What impact do intense events have on aquifer recharge?

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Introduction : Groundwater recharge is an important flux of the hydrological cycle, but is still badly known. Lysimeters can give access to it locally. In this study, the drainage from lysimeters localisated in the north-east of France are analysed to understand the mechanisms controlling groundwater recharge, especially during droughts and intense precipitation events.

Long –term observation

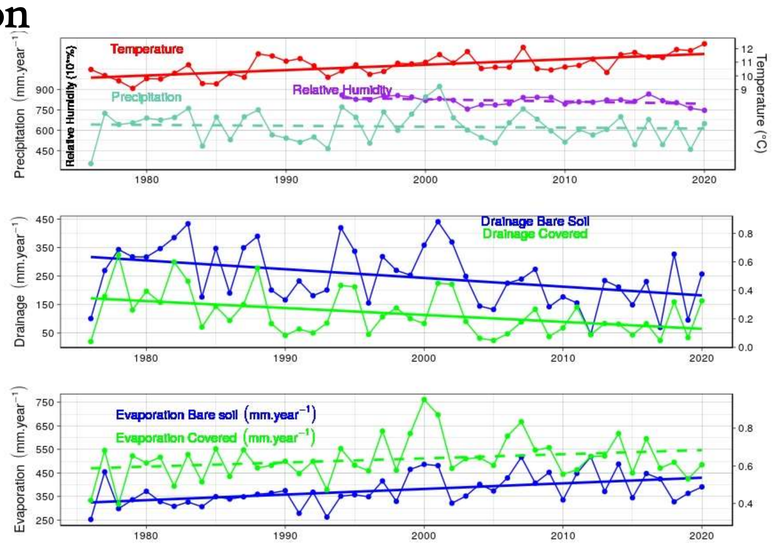


FIG 4 : 45 years of mean annual precipitation, temperature, drainage and evaporation from the bare soil or vegetated lysimeters (Fagnières).

A significantly decrease of the drainage is observed. This trend is not linked of a decrease of precipitation, but with the increase of the evapotranspiration associated of 2m temperature combined with a decrease of 2m relative humidity.

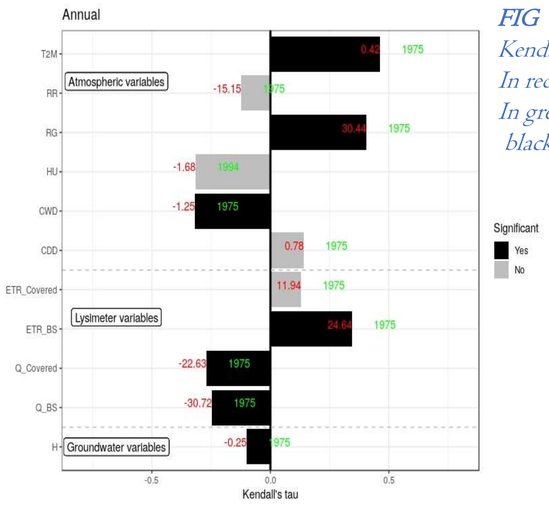


FIG 5 : Mann-Kendall trends in observations. Kendall's tau is the rank correlation coefficient. In red : Sen slope In green : start of measurement black : significant trend

The decrease trends in the observed drainage is also consistent with the significant decrease of the cumulative wet days (CWD), as well as with the decrease of the head (H) observed on a close piezometer.

Lysimeters

In this study, 11 lysimeters, of 2m deep and 1 to 4m² with different land cover available and soil type are analysed. They are located in northeastern France at two experimental sites.

FIG 1 : Lysimeters of OPE, Fagnières sites

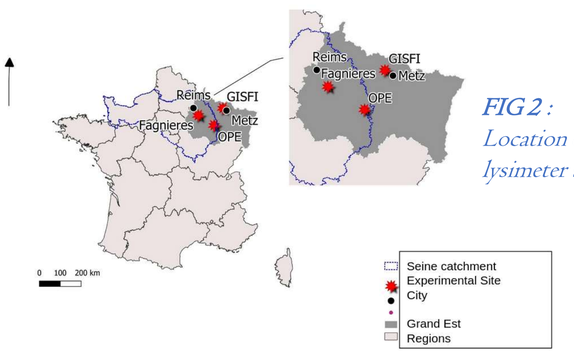


FIG 2 : Location of lysimeter sites

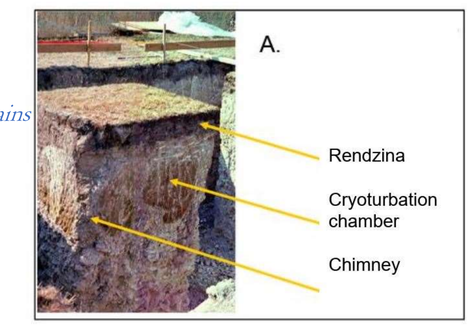


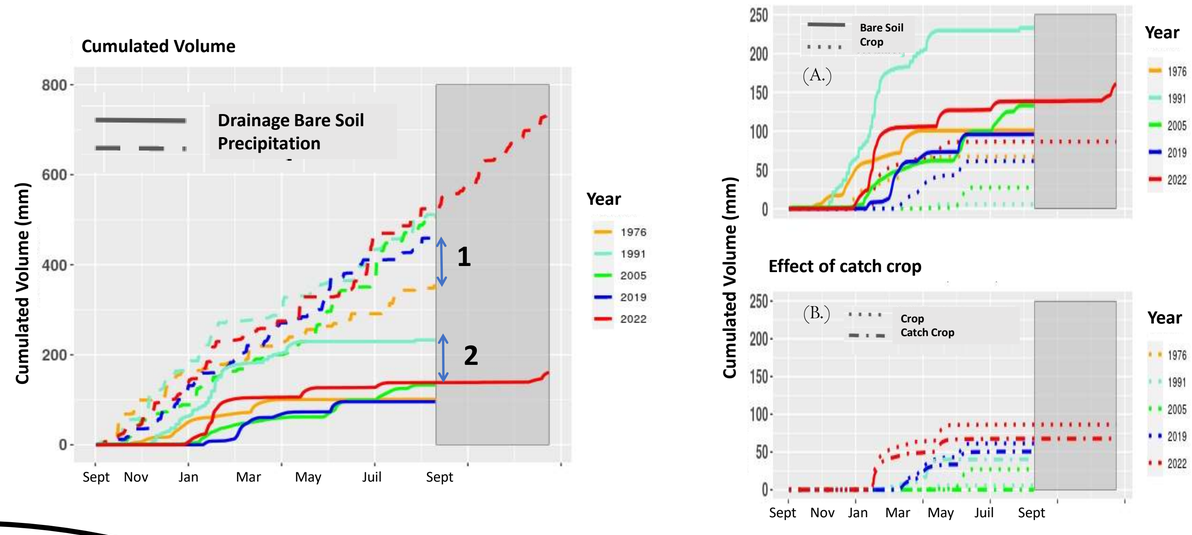
FIG 3 : Soil contains in Fagnières

TAB 1 : Description of lysimeter sites

Site	Fagnières (INRAE) (1973-2023)	OPE (ANDRA) (2014-2023)
Soil	Chalky (rendzina)	Cambisol
Data	Recharge (at 2m)	Recharge (at 2m) Water content/Pressure Temperature (0.2-0.5-1-1.5 m) Total mass

Drought events

FIG 6 : Cumulative precipitation and drainage for 5 dry years (Fagnières)

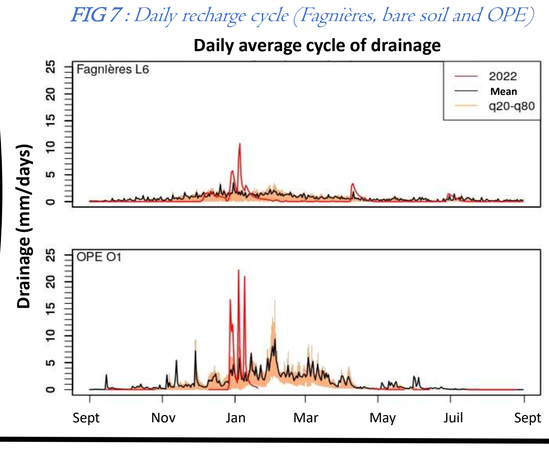


Comparison of cumulative precipitation (dashed lines) and recharge on bare soil (solid lines) over the 5 hydrological drought years (different colors). For the year 2022, we have also highlighted the accumulations for the calendar year (up to December).

- 1976-2019 : Precipitation is higher in 2019, but drainage are identical: Temperature effect + Rain in summer (2019)
- 1991-2022 : Precipitation is identical, but drainage higher in 1991. Temperature + Rain in winter effect
- In 2022, since July, there has been no recharge.

Due to incomplete data, the OPE site cannot be analyzed in detail. However, there is a similar recharge dynamic in 2022 between Fagnière and OPE.

FIG 7 : Daily recharge cycle (Fagnières, bare soil and OPE)



Intense precipitation events

Intense precipitation events are identified as the 99th quantile of the daily precipitation for the rainy days.

FIG 8 : Characterization of an intense precipitation event and drainage associated

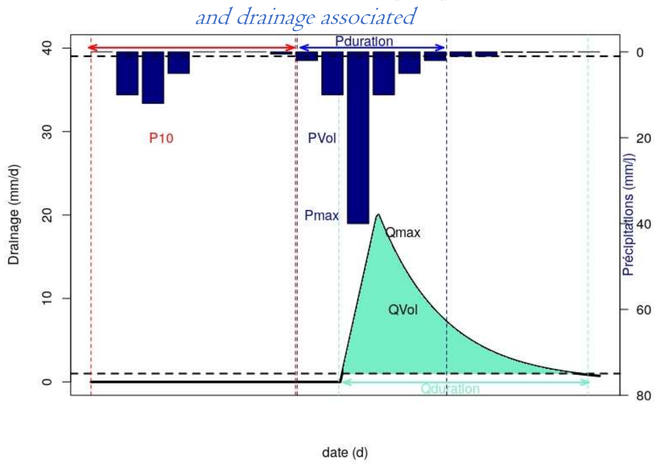
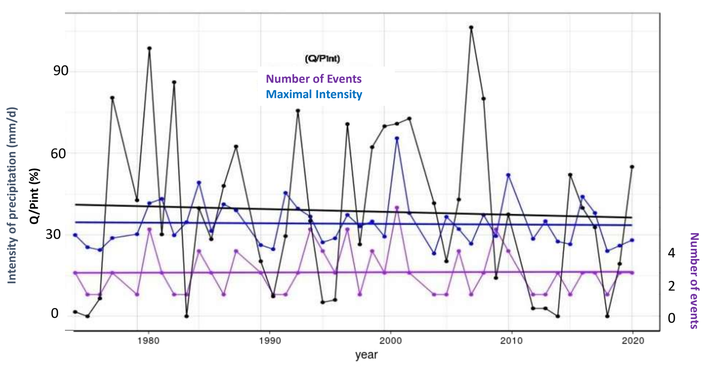


FIG 9 : Evolution of the intense precipitation events

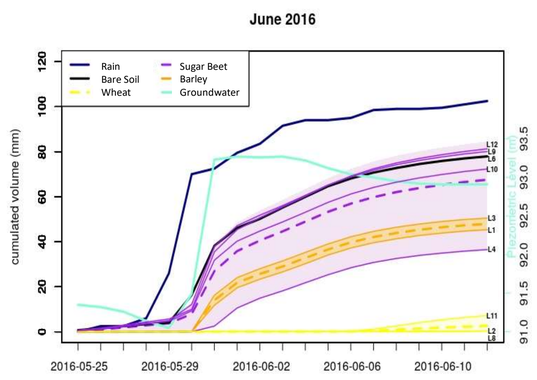


Between late May and mid-June 2016, France, Germany and parts of Europe were affected by exceptional rainfall and heavy flooding.

At the Fagnières site:

- This event lasted 8 days, with a cumulative rainfall of 91.5 mm. The maximum daily intensity was 44 mm.d−1 on the 30 May.
- Drainage varies according to land cover. For all land uses except wheat, maximum daily drainage occurs the day after maximum rainfall. Cumulative drained volumes are relatively similar for bare soil and beet. They are reduced by 6 mm for sugar beet, 32 mm for barley, and no present for wheat.
- This dynamic is similar to that observed in the nearest groundwater aquifer with a very rapid rise in the water table on 31 May (+2.27 m).

FIG 10 : Precipitation and associated drainage in June 2016 on Fagnières according to the vegetation present



To identifying the genesis of a strong reaction after an intense precipitation event, MRTs are used for each lysimeter and each period. For such analysis, it is considered that a strong reaction of the event is with a recharge reaching 30 mm, which corresponds to the 90th quantile of volume drained during intense events.

As an example, a MRT for a W-S-B rotation is presented. A MRT should be read from top to bottom. It shows the explanatory variables that correspond to the limiting factors, with their conditions and the groups of response variables, with their associated mean values in each group of the tree.

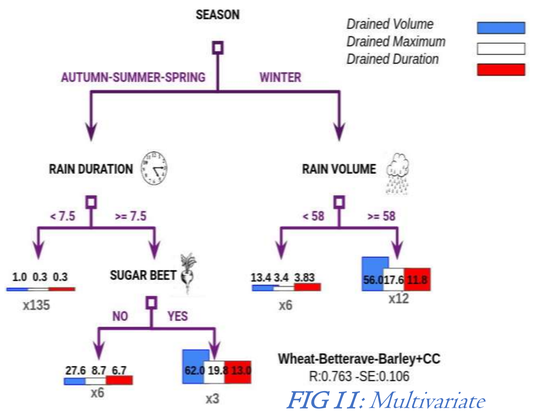
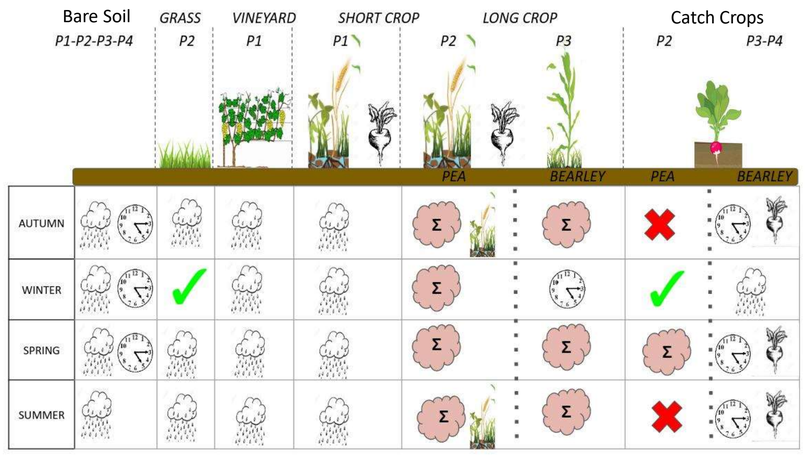


FIG 11: Multivariate regression tree (MRT) for a W-S-B rotation



TAB 2 : Summary of conditions obtained by MRT to obtain high drainage volumes (>30 mm) for each cover during intense precipitation events.

By applying these MRTs to all the soil covers. The conditions for a strong reaction in terms of drainage vary with the soil cover and the season.

Conclusion : Lysimeters enable real-time observation and anticipation if the risks associated with intense events, and can help for management and forecast purposes. It is therefore essential to develop a European lysimeter network.

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