Integrated assessment of groundwater – surface water exchange in the hillslope – riparian interface of a montane catchment

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Introduction

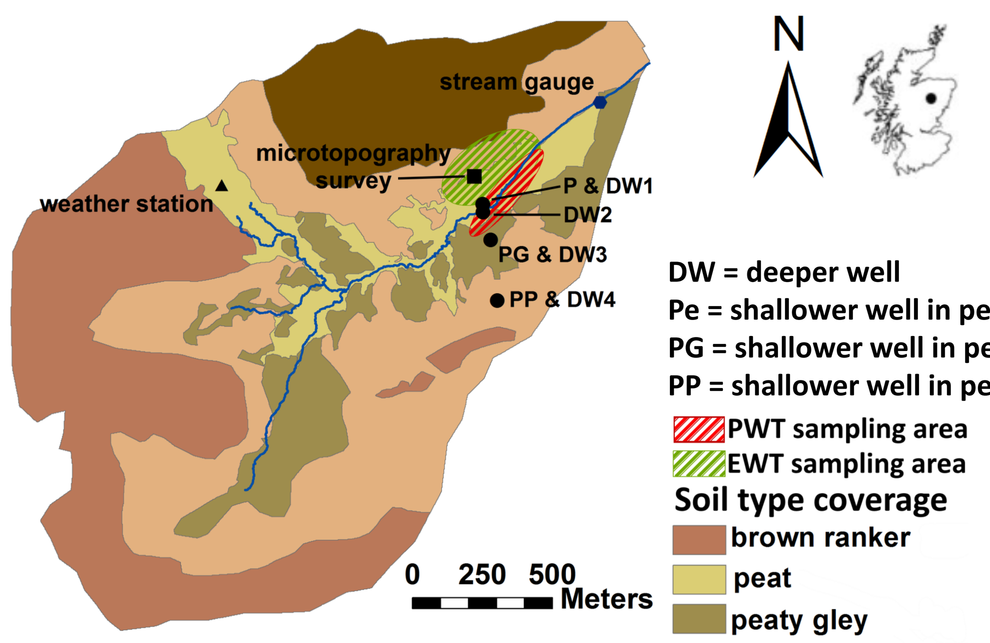
Stream flow generation and the dynamics of riparian saturation are dependen on groundwater - surface water interactions at different spatial and temporal scales. Researching either system separately in connection with the processes above, would not be adequate for the complexity their interlinkages imply. The transition between the hillslopes and riparian zone forms a critical interface for groundwater-surface water interactions which makes it an ideal location for integrated studies using different observational methods.

Objectives

- Identify the dominant controls and the dynamics of hydrological connections between the hillslope and the riparian zone
- Assess the role of micro-topography landscape features on shallow groundwater dynamics in the riparian area
- Use isotopic tracers to differentiate recharge sources as well as quantify how groundwater dynamics affect stream flow

Study Site and Methods

Bruntland Burn catchment, Cairngorm National Park, Scotland UK

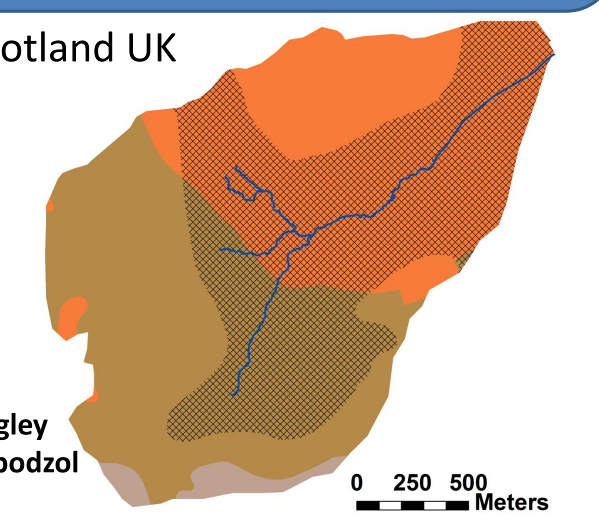


DW = deeper well
Pe = shallower well in peat
PG = shallower well in peaty gley
PP = shallower well in peaty podzol

PWT sampling area
EWT sampling area

Soil type coverage
- brown ranker
- peat
- peaty gley
- peaty podzol
- peaty ranker

Figure 1: Soil distribution within the catchment and equipment locations



- Drift deposit
- Granite
- Ca-rich metasediment
- Si-rich metasediment

Figure 2: Bedrock geology map and drift deposit extend(shaded)

- 3.2 km², 248 – 539 m.a.s.l.
- P ~ 1100 mm/a, Low ET ~ 400 mm/a
- 50% of P events < 10 mm; 75% < 20 mm
- High resolution monitoring of hydrometric components on 15 minutes basis: precipitation, discharge and groundwater components
- 7 wells monitoring the shallower and deeper groundwater along the Hillslope - riparian interface transect; the deeper wells reach into the drift deposit and the shallower wells reach up to a meter in the ground (Fig. 3)
- 10 shallower wells installed in different small scale landscape feature (ridges, pools; Fig. 4)
- Isotopic analysis of the hydrometric components grouped in precipitation, surface water and groundwater
- Surface water sample include daily sample of stream water and perennial water tracks and event based sample of ephemeral water tracks; monthly groundwater samples encloses samples from the deeper & shallower wells

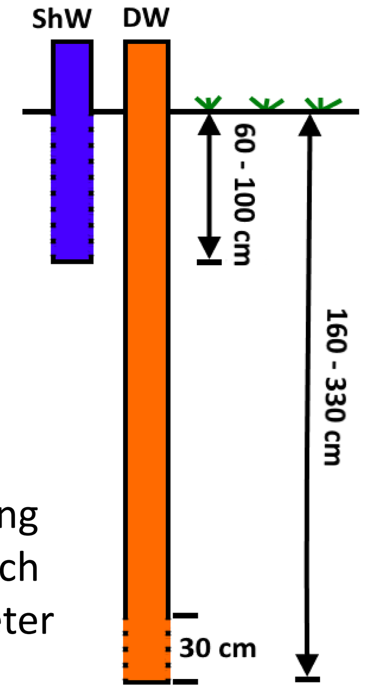


Figure 3: depth reach of the shallower wells (ShW) & deeper wells (DW) install for the micro-topography survey and the along the hillslope – riparian interface transect

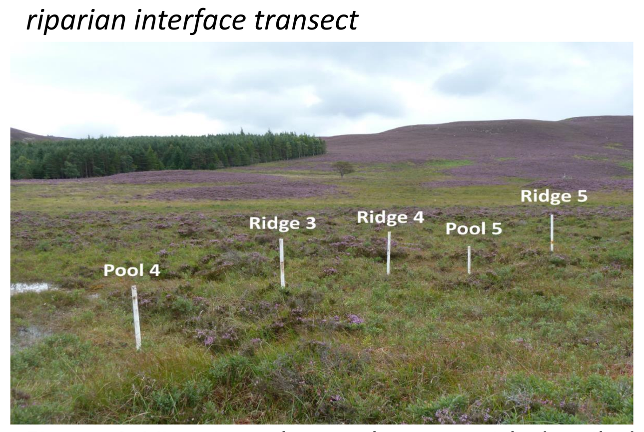


Figure 4: View into the catchment, with detailed equipment of micro-topography survey

Results

Hydrometric Dynamics

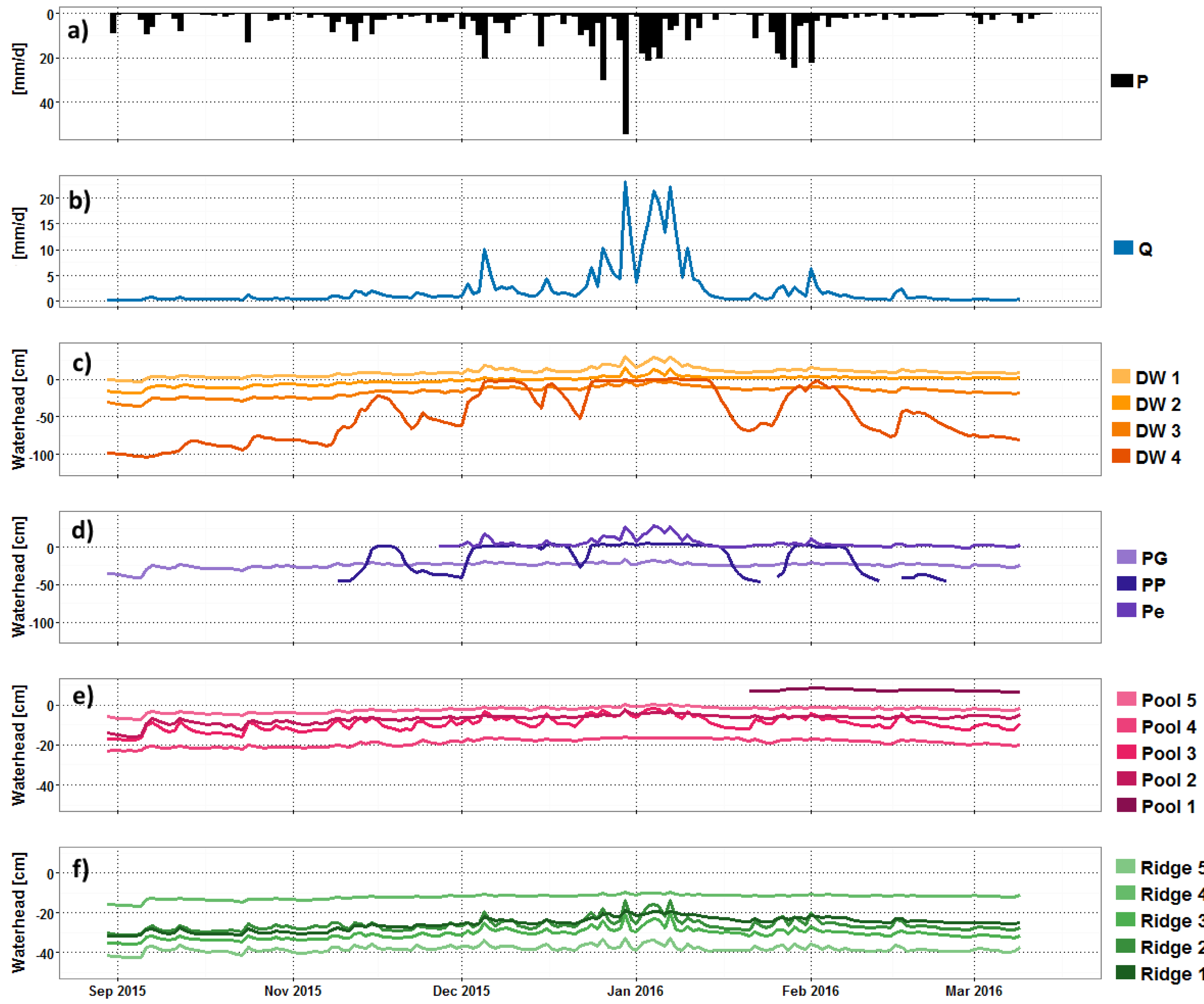


Figure 5: a) Precipitation (P), b) Discharge (Q), dynamics of the groundwater level along the hillslope in the c) deeper wells (DW 1 – DW 4) and d) shallower wells (Pe, PP, PG) as well as dynamics inside e) the pools and f) the ridges of the micro-topography survey

Hillslope – riparian interface

- High groundwater dynamic on the upper regions of the hillslope in peaty podzol and drift deposit (deeper well DW4 & shallower well PP; Fig. 5 c & d)
- Shallower and deeper GW table (DW1, DW2 & Pe; Fig. 5 c & d) in the riparian zone shows a moderate response to large storm events
- GW dynamic in the centre of the hillslope (deeper well DW3 & shallower well PG; Fig. 5 c & d) has a very low variability

Micro-topography survey

- High variability of the shallow groundwater dynamics within most of the ridges (Ridge 1, 2, 3 & 5; Fig. 4 f)
- Majority of the pools have a more stable water level (Pool 1, 2, 4 & 5; Fig. 4 e)

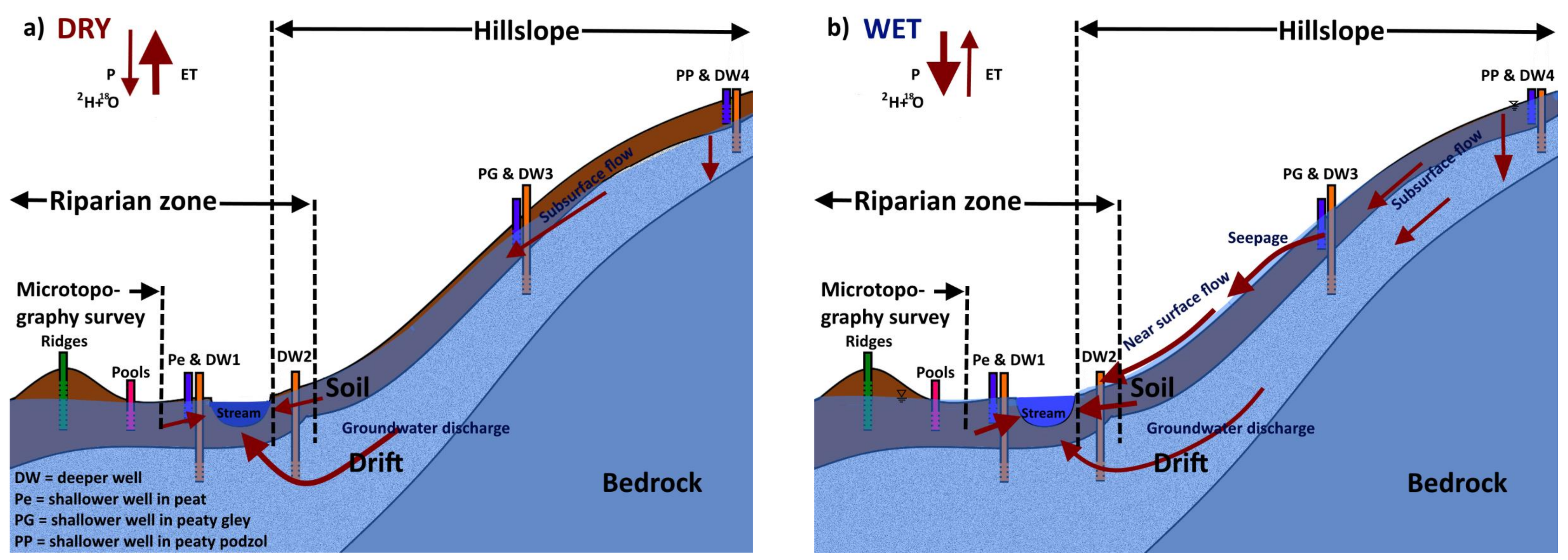


Figure 6: Conceptual scheme of the dynamics in the hillslope, the riparian zone and the area of the micro-topography survey under a) dry and b) wet conditions

Isotopic Dynamics

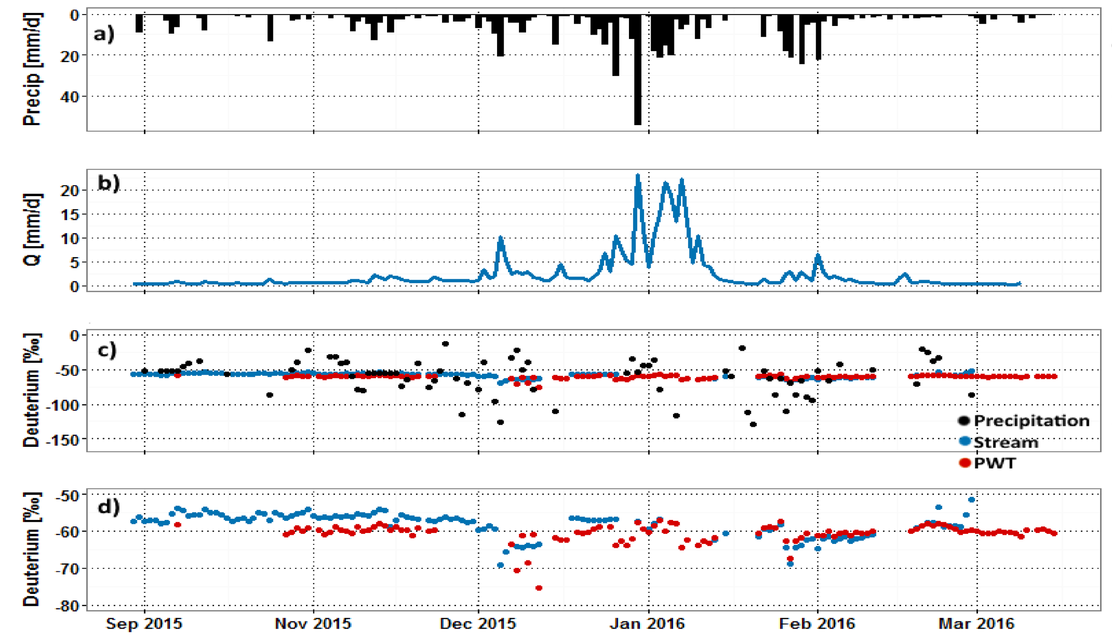


Figure 7: a) Precipitation; b) Discharge; c) Deuterium signal of the precipitation, of the stream water (SW) at the outlet of the catchment and of a perennial water track (PWT); d) Detailed display of the SW and PWT deuterium signal

Surface water

- Stream water generally tends to be more enriched in deuterium than water from the perennial water tracks (Fig. 8 (right) d & e)
- After larger storm events the stream water is more depleted (Fig. 7 a, b & c)
- Ephemeral water tracks display the largest depletion in deuterium (Fig. 8 (right) d, e & f)

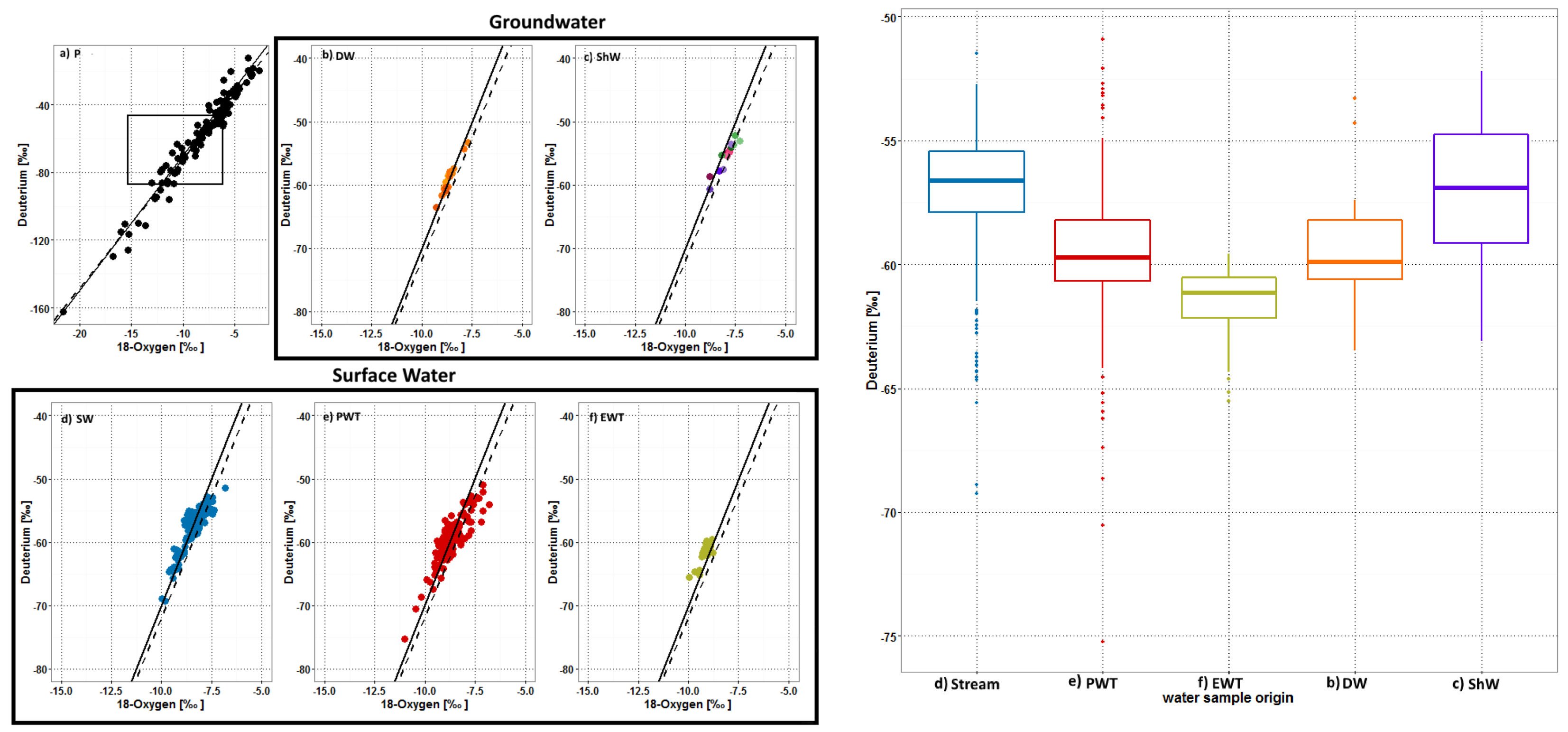


Figure 8: (left) Deuterium and 18-Oxygen distribution of the different water sources in the catchment: a) Precipitation (P), b) Deeper wells (DW), c) Shallower wells (ShW), d) Stream water (SW), e) Perennial water tracks (PWT), f) Ephemeral water tracks (EWT); (right) Deuterium distribution of the different sampling locations

Groundwater

- Water from shallower wells shows a higher variability in their deuterium value than samples from deeper wells (Fig. 8 (right) b & c)
- Deeper groundwater is more likely to be depleted in deuterium than from the shallower groundwater

Conclusions

- Deeper and shallower groundwater exhibit similar responses to storm events in each location along the hillslope – riparian zone transect which suggest that they might be governed by similar controls
- Small scale elevation and geometry differences may explain the stronger responses of the shallow groundwater table in ridges to storm events compared to pools
- Difference in the isotopes signals between shallower and deeper groundwater could be explained by stronger fractionation process in the near surface area of the soil

Future work

- Further investigating the groundwater-surface water interactions during wet and dry periods
- Detailed assessment of the driving factors and differences between the small landscape feature
- Using additional tracers to further to differentiate water sources and quantify related processes

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