Characterizing hydrologic similarity of precipitation and catchment wetness using repeating patterns in runoff

Adriane Hövel[1], Christine Stumpp[1], Heye Bogena[2], Andreas Lücke[2], Michael Stockinger[1]

[1]University of Natural Resources and Life Sciences, Vienna, Department of Water, Atmosphere and Environment, Institute of Soil Physics and Rural Water Management, Muthgasse 18, 1190 Vienna, Austria
[2]Forschungszentrum Jülich GmbH, Institute of Bio- and Geosciences, Agrosphere Institute (IBG-3), Wilhelm-Johnen-Straße, 52425 Jülich, Germany

✉ adriane.hoevel@boku.ac.at

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Relevance and research gap

- Understanding the **rainfall-runoff process** at the catchment scale serves as a basis for a sustainable **water resources management**.
- It is assumed that similar catchment characteristics or meteorological conditions lead to similar runoff responses.
- Existing concepts of **"hydrologic similarity"** are based on comparative catchment studies in space (Fig. 1).

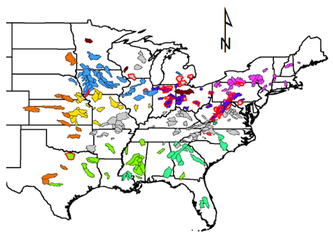

Figure 1. Spatial distribution of catchments sorted into classes (after Sawicz et al., 2011).

- Two catchments can never be completely identical.
- Comparing catchments still carries the risk of **unaccounted impacts** on the runoff response.

⇨ Idea for a **new concept** to compare a catchment to itself **in time:**

- Assuming that similar precipitation and wetness conditions (i.e., soil moisture and groundwater level) lead to a similar runoff response.

Objectives

a) Define **criteria of hydrologic similarity** of precipitation and catchment wetness based on similar runoff events, and determine if the similarity criteria **differ between three study catchments**.

b) Assess whether the defined hydrologic similarity can help **evaluate the driving factors for runoff responses** with respect to precipitation and wetness conditions.

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Study area

Three small catchments with different land use, geology, soil types, and climate (Fig. 2) were assessed.

a) Wüstebach (38.5 ha) b) Rollesbroich (40 ha) c) Petzenkirchen (66 ha)

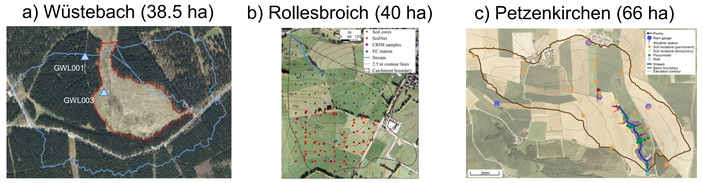


Figure 2. Study catchments of a) Wüstebach (Eifel National Park, Germany, partly forested), b) Rollesbroich (Eifel region, Germany, grassland) and c) Petzenkirchen (Lower Austria, agriculture).

Method

Basis for pattern search: Long-term observation time series (~10 years) of hydrological variables (Fig. 3).

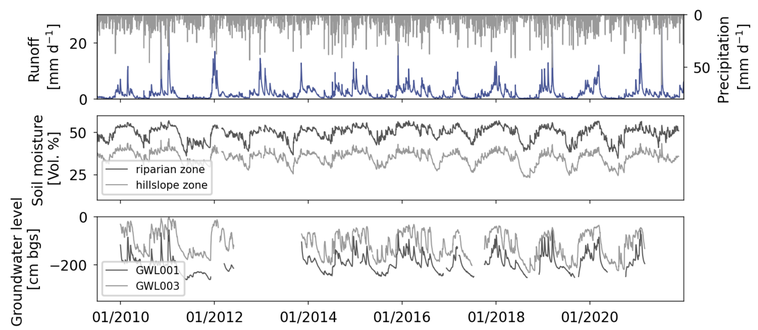


Figure 3. Time series of observed daily precipitation, runoff, soil moisture, and groundwater level in Wüstebach, with soil moisture in the riparian (dark grey) and hillslope (light grey) zones and groundwater level at the stations GWL001 (dark grey) and GWL003 (light grey).

Workflow

1. Compare runoff in time with goodness-of-fit (GOF) criteria

2. If GOF > 0.65: runoff response similar

3. Further grouping with cluster analysis (Fig. 4)

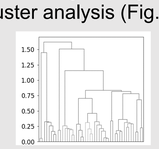


Figure 4. Example of a dendrogram resulting from cluster analysis.

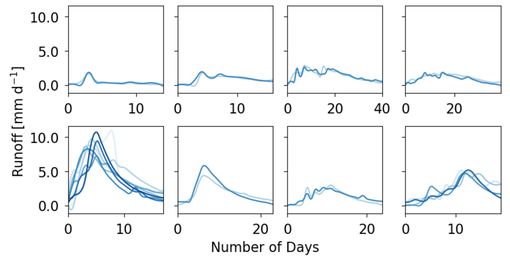
4. Precipitation and wetness conditions

5. Descriptive statistics & Spearman correlation

6. Criteria for hydrologic similarity

Results

Clustering of runoff events:



- Wüstebach ⇨ 8 clusters (Fig. 5)
- Rollesbroich ⇨ 10 clusters
- Petzenkirchen ⇨ 12 clusters

Figure 5. Clusters of runoff events for Wüstebach.

Precipitation and wetness conditions for similar runoff events:

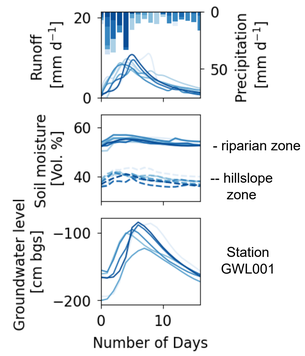


Figure 6. Precipitation and wetness conditions for the largest cluster in Wüstebach.

Table 1. Spearman rank correlation coefficients averaged over all clusters for precipitation (P), soil moisture (SM), and groundwater level (GWL), with measurement locations.

	Wüstebach	Rollesbroich	Petzenkirchen
P	0.255	0.375	0.573
SM	0.757 *(riparian)* 0.758 *(hillslope)*	0.742	0.534
GWL	0.811 *(GWL001)* 0.228 *(GWL003)*	-	0.538 *(H09)* 0.807 *(BP01)*

Conclusions

- **Novel method** to define the hydrologic similarity of precipitation and catchment wetness conditions.
- Similar patterns of the runoff response can be found in all three catchments. However, the **influential factors investigated differ** for the different catchments.
- Soil moisture was **strongly correlated** in Wüstebach and Rollesbroich, indicating possible dominant control on runoff.

References

Sawicz, K., Wagener, T., Sivapalan, M., Troch, P. A., & Carrillo, G. (2011). Catchment classification: Empirical analysis of hydrologic similarity based on catchment function in the eastern USA. *Hydrology and Earth System Sciences*, *15*(9), 2895–2911. https://doi.org/10.5194/hess-15-2895-2011