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Interaction of climate, vegetation, and water age in catchments across scales and climate zones

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1 Introduction

Recent studies have demonstrated a direct relation between climate characteristics and vegetation in catchments. For example, plants develop a root system that allows both optimal growth and resistance against region-specific droughts. As climatic conditions also affect the way catchments store and release water (i.e., the transit times), we are analysing **links between vegetation and transit times**. This may help us understand how changing vegetation might affect catchment water storage and release in future.

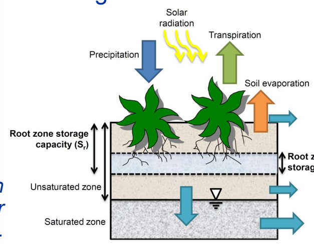
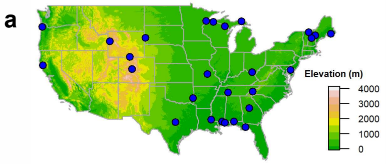


Fig. 1: Interactions between root zone storage and water storage and release.

How do **transit time metrics** vary as a function of plant-accessible water storage in the unsaturated root zone, i.e. **root zone storage capacities**?

2 Study catchments



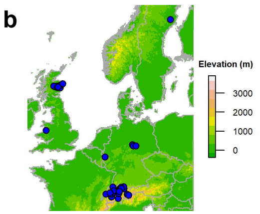


Fig. 2: Study catchments in the USA[1] (a) and Europe (b).

3 Methods

(1) DATA

- 67 catchments (0.385–8264.9 km^2)
- **Isotopes**: monthly $\delta^{18}O$ in precipitation (P) and streamflow (Q)
- **Water balance**: daily P, T (or PET) and Q data
- Where $\delta^{18}O$ in P not available: $\delta^{18}O_P$ amplitude map[2]

(2) YOUNG WATER FRACTIONS (F_{yw})

- Proportion of water ages below 2–3 months
- **Sine-wave regression** of $\delta^{18}O_P$ and $\delta^{18}O_Q$ → approximation by amplitudes A_Q and A_P:

$$F_{yw} = A_Q / A_P$$

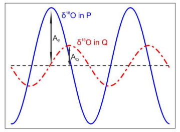


Fig. 3: Approximation of F_{yw} by A_Q and A_P.

(3) ROOT ZONE STORAGE CAPACITIES

- Annual maximum storage water deficits (S_R) derived from catchment evapotranspiration (E_t) and effective precipitation (P_e):

$$S_R = \max \int (E_t - P_e)dt$$

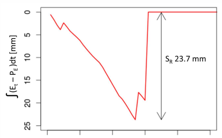


Fig. 4: S_R equals the cumulative difference between E_t and P_e (modified from [3]).

- Root zone storage capacity as S_R with **return period of 20 years**[4] ($S_{R,20}$) using the Gumbel extreme value distribution

4 Results

(1) YOUNG WATER, STORAGE CAPACITY & VEGETATION

- $S_{R,20}$ increases from heathland to broadleaf forests (Fig. 5a).
- F_{yw} increases from arable land to broadleaf forests (Fig. 5b).

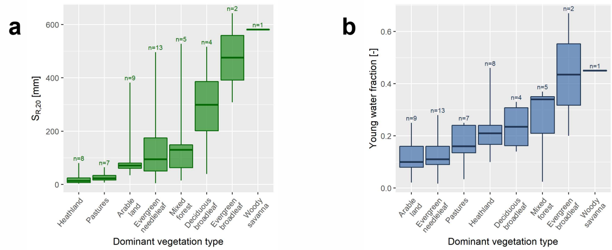


Fig. 5: Root zone storage capacity with return period of 20 years (a) and young water fraction (b) vs. dominant vegetation type in catchments.

(2) YOUNG WATER FRACTION vs. STORAGE CAPACITY

- $S_{R,20}$ in European catchments mostly below 100 mm
- Slight decrease in F_{yw} with increasing $S_{R,20}$ in UK and CH
- No clear overall relationship between F_{yw} and $S_{R,20}$

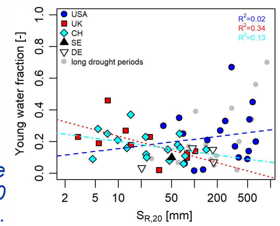


Fig. 6: Young water fractions vs. root zone storage capacities with return period of 20 years ($S_{R,20}$).

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5 Conclusions and Outlook

- **F_{yw} is slightly decreasing with increasing $S_{R,20}$** in European catchments, where $S_{R,20}$ mostly < 100 mm
- Catchments with large $S_{R,20}$ show large range of F_{yw} → decoupling between water storage by plants and runoff generation?
- Next: inclusion of catchments in New Zealand, Australia, Africa and South America

We need a unified framework to store and provide streamflow isotope data as a basis for further (global) analyses. Ideas on platforms, implementation, datasets? Let me know!

References

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