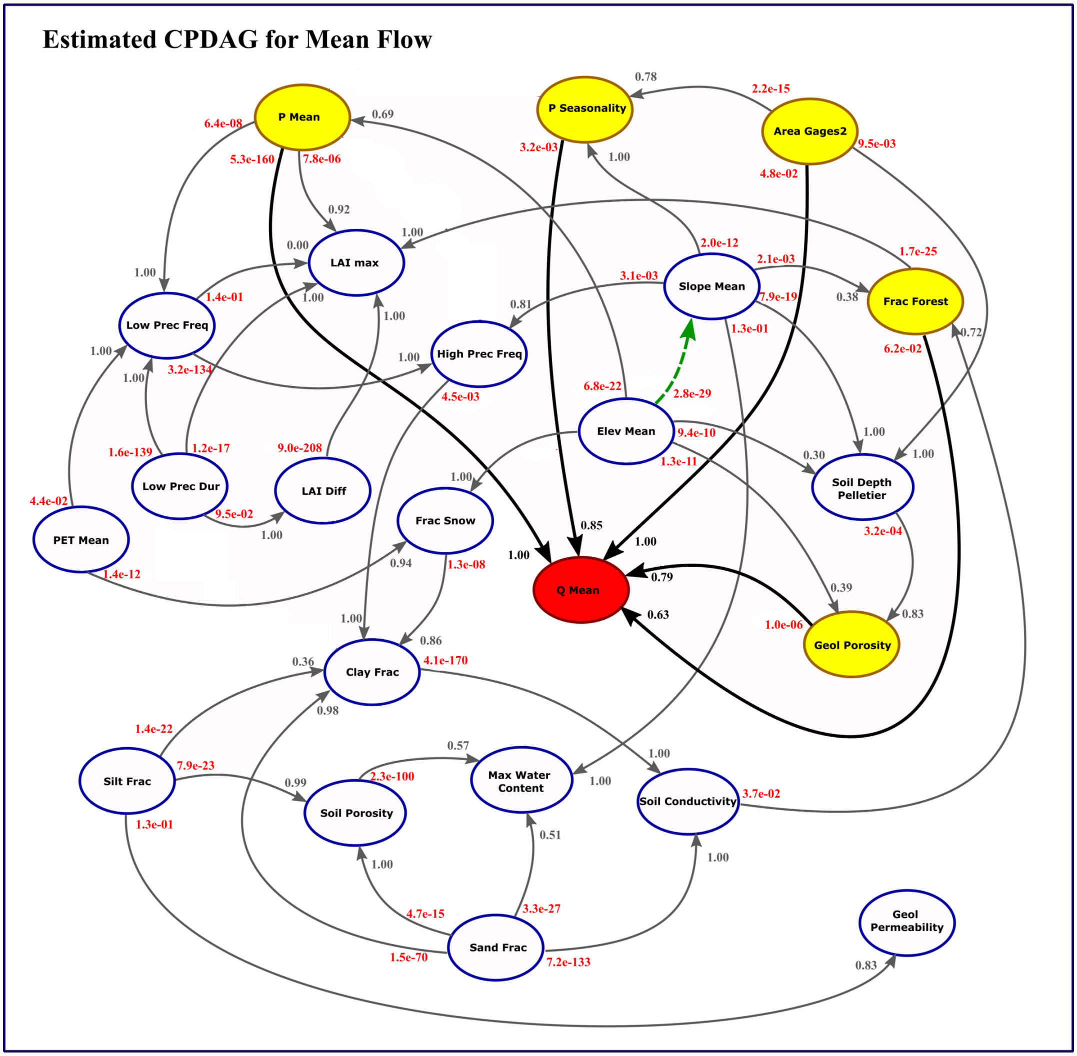

Fig. S33. Directed Acyclic Graph (DAG) for the Mean Daily Flow. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

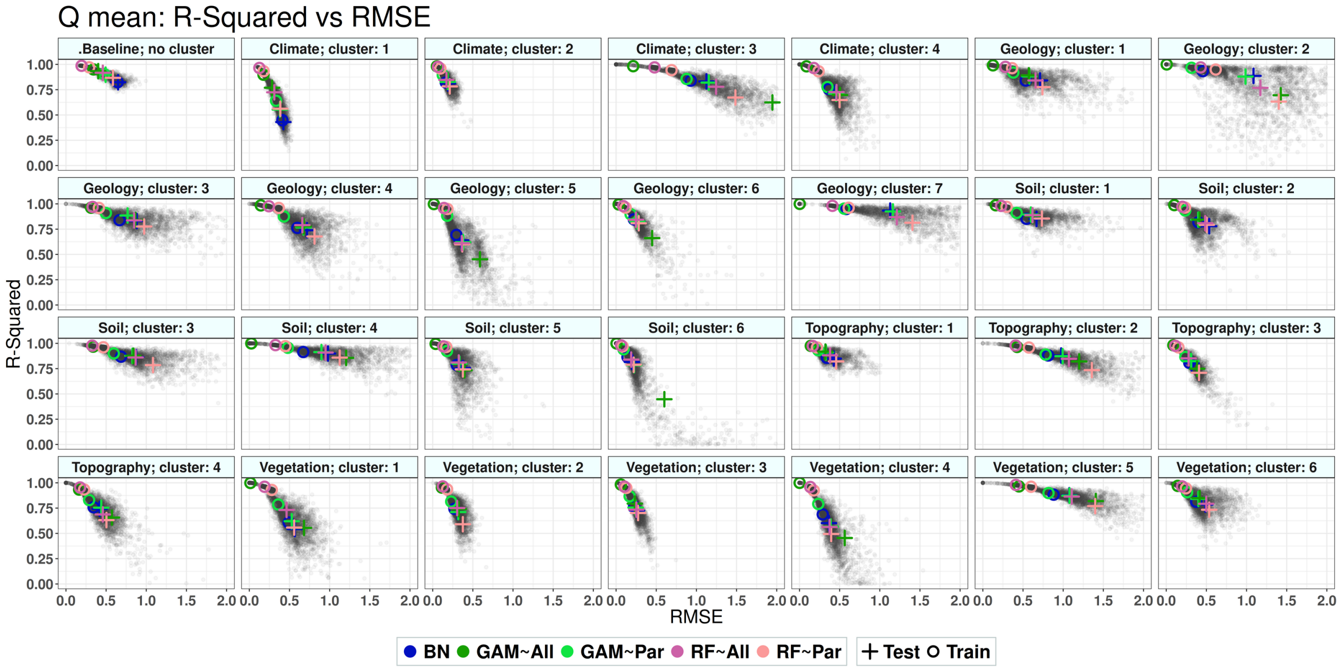

Fig. S34. R squared vs RMSE in each cluster for all models for mean daily flow.

S2.7 Recovered causal structure and prediction results for the Low Flow (q5)

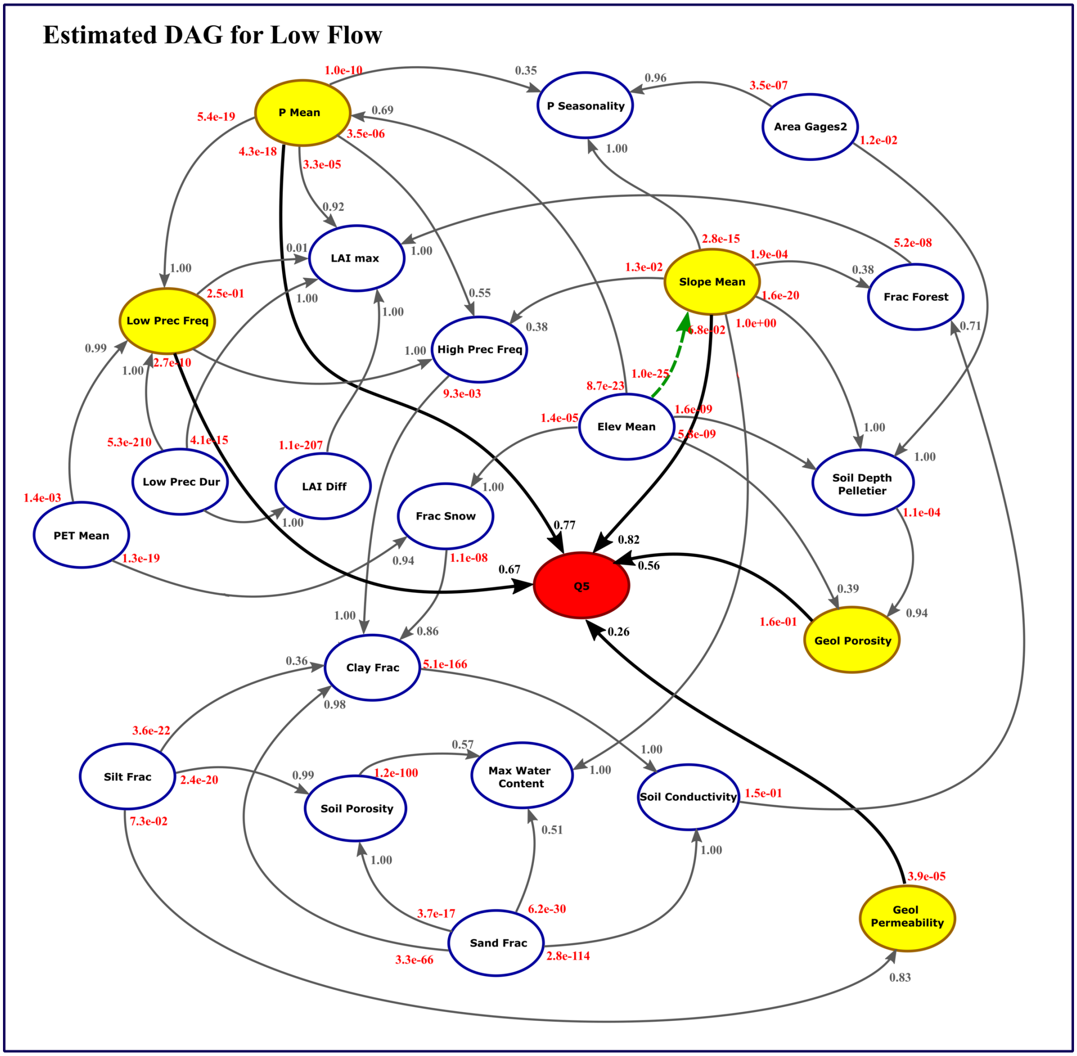

Fig. S35. Directed Acyclic Graph (DAG) for the Low Flow. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

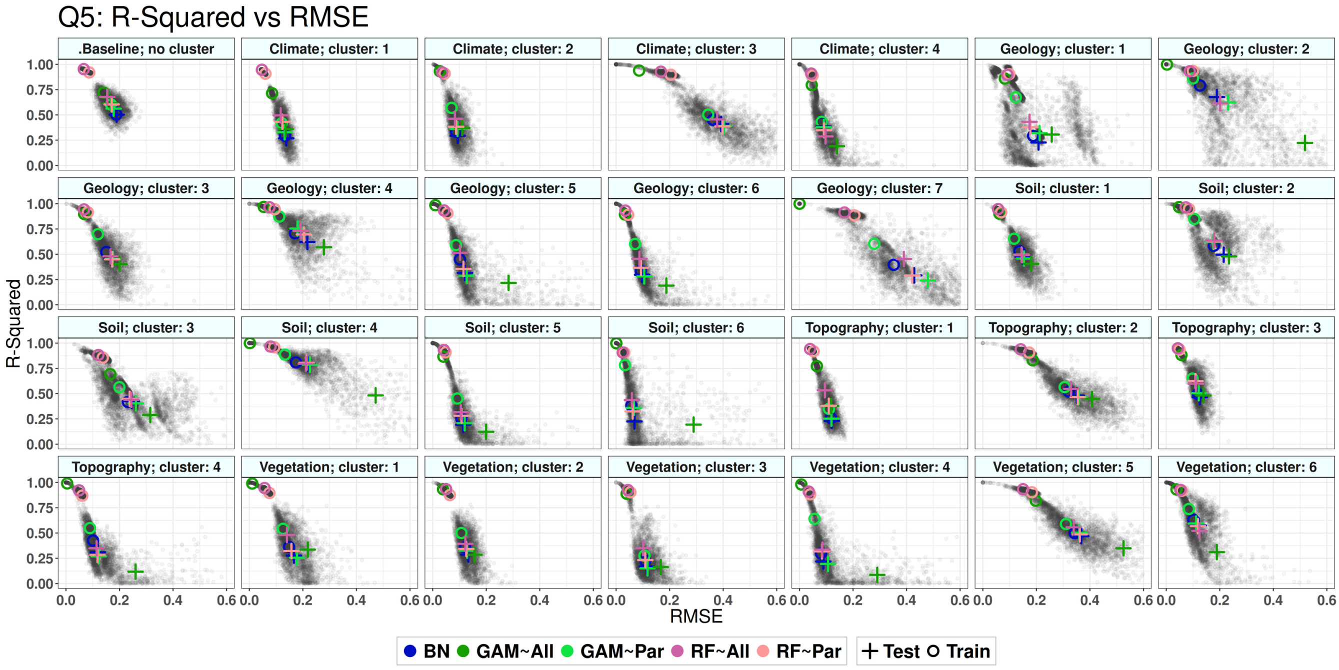

Fig. S36. R-squared vs RMSE in each cluster for all models for low flow.

S2.8 Recovered causal structure and prediction results for the High Flow (q95)

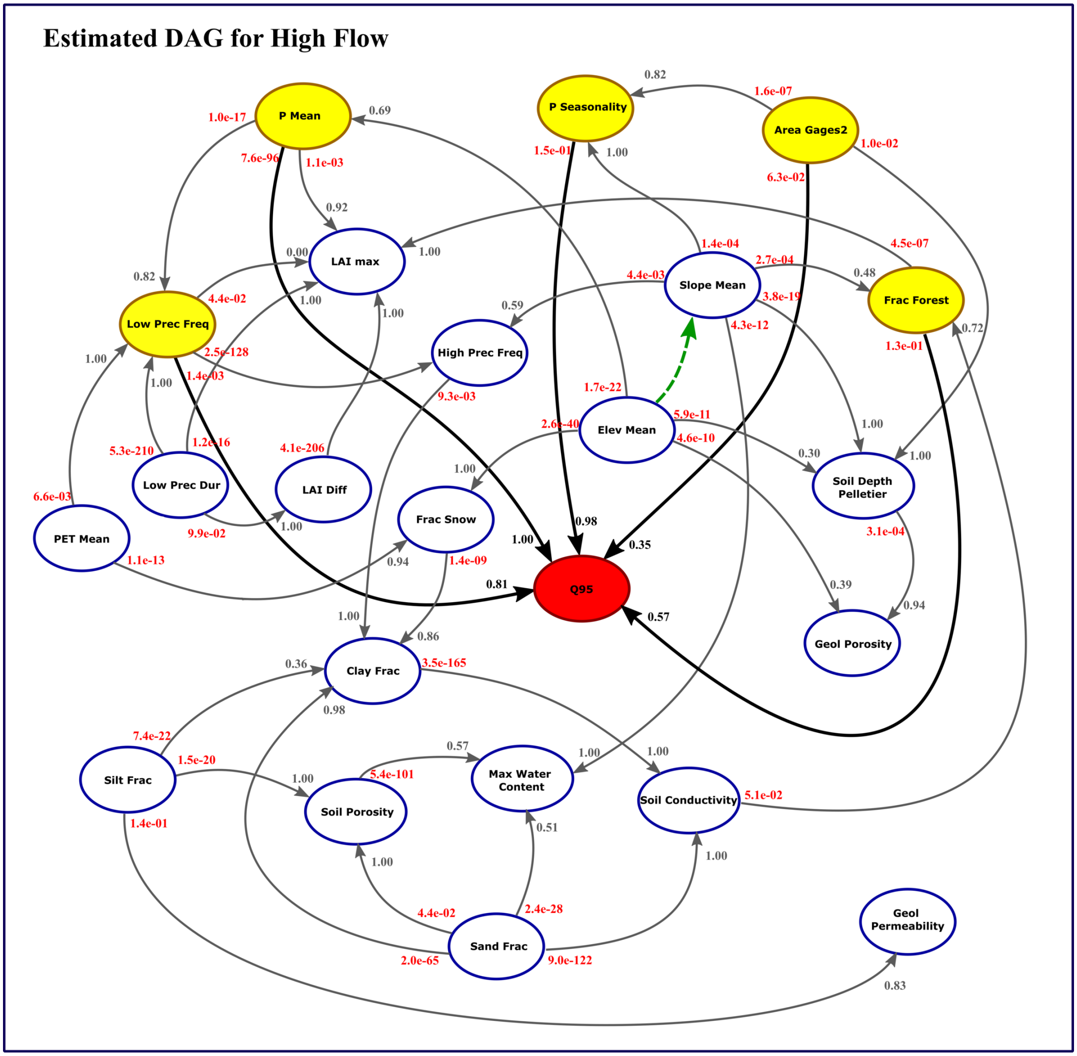

Fig. S37. Directed Acyclic Graph (DAG) for the High Flow. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

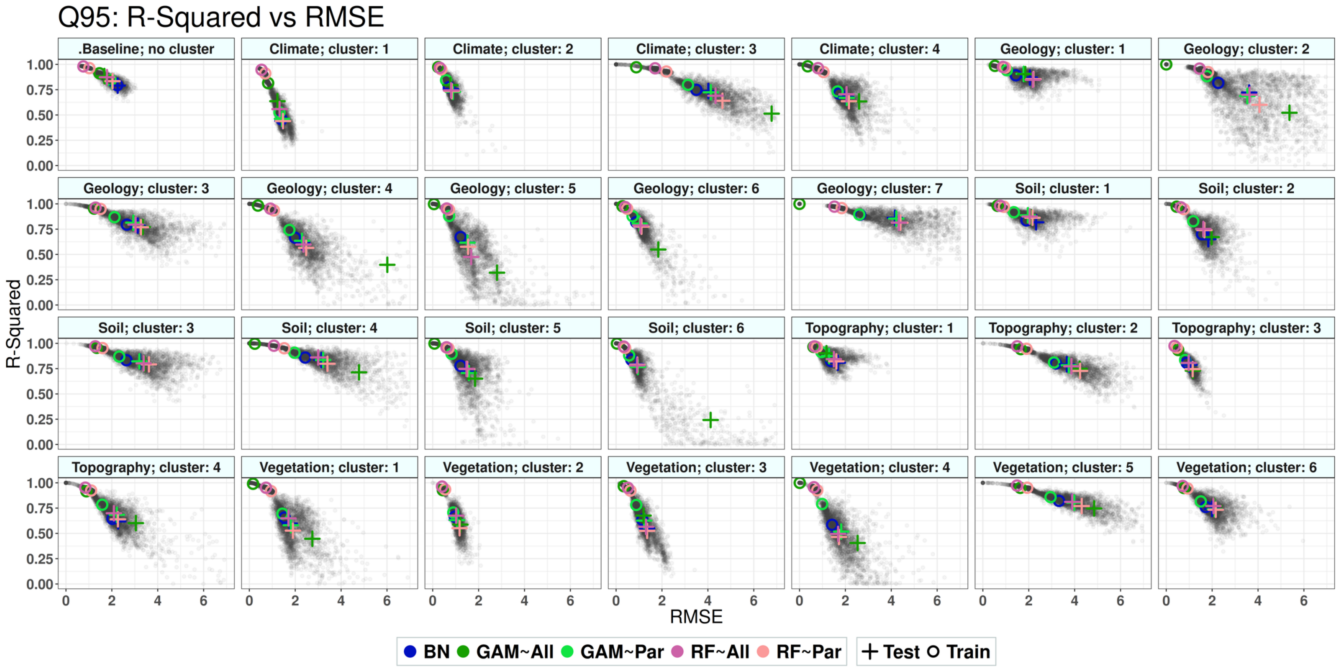

Fig. S38. R-squared vs RMSE in each cluster for all models for high flow.

S2.9 Recovered causal structure and prediction results for the Runoff Ratio (runoff_ration)

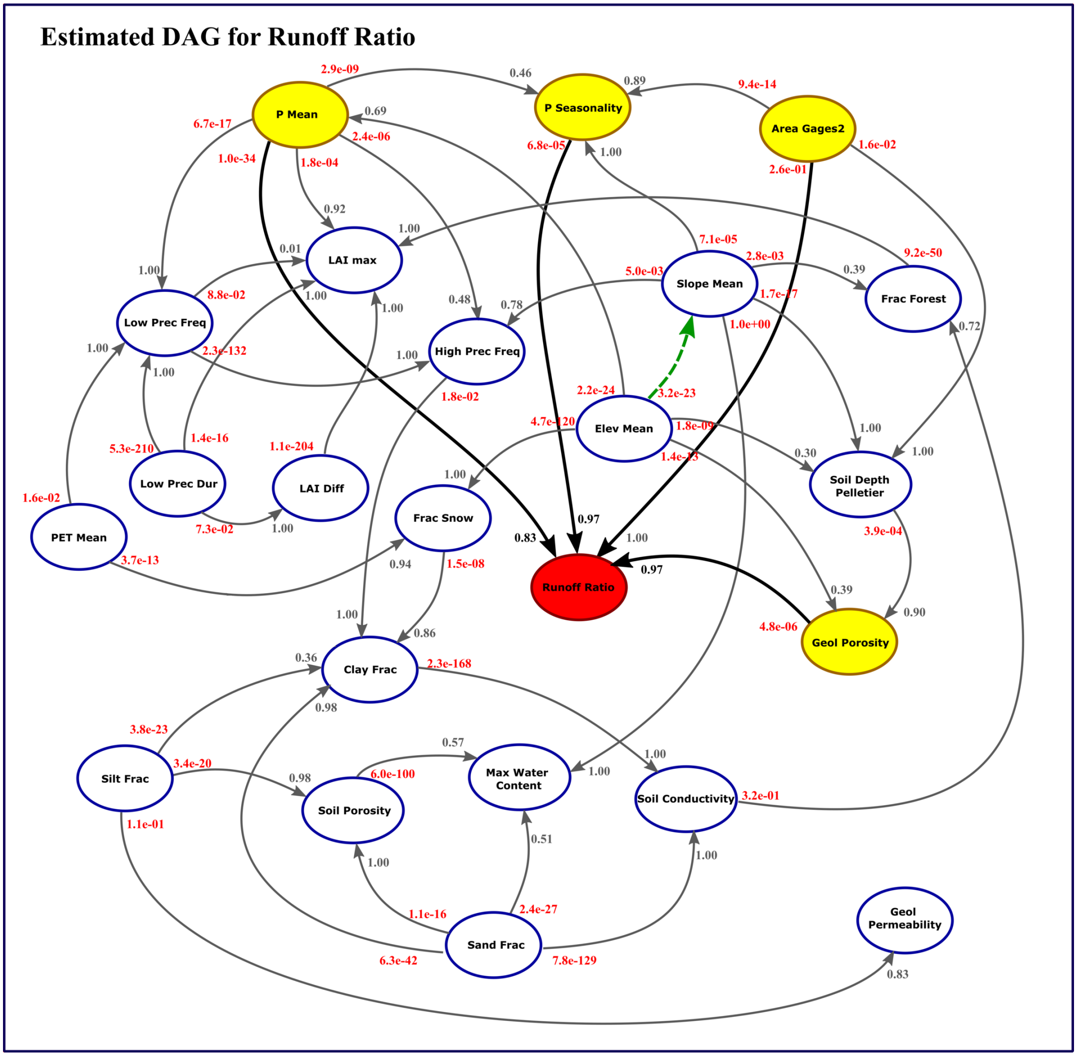

Fig. S39. Directed Acyclic Graph (DAG) for the Runoff Ratio. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

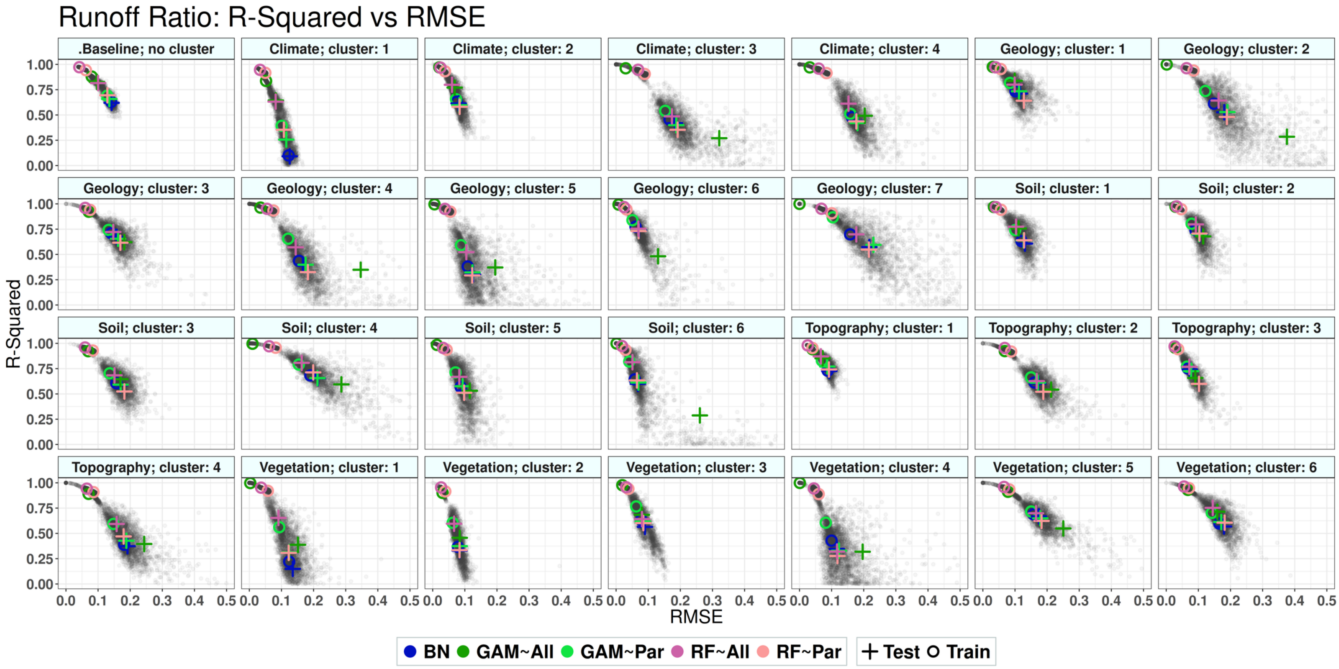

Fig. S40. R-squared vs RMSE in each cluster for all models for runoff ratio.

25 S2.10 Recovered causal structure and prediction results for the Slope of Flow Duration Curve (slope_fdc)

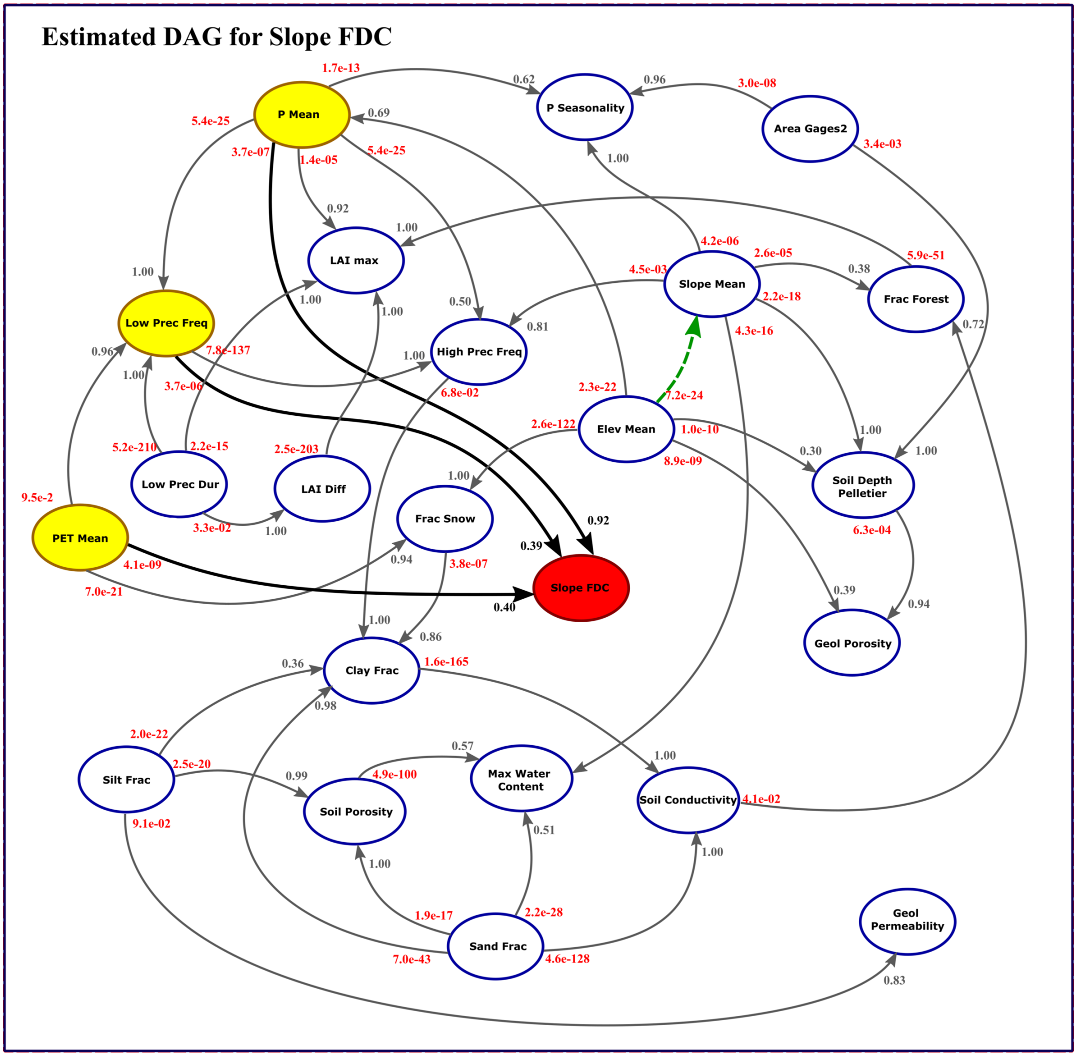

Fig. S41. Directed Acyclic Graph (DAG) for the Slope of Flow Duration Curve. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

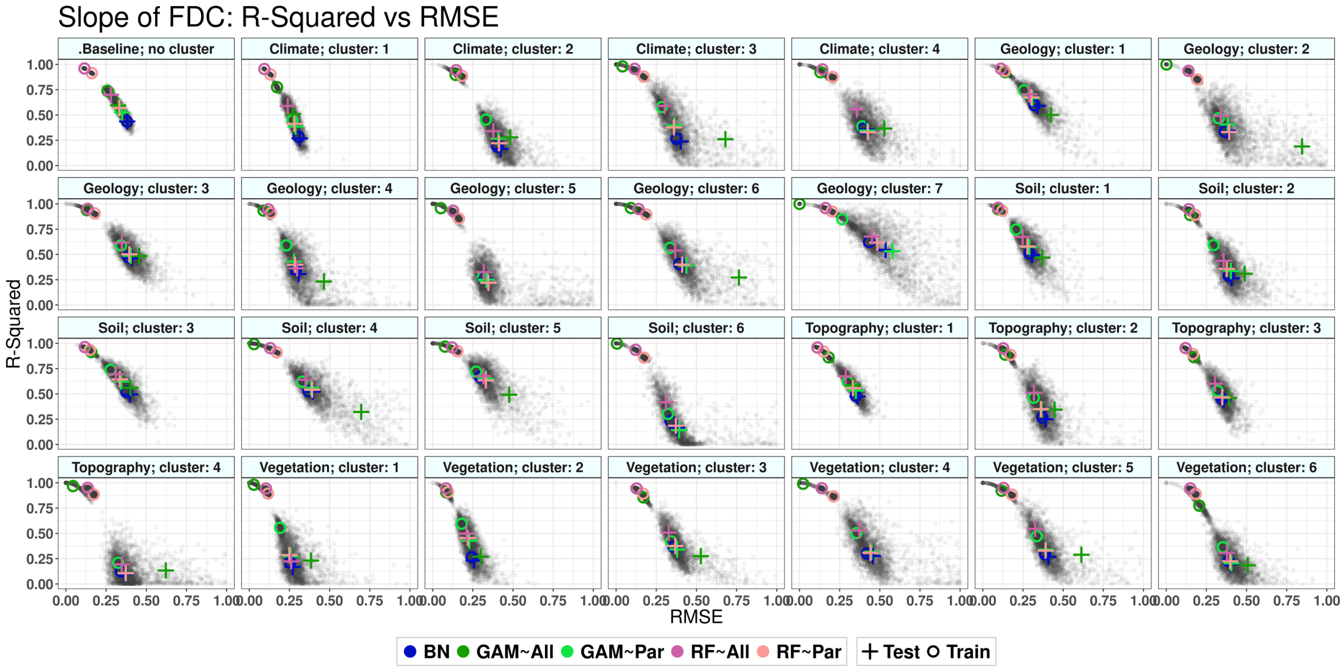

Fig. S42. R-squared vs RMSE in each cluster for all models for the slope of the flow duration curve.

S2.11 Recovered causal structure and prediction results for the Stream Elasticity (stream_elas)

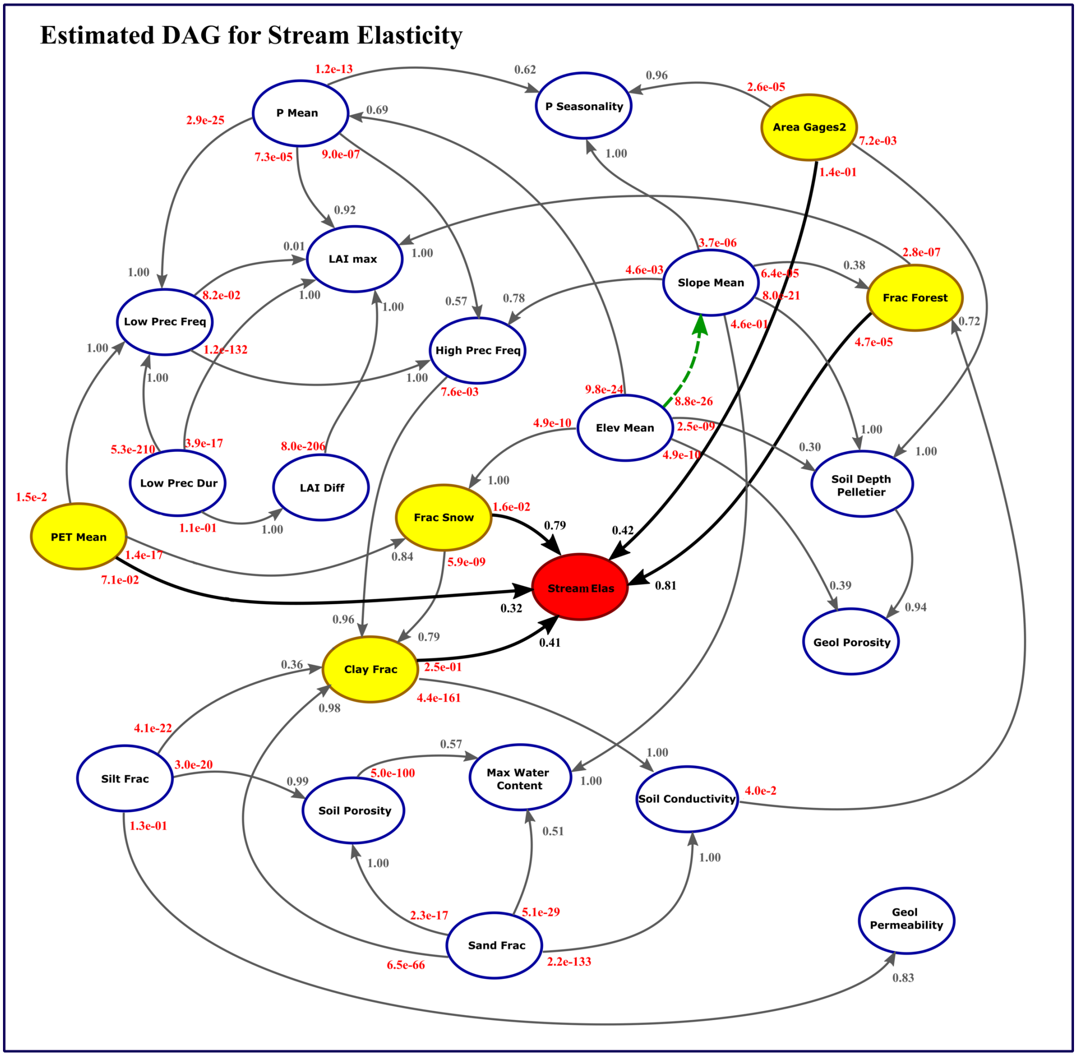

Fig. S43. Directed Acyclic Graph (DAG) for the Stream Elasticity. Arrows indicate the causal links between variables. The green dashed arrow represents an oriented edge that was originally undirected in the CPDAG derived from the PC algorithm. The red node denotes the target variable (runoff signature), the yellow nodes represent its causal parents. Red numbers at the beginning of each arrow correspond to the p-values from the likelihood ratio tests, and the grey (or black for the target variable) numbers indicate the edge strengths derived from 1000 bootstrap resamples.

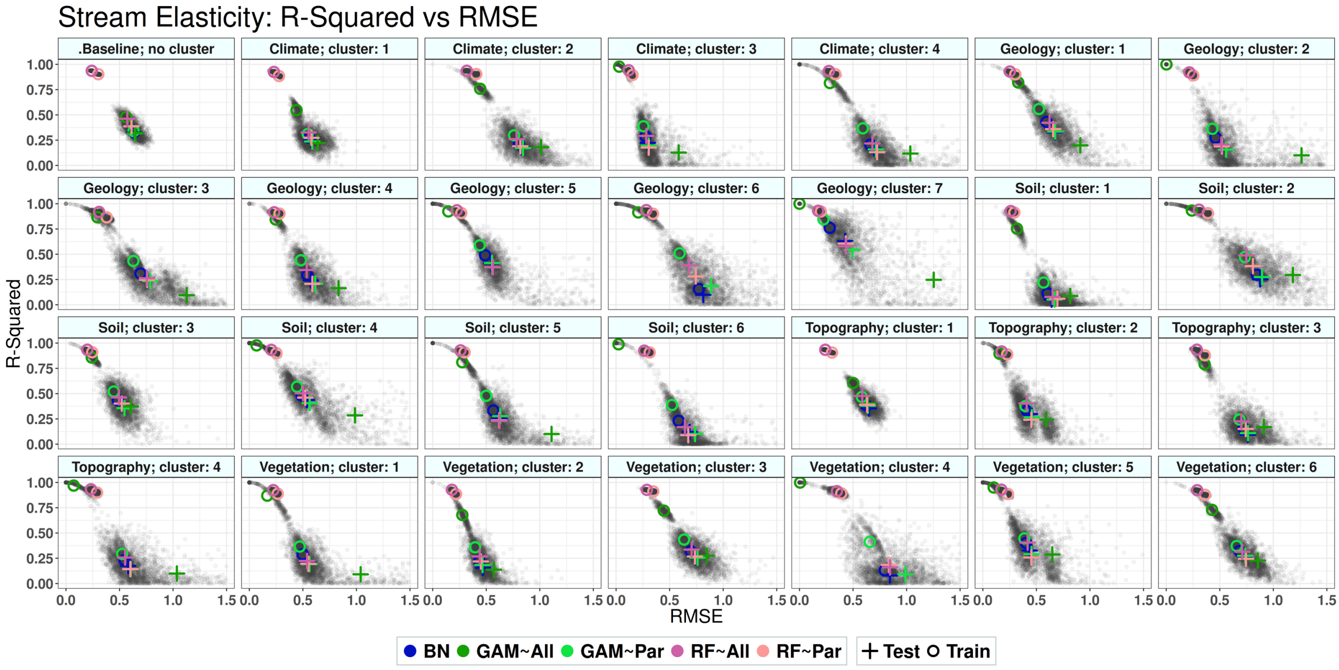

Fig. S44. R-squared vs RMSE in each cluster for all models for streamflow elasticity.

S3 Statistical significance of differences between causal and non-causal models

To assess the statistical significance of the difference between the causal (∼Par) and non-causal (∼All) Generalized Additive Model (GAM) and Random Forest (RF) models, we employ a non-parametric permutation test. In this test, the R^2 and $RMSE$ values of training obtained from 500 runs of each model are resampled (with replacement) to construct a null hypothesis distribution of performance differences. This is achieved by randomly shuffling the labels of Model∼All and Model∼Par for GAM and RF models, recalculating the performance difference for each shuffle. A total of 10,000 permutations are performed to ensure the robustness of the null distribution for both train and test results. The P-value is then determined as the proportion of permuted differences that are as large or larger than the observed difference. A significance threshold (a) of 0.05 is used to evaluate the results. If the obtained P-value is greater than 0.05, the difference between ∼All and ∼Par is not statistically significant.

In this study, we compare two models:

- $M_{\text{Model}\sim\text{Par}}$: Performance of a causal model using a subset of predictors. It can be R^2 or $RMSE$.
- $M_{\text{Model}\sim\text{All}}$: Performance of a non-causal model using all available predictors. It can be R^2 or $RMSE$.

We assess whether the observed difference in mean performance is statistically significant. Let:

$$X = \{X_1, X_2, \ldots, X_n\} \quad \text{(Values from } M_{\text{Model}\sim\text{Par}})$$
$$Y = \{Y_1, Y_2, \ldots, Y_n\} \quad \text{(Values from } M_{\text{Model}\sim\text{All}})$$

The observed difference in means is:

$$\delta_{\text{obs}} = \frac{1}{n}\sum_{i=1}^{n} X_i - \frac{1}{n}\sum_{i=1}^{n} Y_i \tag{S1}$$

Permutation Procedure:

1. Combine the performance metric from $M_{\text{Model}\sim\text{Par}}$ and $M_{\text{Model}\sim\text{All}}$ to create a single pool of all values:

$$Z = \{X_1, \ldots, X_n, Y_1, \ldots, Y_n\} \tag{S2}$$

2. Reassign groups by randomly sampling Z with replacement and splitting it into two groups of size n each:

$$X_{\text{perm}} = \{Z_1, Z_2, \ldots, Z_n\}$$
$$Y_{\text{perm}} = \{Z_{n+1}, Z_{n+2}, \ldots, Z_{2n}\}$$

3. Compute the permuted difference:

$$\delta_{\text{perm}} = \frac{1}{n}\sum_{i=1}^{n} X_{\text{perm},i} - \frac{1}{n}\sum_{i=1}^{n} Y_{\text{perm},i} \tag{S3}$$

4. Repeat the permutation N times (10,000 times in this study) to generate a distribution of δ_{perm}.
5. Calculate the p-value as the proportion of permuted differences that are at least as extreme as the observed difference:

$$p = \frac{\sum_{i=1}^{N} \mathbb{1}\left(|\delta_{\text{perm},i}| \geq |\delta_{\text{obs}}|\right)}{N} \tag{S4}$$

where $\mathbb{1}(\cdot)$ is an indicator function that counts occurrences where $|\delta_{\text{perm},i}|$ is greater than or equal to $|\delta_{\text{obs}}|$.

6. Decision Rule:

- If p is small (here is $p < 0.05$), we reject the null hypothesis, indicating a statistically significant difference between the causal and non-causal models.

- If p is large, we fail to reject the null hypothesis, suggesting that the difference between causal and non-causal models is not significant.

Table S1. Statistical significance of differences between causal (GAM∼Par) and non-causal (GAM∼All) models. The significance level (a) is set to 0.05, and P-values are calculated using the permutation test for both train and test results. The stars, *****, indicate statistically significant differences between causal and non-causal models, and **NS** stands for Not Significant within the respective environment, indicating that the null hypothesis has not been rejected. In the "Environment" column, "Clim" refers to climate, "Geol" to geology, "Topo" to topography, and "Vege" to vegetation.

Statistical significance of difference between GAM∼Par and GAM∼All												
Environment	**Baseflow Index**		**High Q Dur**		**High Q Freq**		**Low Q Dur**		**Low Q Freq**		**Q mean**	
	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test
Baseline	*	*	*	*	*	*	*	*	*	*	*	NS
Clim 1	*	*	*	NS	*	*	*	NS	*	NS	*	*
Clim 2	*	NS	*	NS	*	NS	*	NS	*	NS	*	*
Clim 3	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Clim 4	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 1	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 2	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 3	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 4	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 5	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 6	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 7	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 1	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 2	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 3	*	NS	*	NS	*	NS	*	NS	*	NS	*	*
Soil 4	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 5	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 6	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Topo 1	*	*	*	NS	*	*	*	NS	*	*	*	NS
Topo 2	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Topo 3	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Topo 4	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 1	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 2	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 3	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 4	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 5	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 6	*	NS	*	NS	*	NS	*	NS	*	NS	*	NS

Table S1. (continued) Statistical significance of differences between causal (GAM∼Par) and non-causal (GAM∼All) models. The significance level (a) is set to 0.05, and P-values are calculated using the permutation test for both train and test results. The stars, *, indicate statistically significant differences between causal and non-causal models, and **NS** stands for Not Significant within the respective environment, indicating that the null hypothesis has not been rejected. In the "Environment" column, "Clim" refers to climate, "Geol" to geology, "Topo" to topography, and "Vege" to vegetation.

Statistical significance of difference between GAM∼Par and GAM∼All										
Environment	**Q5**		**Q95**		**Runoff Ratio**		**Slope of FDC**		**Stream Elas**	
	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test
Baseline	*	*	*	*	*	*	*	*	*	NS
Clim 1	*	NS	*	*	*	*	*	*	*	NS
Clim 2	*	NS	*	*	*	*	*	NS	*	NS
Clim 3	*	NS	*	NS	*	NS	*	NS	*	NS
Clim 4	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 1	*	NS	*	NS	*	*	*	NS	*	NS
Geol 2	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 3	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 4	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 5	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 6	*	NS	*	NS	*	NS	*	NS	*	NS
Geol 7	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 1	*	NS	*	NS	*	*	*	NS	*	NS
Soil 2	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 3	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 4	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 5	*	NS	*	NS	*	NS	*	NS	*	NS
Soil 6	*	NS	*	NS	*	NS	*	NS	*	NS
Topo 1	*	NS	*	*	*	*	*	*	*	NS
Topo 2	*	NS	*	NS	*	NS	*	NS	*	NS
Topo 3	*	NS	*	NS	*	NS	*	NS	*	NS
Topo 4	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 1	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 2	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 3	*	NS	*	NS	*	*	*	NS	*	NS
Vege 4	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 5	*	NS	*	NS	*	NS	*	NS	*	NS
Vege 6	*	NS	*	NS	*	NS	*	NS	*	NS

Table S2. Statistical significance of differences between causal (RF∼Par) and non-causal (RF∼All) models. The significance level (a) is set to 0.05, and P-values are calculated using the permutation test for both train and test results. The stars, *, indicate statistically significant differences between causal and non-causal models, and **NS** stands for Not Significant within the respective environment. In the "Environment" column, "Clim" refers to climate, "Geol" to geology, "Topo" to topography, and "Vege" to vegetation.

Statistical significance of difference between RF∼Par and RF∼All												
Environment	**Baseflow Index**		**High Q Dur**		**High Q Freq**		**Low Q Dur**		**Low Q Freq**		**Q mean**	
	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test
Baseline	*	*	*	*	*	*	*	*	*	*	*	*
Clim 1	*	*	*	*	*	*	*	NS	*	*	*	*
Clim 2	*	*	*	NS	*	*	*	*	*	*	*	*
Clim 3	*	*	*	NS	*	*	*	*	*	*	*	*
Clim 4	*	*	*	*	*	*	*	*	*	*	*	*
Geol 1	*	*	*	*	*	*	*	NS	*	NS	*	*
Geol 2	*	NS	*	*	*	*	*	NS	*	NS	*	*
Geol 3	*	*	*	*	*	*	*	NS	*	*	*	*
Geol 4	*	*	*	NS	*	*	*	NS	*	*	*	*
Geol 5	*	*	NS	NS	*	NS	*	NS	*	*	*	NS
Geol 6	*	*	*	NS	*	*	*	*	*	*	*	*
Geol 7	*	NS	*	*	*	NS	*	NS	*	NS	*	*
Soil 1	*	*	*	*	*	*	*	NS	*	*	*	*
Soil 2	*	*	*	NS	*	*	*	*	*	*	*	NS
Soil 3	*	*	*	*	*	*	*	*	*	*	*	*
Soil 4	*	*	*	*	*	*	*	NS	*	*	*	*
Soil 5	*	*	*	NS	*	NS	*	NS	*	NS	*	*
Soil 6	*	*	*	*	*	*	NS	*	*	*	*	*
Topo 1	*	*	*	*	*	*	*	*	*	*	*	*
Topo 2	*	*	*	NS	*	*	*	*	*	*	*	*
Topo 3	*	*	*	*	*	*	*	NS	*	*	*	*
Topo 4	*	*	*	*	*	*	*	NS	*	NS	*	*
Vege 1	*	*	*	*	*	*	*	*	*	*	*	*
Vege 2	*	*	*	NS	*	*	*	*	*	*	*	*
Vege 3	*	*	*	NS	*	*	*	*	*	*	*	*
Vege 4	*	*	*	*	*	*	*	NS	*	NS	*	*
Vege 5	*	*	*	NS	*	*	*	*	*	*	*	*
Vege 6	*	*	*	*	*	*	*	NS	*	*	*	*

Table S2. (continued) Statistical significance of differences between causal (RF∼Par) and non-causal (RF∼All) models. The significance level (a) is set to 0.05, and P-values are calculated using the permutation test for both train and test results. The stars, *, indicate statistically significant differences between causal and non-causal models, and **NS** stands for Not Significant within the respective environment. In the "Environment" column, "Clim" refers to climate, "Geol" to geology, "Topo" to topography, and "Vege" to vegetation.

Statistical significance of difference between RF∼Par and RF∼All										
Environment	**Q5**		**Q95**		**Runoff Ratio**		**Slope of FDC**		**Stream Elas**	
	Train	Test	Train	Test	Train	Test	Train	Test	Train	Test
Baseline	*	*	*	*	*	*	*	*	*	*
Clim 1	*	*	*	*	*	*	*	*	*	*
Clim 2	*	*	*	NS	*	*	*	*	*	*
Clim 3	*	*	*	*	*	*	*	*	*	*
Clim 4	*	NS	*	*	*	*	*	*	*	*
Geol 1	NS	NS	*	NS	*	*	*	*	*	*
Geol 2	NS	NS	*	*	*	*	*	*	*	NS
Geol 3	*	*	*	*	*	*	*	*	*	NS
Geol 4	*	*	*	*	*	*	*	NS	*	*
Geol 5	*	*	*	*	*	*	*	*	*	NS
Geol 6	*	*	*	*	*	NS	*	*	*	*
Geol 7	*	*	*	NS	*	*	*	*	*	NS
Soil 1	*	NS	*	*	*	*	*	*	*	*
Soil 2	*	NS	*	NS	*	*	*	*	*	*
Soil 3	*	NS	*	NS	*	*	*	*	*	*
Soil 4	*	NS	*	*	*	*	*	*	*	*
Soil 5	*	*	*	NS	*	*	*	*	*	NS
Soil 6	NS	*	*	NS	*	*	*	*	*	*
Topo 1	*	*	*	*	*	*	*	*	*	*
Topo 2	*	*	*	*	*	*	*	*	*	*
Topo 3	*	NS	*	*	*	*	*	*	*	*
Topo 4	*	NS	*	*	*	*	*	*	*	*
Vege 1	*	*	*	*	*	*	*	NS	*	*
Vege 2	*	*	*	*	*	*	*	*	*	*
Vege 3	*	*	*	NS	*	*	*	*	*	*
Vege 4	*	NS	*	NS	*	NS	*	*	*	NS
Vege 5	*	*	*	*	*	*	*	*	*	*
Vege 6	*	NS	*	*	*	*	*	*	*	*