Deuterium labeling of soil water movement in the Cuvelai-Etosha Basin, Namibia

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1. Motivation & Objectives

Water movement in the unsaturated zone, where a complex interaction of climate, vegetation, soil type and geology is present, is yet not fully understood. The stable isotopes deuterium (^2H) and oxygen-18 (^{18}O) have been shown suitable for such investigations and a description of related processes within the unsaturated zone. In this study, a field experiment using deuterated water as an artificial tracer (^2H_2O, 70%) was conducted to characterize water movement during and after synthetic rain events.

Main research questions addressed are:

- description of water and ^2H movement at two differing sites after a rain event of known amount and intensity
- identification and interpretation of important processes within the unsaturated zone (deep drainage, root water uptake, hydraulic redistribution, preferential flow)
- determination of potential for local groundwater recharge at investigated sites

2. Methodology

Fig. 1: Application of deuterated water at 25 cm depth

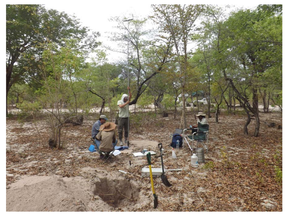

Fig. 2: Soil sampling at Eenhana forest site

1. Selection of study sites with focus on different hydraulic and morphological characteristics: a) deep sandy soil (Fig. 4) and b) sandy loam underlain by calcrete layer (Fig. 5)
2. Pre – saturation of soils → triggering of rainy-season condition
3. Application of ~2 mm (500ml) deuterated water at 25 cm depth (Fig. 1)
4. Re – filling of soil; Artificial rain event of ~20 mm
5. Collection of soil samples at each 10 cm to a maximum depth of 2.5 m after 1 d, 2 d (not shown here), 5 d and 10 d, respectively (Fig. 2)
6. Cryogenic vacuum extraction of soil water (Koeniger et al., 2010)
7. Determination of ^2H using a Thermo Finnigan Delta Plus IRMS connected to H – device
8. Lab analysis of grain size distribution, soil water content and soil hydraulic properties

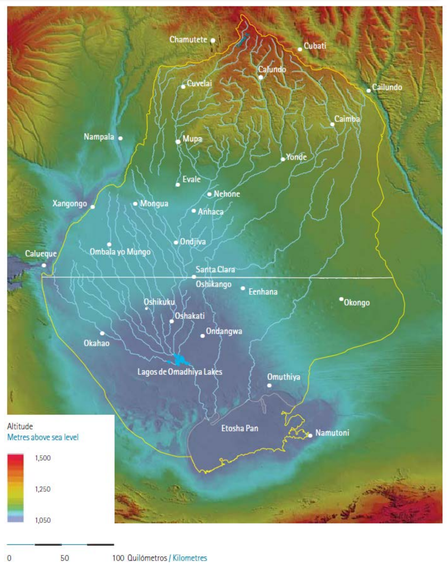

Fig. 3: Cuvelai-Etosha Basin has a size of 97600 km³ and is shared almost equally by Namibia and Angola. Climate is characterized as semiarid with a high variability (Mendelsohn et al., 2013)

3. Results

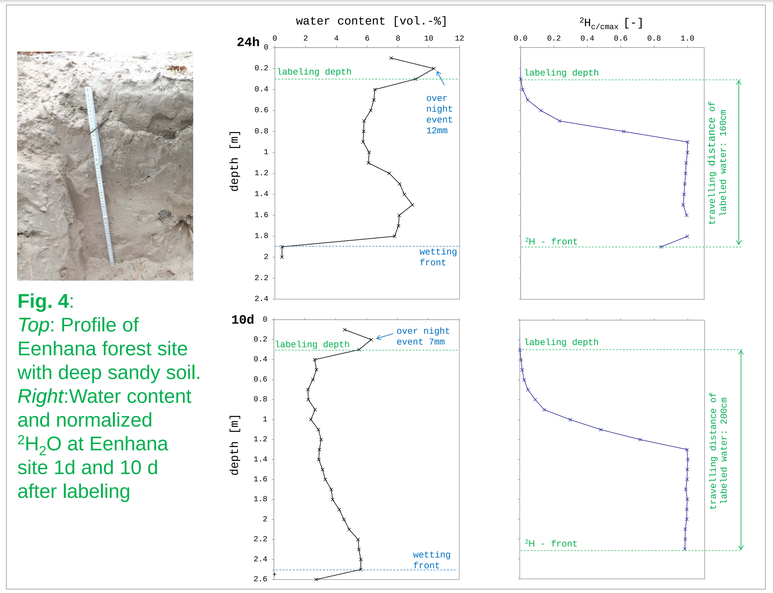

Fig. 4:
Top: Profile of Eenhana forest site with deep sandy soil.
Right:Water content and normalized ^2H_2O at Eenhana site 1d and 10 d after labeling

- clear shift of ^2H - peak
- very high hydraulic conductivity (ks~1,700 cm/d)
- no upward water movement of labeled water identified at Eenhana
- water movement up to depth, where no evaporation is expected (2.4 m after 10 d) → potential groundwater recharge area

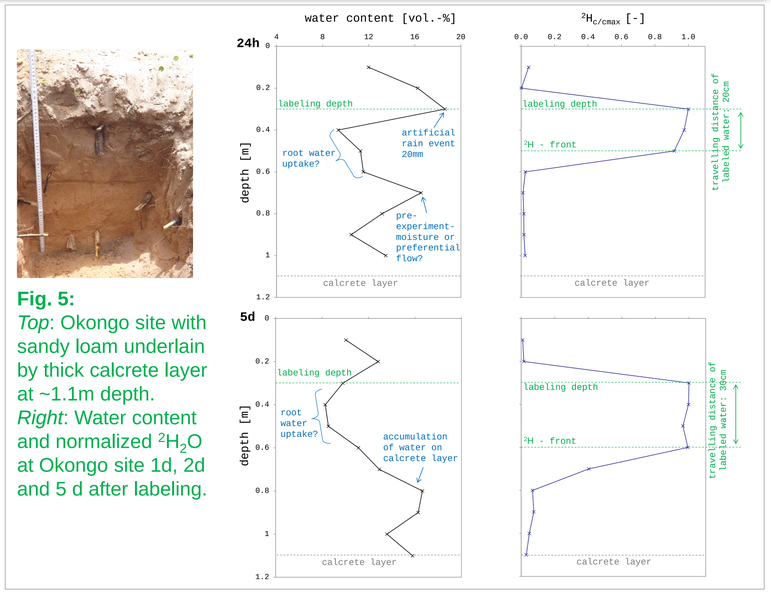

Fig. 5:
Top: Okongo site with sandy loam underlain by thick calcrete layer at ~1.1m depth.
Right: Water content and normalized ^2H_2O at Okongo site 1d, 2d and 5 d after labeling.

- less pronounced shift of tracer peak
- upward water movement of tracer observed (upper 30 cm)
- high hydraulic conductivity at upper horizon (ks~1,000 cm/d)
- accumulation of water on top of impermeable calcrete available for plants and evaporation → if recharge, then through cracks/fissures

4. Discussion & Outlook

- study serves as pre-experiment for infiltration behavior
- investigation provides indicators for existence of preferential flow paths and areas of main root activity
- main purpose of investigation will be answered after deep sampling (>5 m) campaign after rainy season :
  Can ^2H be found after rainy season?
  → indicator for GW recharge
- role of deep roots yet unclear
  → modification of experimental setup planned
- investigation of thresholds for recharge events or situations (extreme events, wet spells,…) → modeling studies

References

Koeniger, P., Leibundgut, C., Link, T., Marshall, J.D., 2010. *Stable isotopes applied as water tracers in column and field studies*. Organic Geochemistry 41, 31–40.
Mendelsohn, J. M., Jarvis, A., & Robertson, T., 2013. *A profile and Atlas of the Cuvelai-Etosha basin*. RAISON & Gondwana Collection, Windhoek, Namibia, 170p.

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