Effects of Conservation Soil Water Management Practices on Soil Moisture Dynamics across Growth Stages and Soil Depths in Rainfed Maize

16 – 18 September, Gottingen/Kassel

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Introduction

Rainfed maize productivity is increasingly constrained by climate-driven rainfall variability and soil moisture deficits (Zizinga et al., 2026). However, the mechanisms through which conservation soil water management practices (CSWMPs) regulate soil moisture across crop growth stages and soil depths remain poorly understood. This study quantifies dynamics to improve water productivity and strengthen climate resilience in rainfed maize

Objectives

1. To quantify soil moisture dynamics across maize growth stages and soil depths under contrasting CSWMPs.
2. To evaluate the effects of CSWMPs on soil water retention, water use efficiency, and maize productivity.
3. To Identify the key soil hydraulic and phenological factors regulating root-zone soil moisture under variable rainfall conditions.

Fig 1. Soil water monitoting for three seasons

Conclusion

- CSWMPs significantly improved soil moisture retention across maize growth stages and soil depths compared with conventional tillage.
- HM, M, and PPB enhanced root-zone water storage, increased grain yield (up to 8.23 t ha⁻¹) and improved water use efficiency (up to 17.65 kg ha⁻¹ mm⁻¹) without increasing evapotranspiration.
- Soil moisture dynamics were primarily regulated by crop growth stage, soil water storage, and soil hydraulic properties, highlighting the importance of integrating CSWMPs into climate-resilient rainfed maize production

Outlook

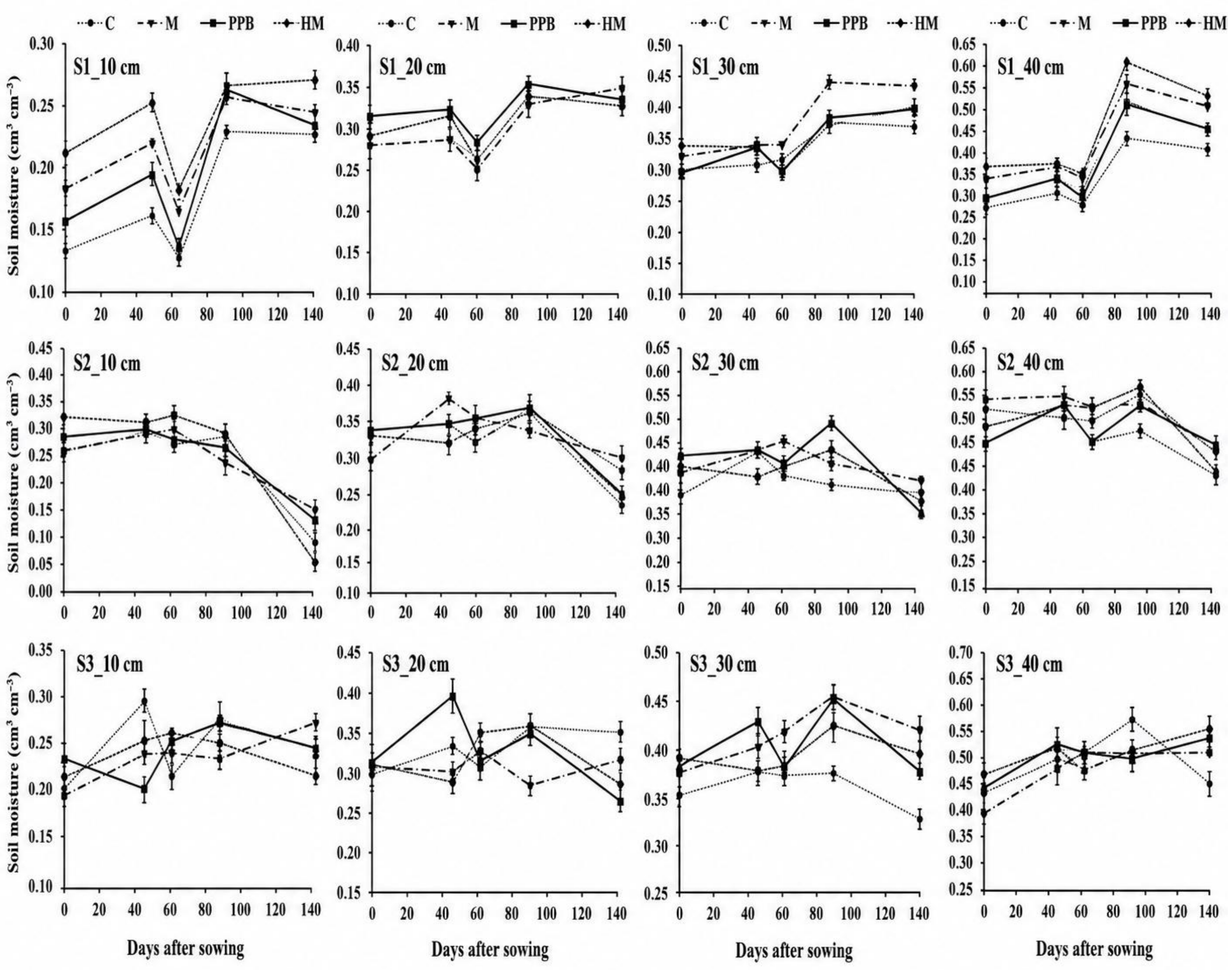
➤ Promote CSWMPs as scalable climate-smart technologies and evaluate their long-term performance across diverse agroecological zones under future climate variability.

Material and Methods

A three-season field experiment was conducted in a rainfed maize system at Bulindi, mid-western Uganda using a Randomized Complete Block Design experiment with four treatments: conventional tillage (C), straw mulch (M), half-moon pits (HM), and permanent planting basins (PPB), each replicated five times. Volumetric soil moisture was monitored at 0-40 cm depth using calibrated Frequency Domain Reflectometry probes across the maize growth stages. Soil water storage, available water, evapotranspiration, water use efficiency, grain yield, and soil physical properties were quantified. The treatment effects were evaluated using two-way ANOVA and Linear Mixed effects models to determine the influence CSWMPs, soil depth, and crop phenology on soil moisture dynamics.

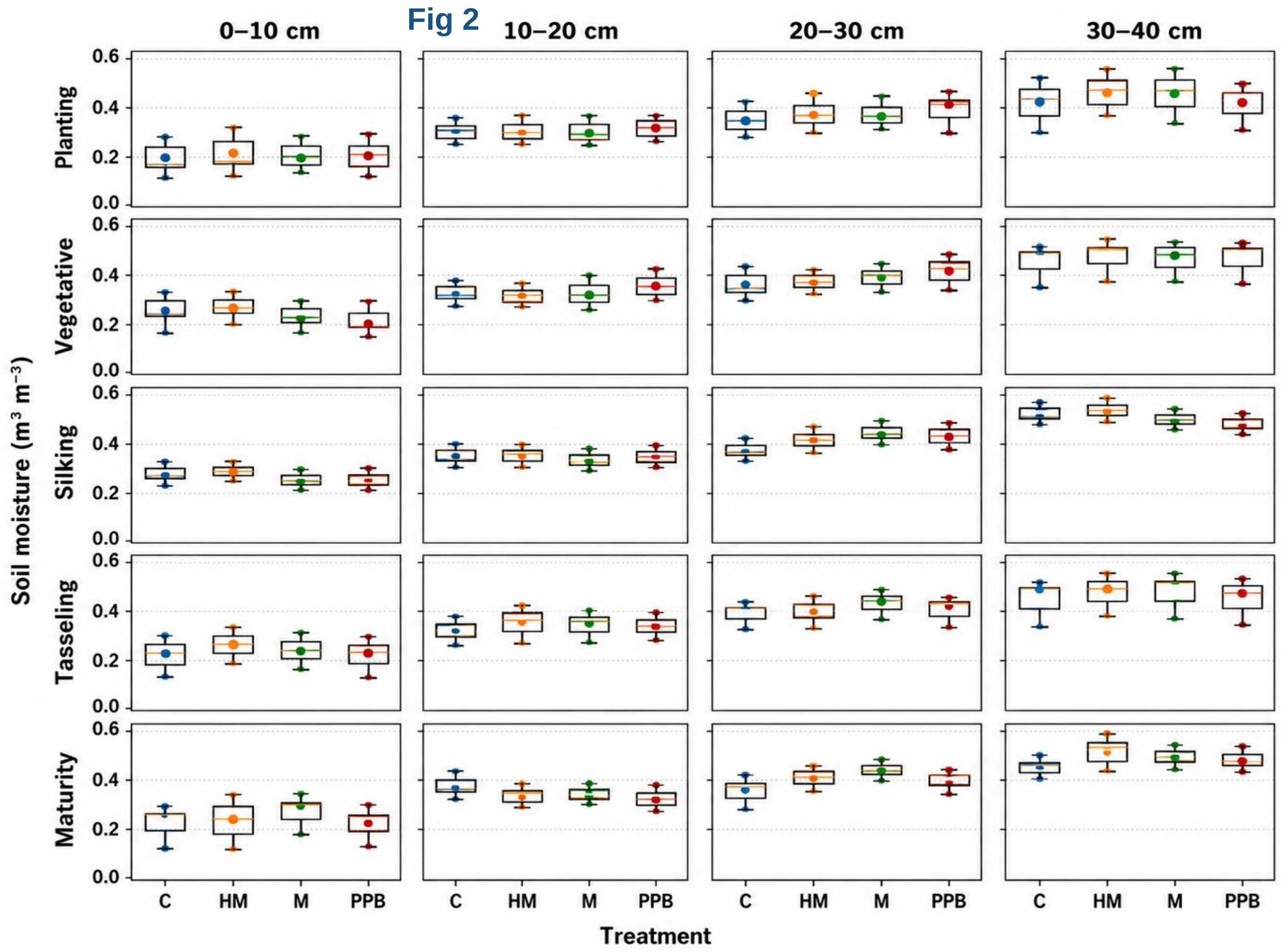
Results and Discussion

Fig 3



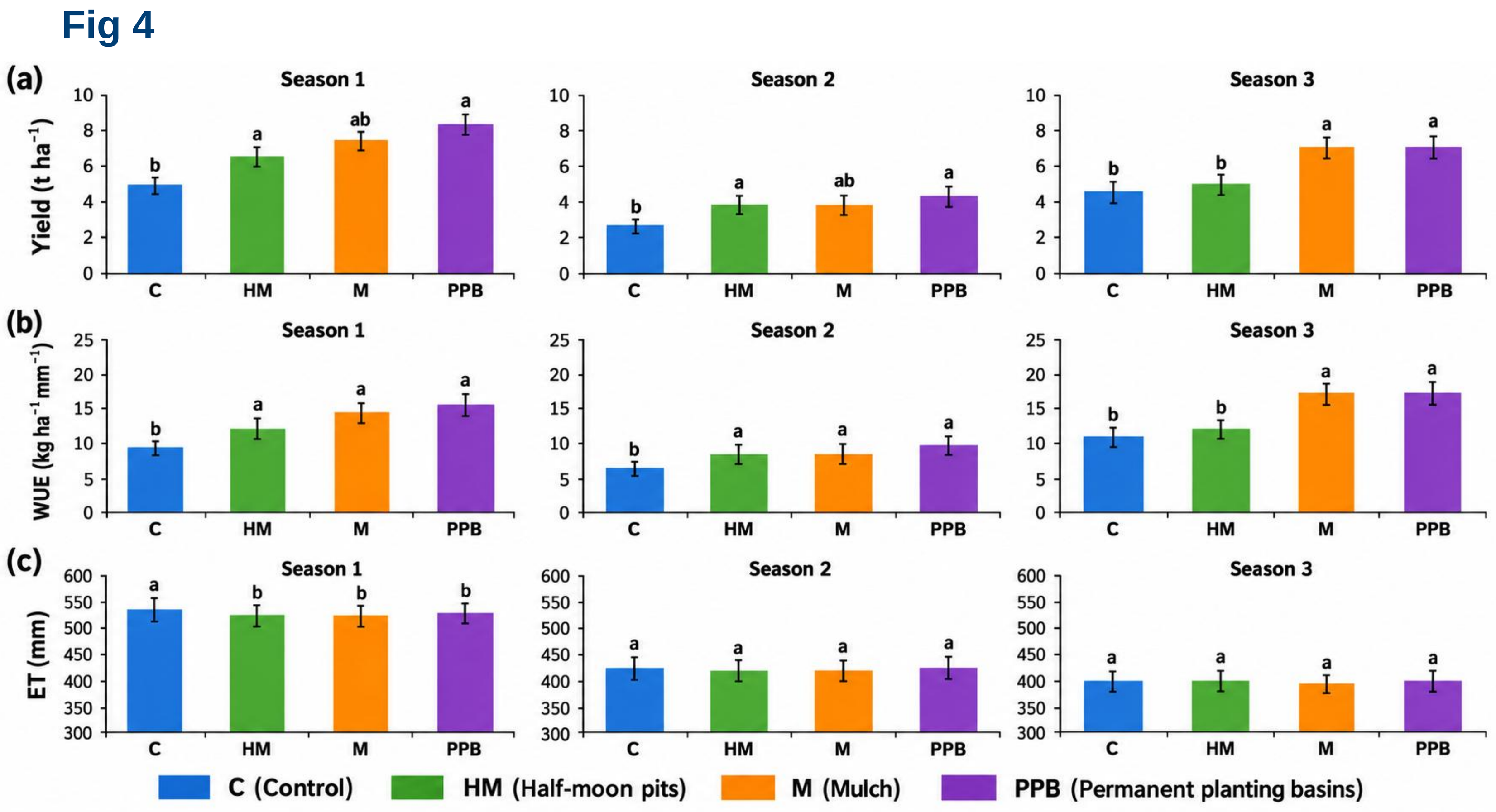
- **Fig 3:** Soil moisture differed significantly among CSWMPs, crop growth stages, and seasons ($p \leq 0.05$).
- HM, PPB, and M consistently maintained higher soil moisture than the C, particularly during tasseling and silking growth stages.
- ➤ **Discussion:** CSWMPs enhanced root-zone water storage and buffered crops against rainfall variability during critical reproductive stages, improving drought resilience.

Fig 2



- **Fig 2:** Soil moisture increased with depth, with the highest values at 30-40 cm and greatest variability in the surface layer (0 – 10 cm).
- CSWMPs significantly increased moisture retention in the 20 – 40 cm rooting zone across all seasons ($p < 0.05$).
- ➤ **Discussion**: Improved infiltration and reduced evaporation under CSWMPs enabled deeper water storage, ensuring sustained moisture supply during crop development.

Fig 4



- **Fig 4:** M and PPB produced the highest grain yields (up to 8.23 t ha⁻¹) and water use efficiency (up to 17.65 kg ha⁻¹ mm⁻¹).
- Evapotranspiration remained statistically similar across treatments, indicating yield gains were achieved without increasing water consumption.
- ➤ **Discussion:** CSWMPs improved the partitioning of available water into productive transpiration rather than increasing total water use, resulting in higher apparent water productivity and climate resilience.

Reference

Zizinga, A., Mwanjalolo, J. G. M., Pathak, H., Katusiime, J., Bedadi, B., & Tietjen, B. (2026). Effects of conservation soil water management practices on soil moisture dynamics across growth stages and soil depths in rainfed maize. Ecohydrology & Hydrobiology, 26(4), 100789. https://doi.org/10.1016/j.ecohyd.2026.100789

Acknowledgement

Funding from Agroecosystem 4CSA initiative