# Assessing the time-variable functioning of temporary storage areas in headwater catchments for natural flood management

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## 1. Introduction

Flooding is a pressing problem, but management strategies are currently being expanded to include Nature-based Solutions (NbS).

Read more about TSAs

Small-scale (<10,000 m$^3$) headwater **Temporary Storage Areas (TSAs)** are a type of NbS which create dispersed and new catchment-based storage to mitigate flooding and soil erosion.

Currently there is no systematic approach for characterising TSA functioning, and the oversight of time-variable drainage rates may impact future TSA design and performance.

**Study aim: Assess various TSA types, their individual functioning, explore time-variable drainage rates, and consider implications for local TSA flood mitigation effectiveness.**

**Objectives:**

1. Develop a systematic approach for characterising TSA functioning.
2. Establish whether there are time-variable drainage rates in long-term TSA datasets.
3. Determine if any such time-variable functioning varies across locations or TSA designs.
4. Explore the effect of time-variability on TSA performance during a large storm event.

## 2. Study sites

*Table 1: Summary of TSA dimensions and catchment information.*

| | Tarland (T) | Belford (B) | | Glenlivet (G) | |
|---|---|---|---|---|---|
| TSA name and type | Tarland bund | Belford bund | Belford offline pond | Wooden leaky barrier | Earth leaky barrier |
| TSA storage capacity (m$^3$) | ~200 | ~500 | ~800 | ~0.1 | ~0.2 |
| TSA height (m) | 0.5 | 1 | 1 | 0.35 | 0.5 |
| TSA outlet design | Pipe | Pipe | Leaky wall | Leaky wall and weir notch | None |
| Land use | Arable | Arable and grass | Grass | Heather | Heather |
| Monitoring period | Jul 2015 to Feb 2023 | Feb 2010 to Mar 2011 | Aug 2008 to Mar 2011 | May 2021 to Jul 2023 | May 2021 to Jul 2023 |
| Soil | **WRB:** Cambisols **Drainage:** Free | **WRB:** Stagnosols **Drainage:** Poor | | **WRB:** Podzols / Histosols **Drainage:** Free / Poor | |

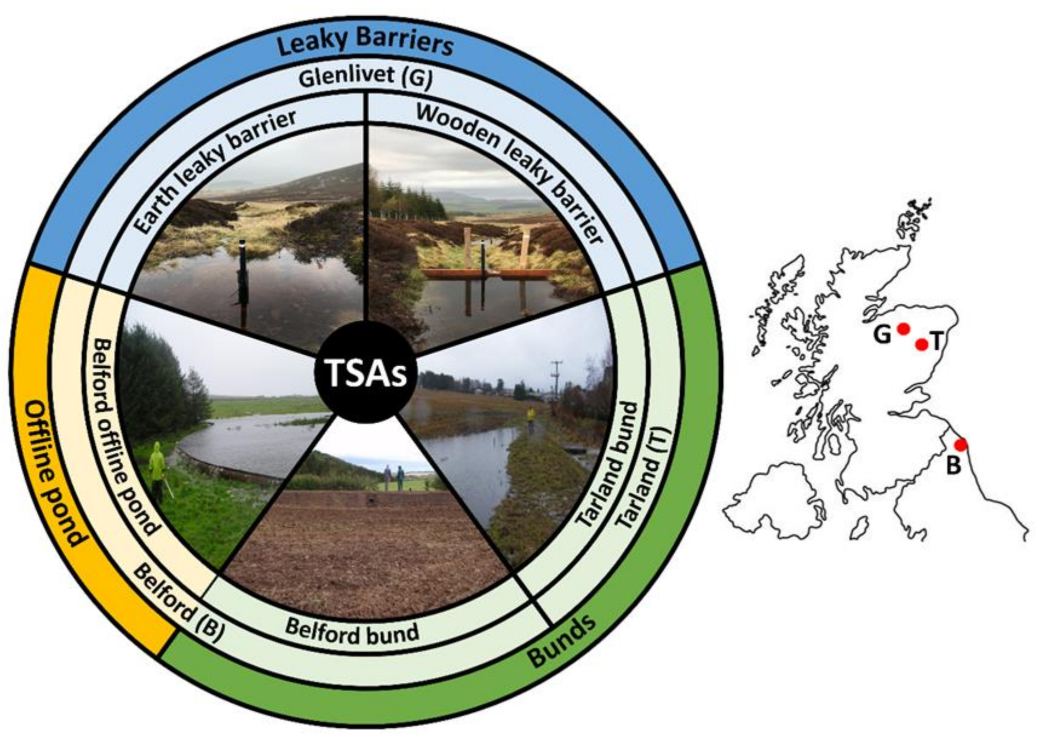



*Figure 1: TSA case studies in the NE of the UK for Belford (B), Glenlivet (G) and Tarland (T).*

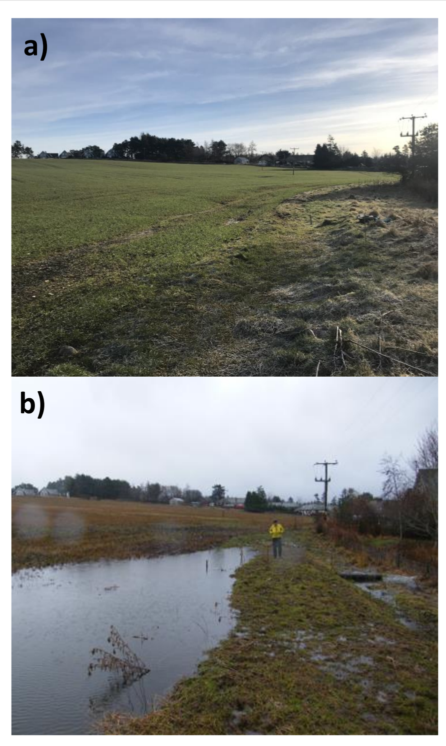
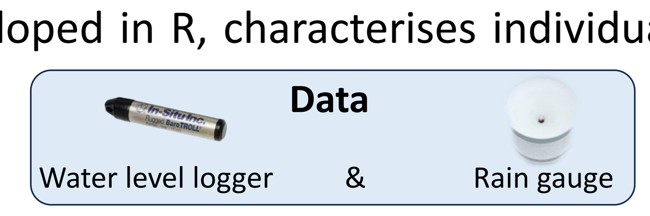



*Figure 2: Tarland bund (200 m$^3$) a) empty, b) full.*

## 3. Data and Methods

The **TSA Drainage Rate Analysis (TSA-DRA) tool,** developed in R, characterises individual TSA functioning using only water level and rainfall data.



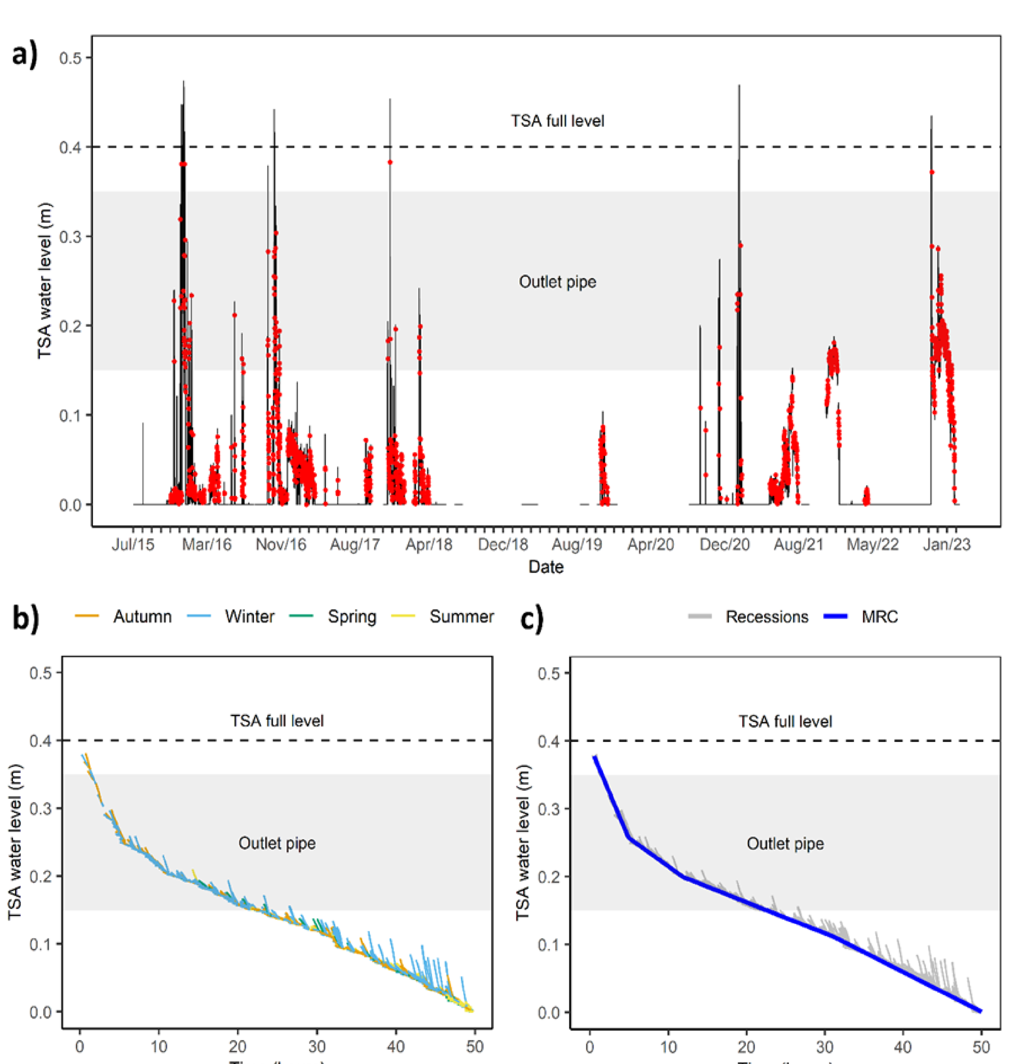




*Figure 3: Example of TSA-DRA tool. a) extraction of recession curves (red dots), b) creation of MRC, c) fitting segmented linear model to describe drainage*

**TSA-DRA tool method:**

**1. Extraction of recession periods** (Fig 3a)

$$Recessions = dL/dt < 0 \,\&\, L < TSA\ full\ level \,\&\, cum.P \leq 0.2 \,\&\, T > 0$$

**dL/dt** = diff in level between time steps.
**L** = TSA level.
**cum.P** = cumulative precipitation
**T** = temperature.

**2. Master recession curve (MRC)** (Fig. 3b)

MRCs overcome the variability of individual recessions by considering several curves over a longer period to describe the drainage rate.

**3. Fitting model to MRC** (Fig. 3c)

A segmented linear model approach was chosen for a simplified and TSA type transferable analysis.

**Time-variable drainage rates**

Overall Seasons Years

## 4. Results

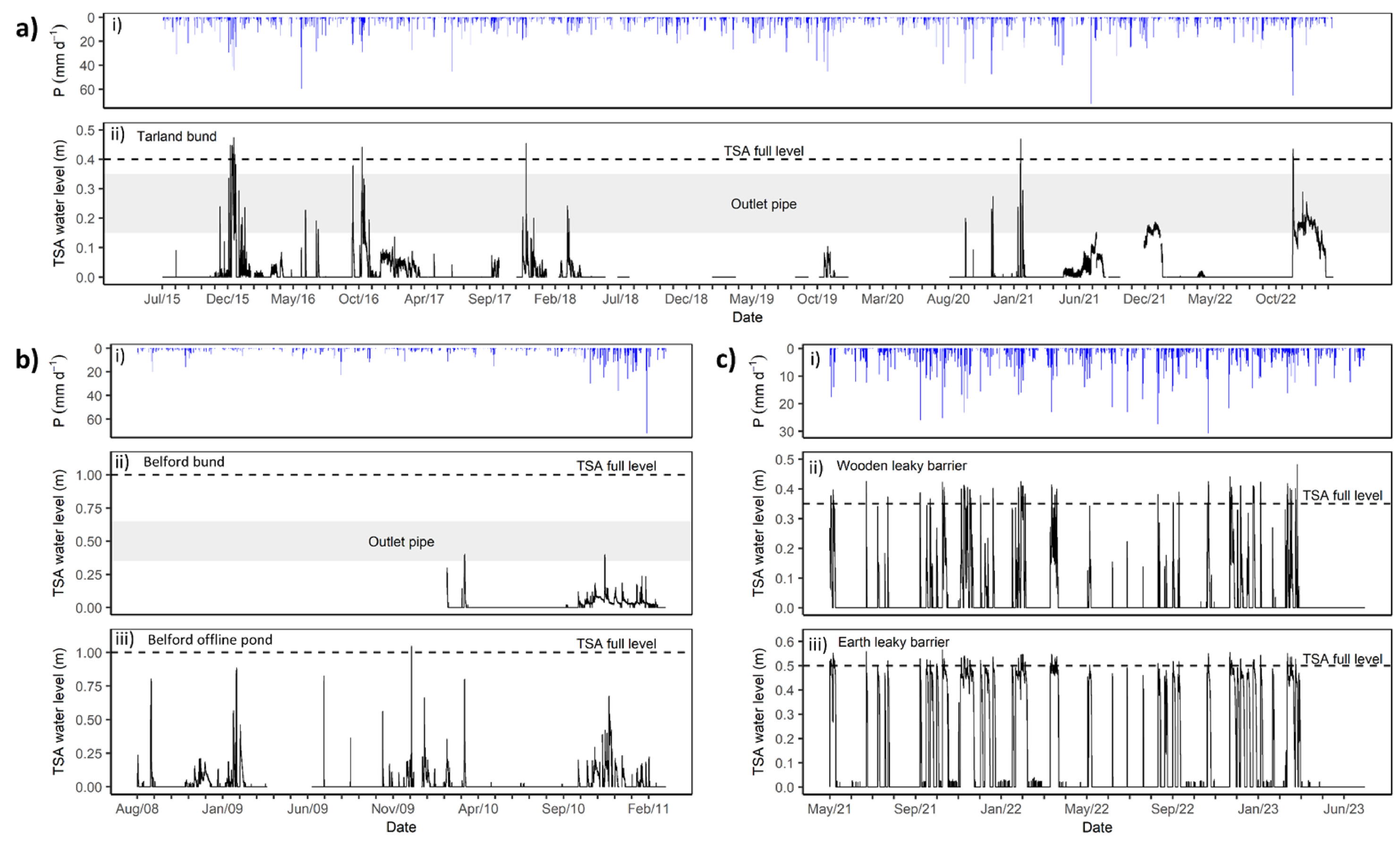



*Figure 4: TSA timeseries data. a) Tarland, b) Belford, c) Glenlivet, i) = precipitation (P), ii - iii) = TSA water level.*

For larger volumed TSAs (Table 1), outlet pipes only become active during extreme events (Fig. 4).

TSA functioning is highly variable due to differences in design (Fig. 5).

Time variability is most noticeable at lower levels (<50%) when soil infiltration is the main outflow (Fig. 5).

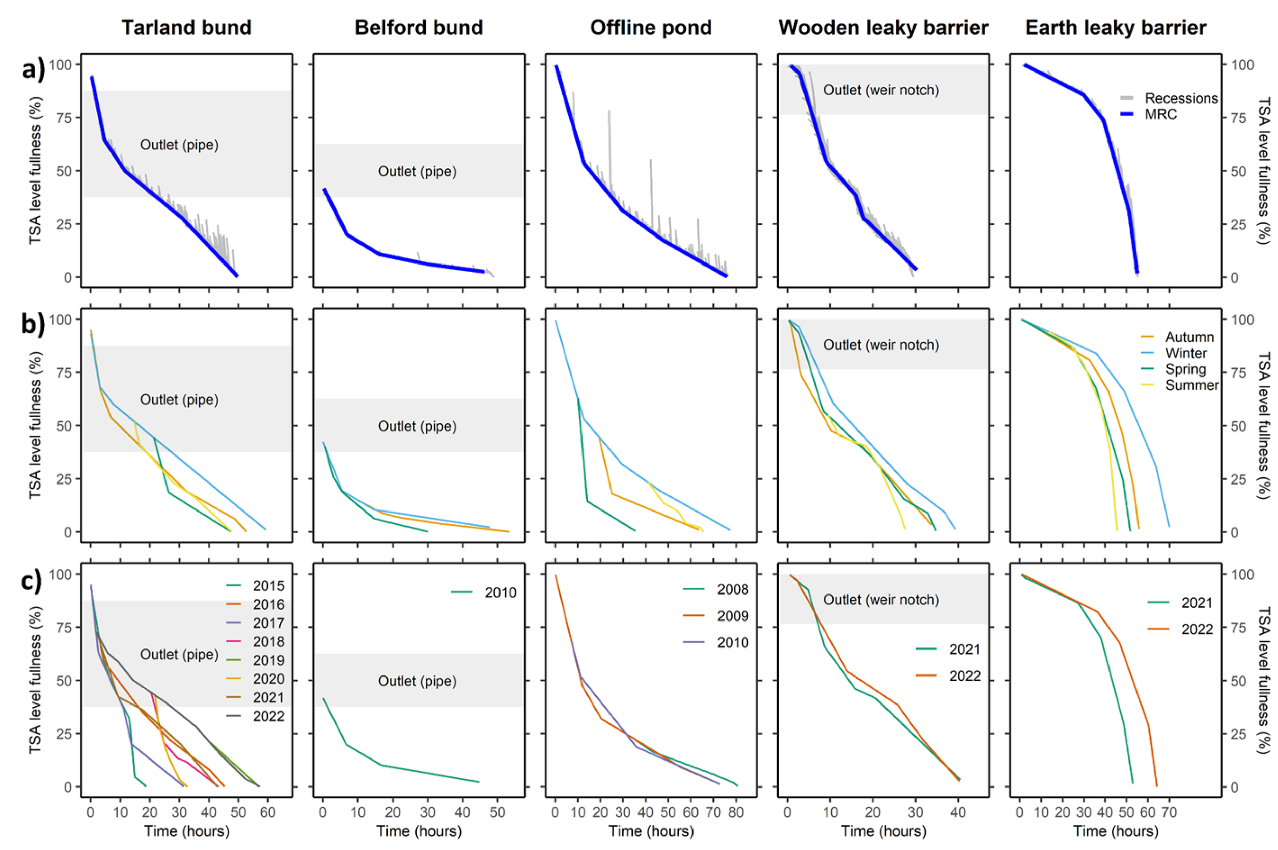
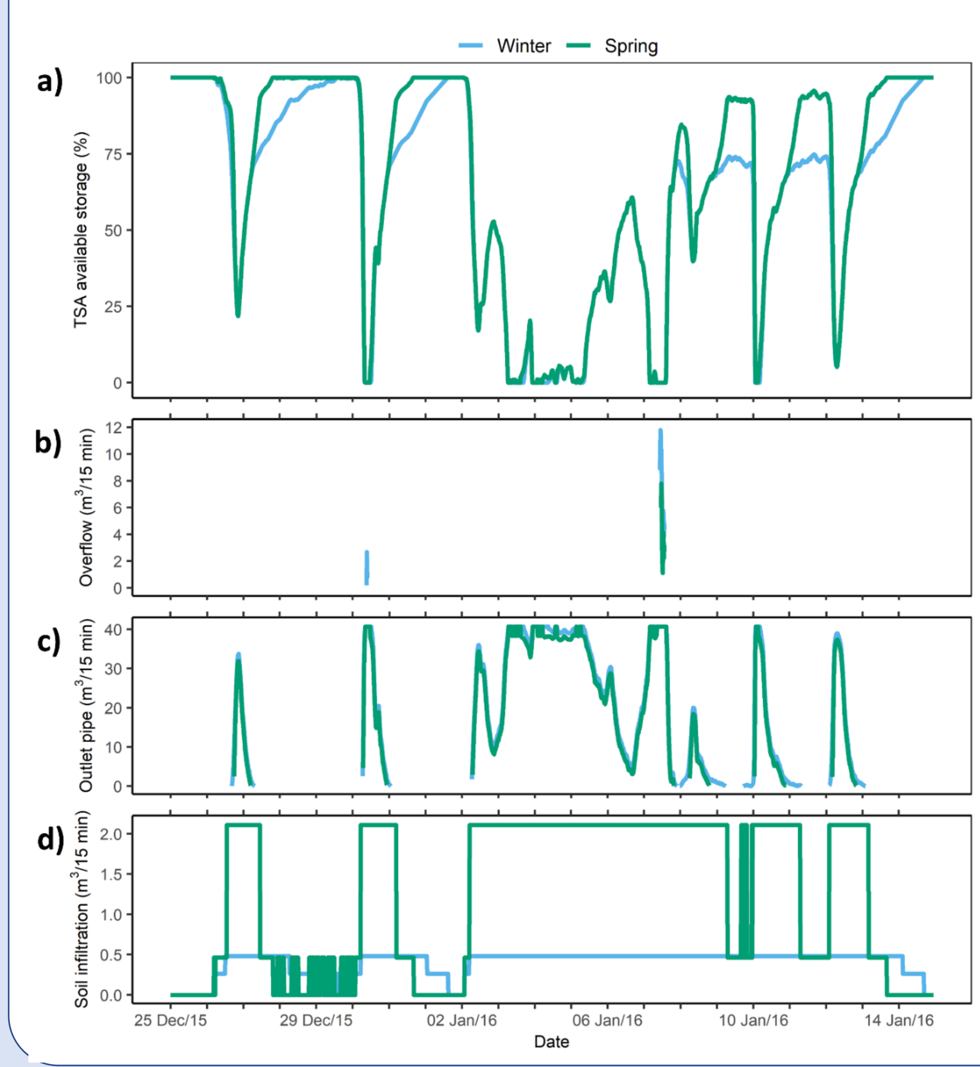



*Figure 5: TSA time-variable MRCs. a) overall, b) seasonal, c) annual.*




The TSA model assesses the effect of time-variable drainage rates on available storage during a large storm event (Fig. 6).

Time-variable soil infiltration can still impact TSA flood mitigation effectiveness during large storm events.

Figure 6b reveals that during spring, the frequency and magnitude of overflow is less compared to winter.

Overflow represents unattenuated flood water.

*Figure 6: Impact of time-variable drainage rates on the Tarland bund's available storage during a large storm event.*

## 5. Discussion and Conclusions

The TSA-DRA tool can be used to systematically characterise drainage rates of different TSAs and reveals various factors that influence TSA drainage rates.

Outlet design is important for maintaining TSA available storage and is the dominant outflow when levels exceed 50% fullness.

Seasonal MRCs identified that TSAs generally drained slowest in winter and quickest in spring (Figure 4b)

Soil is important for TSA functioning, especially at lower TSA levels.

Time-variable differences can be explained by temporal changes in soil structure, which is influenced by factors such as major weather events, tillage, or biological activity.

Frequent and prolonged inundation can reduce soil infiltration rates due to soil structural degradation and erosional deposits.

Periodic tillage at Tarland was found to mitigate the impact of inundation on soil infiltration rates over time.

**Future work will explore the soil processes that cause time-variable TSA functioning.**

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