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Understanding spatial and temporal functioning of temporary storage areas to improve their flood mitigation effectiveness

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Temporary Storage Areas (TSAs), such as bunds, offline ponds and leaky barriers represent a nature-based solution that can offer additional storage during storm events. They are designed to intercept and attenuate surface runoff, thereby addressing various catchment challenges, including flooding, water scarcity, and soil erosion. Soil infiltration is a key TSA outflow, particularly for more common small to medium storm events, meaning TSA functioning may vary between sites with different soil properties and be time-variable due to the dynamic nature of soil structure. The lack of understanding of TSA functioning in space and time represents a major knowledge gap and acts as a limiting factor for the widespread implementation of TSAs. To address these challenges, there is a need for a TSA analysis approach that allows for the systematic evaluation of TSA functioning. The overall aim of this study was to enhance understanding of TSA functioning and explore variability in functioning with space and time. Specifically, the objectives were to: (i) develop a systematic data-based method for characterising the functioning of various TSA types; and (ii) assess the effect of spatial and temporal soil variability on TSA functioning and flood mitigation effectiveness.

Here we present the TSA Drainage Rate Analysis tool (TSA-DRA tool), a new data-based mechanistic approach that utilises only rainfall and water level to characterise drainage of individual TSAs. Results from a multi-site TSA assessment in the UK revealed time-variable functioning, especially at lower levels when soil infiltration is the dominant outflow. We explored this further by assessing changes in soil physical properties (bulk density, macroporosity and saturated hydraulic conductivity) at two TSA sites. These sites shared the same TSA type (bund) and had similar volumes (~250 m^3) and soils (Cambisols). However, they differed in land use (winter wheat vs spring barley and blackcurrants) and TSA surface area (800 m^2 vs 2800 m^2). Soil cores were taken across three spatial zones: (1) TSA active zone (<10% full) – inundated for the longest time; (2) full zone (>50% full) – active during large storms; and (3) Field zone – field control points outside the wetted footprint. This assessment was then repeated for significant temporal events e.g., post-harvest, growing season and post-flood. Results show significant soil structure variations over time and space, with degradation more pronounced in soils within the TSA wetted footprint due to inundation. While tillage effectively reset topsoil structure at one site, its impact was negligible at the other site due to variations in land management, coupled with high sedimentation post-flooding, altering near-surface soil texture. Results from a modelling exercise suggest that well-structured soils with higher infiltration rates can improve TSA effectiveness during a large storm event by reducing the volume and frequency of overflow compared to a degraded soil. Gaining insights into spatial and temporal variations in TSA functioning is crucial for optimising both current and future TSA designs and maintenance regimes.