Street-Scale Monitoring of Trees and SuDS Planters for Urban Flood Reduction

Surveillance à l'échelle de la rue des arbres et SuDS des bacs pour la réduction des inondations urbaines

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RÉSUMÉ

Face à des pluies plus intenses et fréquentes, les systèmes de drainage traditionnels peinent à fonctionner, entraînant des inondations de surface. Pour remédier à ce problème, des systèmes de drainage durable peuvent ralentir l'écoulement de l'eau provenant du toit. Des capteurs montrent que le système redistribue l'eau progressivement, ce qui aide le drainage traditionnel à absorber les variations de débit, grâce à ses couches internes qui freinent l'écoulement. Des arbres peuvent aussi être intégrés dans les espaces urbains pour contribuer à la gestion de l'eau tout en offrant de nombreux avantages à la communauté. Les besoins hydriques des arbres et les interactions sol–arbre–atmosphère sont étudiés dans une campagne de suivi menée à Newcastle upon Tyne, au Royaume-Uni, à l'aide de débitmètres de sève, de capteurs d'humidité du sol et de stations météorologiques. Le projet, initialement limité à un essai préliminaire (arbre planté dans un jardin de pluie), s'étend maintenant à d'autres sites afin d'étudier l'effet de la maturité, de l'espèce et du contexte des arbres. Des recommandations basées sur des données aideront ensuite à mieux intégrer arbres et systèmes de drainage durable pour réduire les inondations de surface. Cette recherche ouvre la voie à des projets de verdissement urbain où la nature devient un élément actif du réseau de drainage.

ABSTRACT

As we face more intense and frequent rainfall events many traditional drainage systems, such as drains and pipes, struggle to cope resulting in surface water flooding. To address this, a Sustainable Drainage Systems planter can be used to slow water diverted from a roof. Sensors evidence that the planter distributes water over time allowing the traditional system to cope. It achieves this by using the multiple internal layers designed to slow the water down. Trees can also be introduced into urban spaces to help manage the water while also providing multiple benefits to the community. Tree water demand and the soil-tree-atmosphere interaction is being established via monitoring campaign across Newcastle-upon-Tyne, UK. Instrumentation includes sap flow meters, soil moisture sensors and meteorological stations across the city. This research initiative is expanding, from a preliminary trial (tree planted within a rain garden) to other sites exploring the impact of tree maturity, species and context. Evidence-based guidance will then allow stakeholders to better implement both trees and Sustainable Drainage Systems to better reduce surface water flooding. Overall, this research provides a pathway for city-scale greening projects to incorporate nature as an active part of the city's drainage network.

KEYWORDS

Monitoring, Sap flow, Sustainable Drainage Systems (SuDS), Trees, Urban

1 INTRODUCTION

Rainfall events are increasing in intensity and frequency due to factors including climate change and their impact amplified by urbanisation. Traditional drainage infrastructure, such as drains and pipes, struggle to cope with this change resulting in urban areas experiencing surface water flooding. Surface water flooding can damage homes and businesses as well as disrupt transport networks and essential services across communities. In England, 4.6 million properties (two in eleven properties) are currently deemed to be at risk of surface water flooding (Environment Agency, 2025). However, the number of at-risk properties is expected to increase so there is an opportunity for traditional systems to be increasingly supported by Sustainable Drainage Systems (SuDS). SuDS are designed to slow, store, and filter water as close as possible to where it falls, often using vegetation, which introduces additional benefits.

Newcastle upon Tyne, in the Northeast of England, is known to experience recurrent surface water flooding issues. A significant event in 2012, known locally as ‘Thunder Thursday’ or ‘Toon Monsoon’, caused flooding in over 500 homes and caused £760 million of damage to the local economy (Newcastle City Council, 2025). Consequently, events like ‘Thunder Thursday’ have resulted in stakeholders within the area seeking to invest to create a more resilient community. Blue Green Newcastle (BGN) is a scheme launched by the local authority, Newcastle City Council in partnership with Northumbrian Water (water company) and the Environment Agency (environmental regulator). BGN is a five phased project designed to involve many stakeholders including people who live, work and visit the area to reduce flood risk. This research supports BGN in introducing, monitoring and evaluating SuDS to reduce flood risk and provide wider co-benefits.

2 SUDS PLANTER

There are many types of SuDS that can be introduced to help projects like BGN to succeed. One example are SuDS planters, which slow water diverted from a roof before it (typically) enters the traditional drainage system. A SuDS planter (seen in Figure 1) has been designed and constructed on a domestic scale using an intermediate bulk container (IBC) with multiple internal layers to slow water down (seen in Figure 2). The layers include a topsoil, SuDS soil, geotextile (to maintain separation between layers) and a coarse gravel, storage layer. Modelling was undertaken prior to construction, using Hydrus-1D, to determine the optimal planter depth and layer thicknesses. The model considered a fixed IBC area and varied the total depth and layer thickness ratios. Simulations were run using the calculated inflow expected during a 1 in 100 year rainfall event plus 45% uplift. This procedure identified the optimum SuDS planter design for this scenario. It is recognised that the specific design may not be universally appropriate if variables, including material properties and roof area, change. However, design aspects such as an appropriate maintenance height, sufficient topsoil to support vegetation and inclusion of a storage layer, are all universal factors that need to be considered.

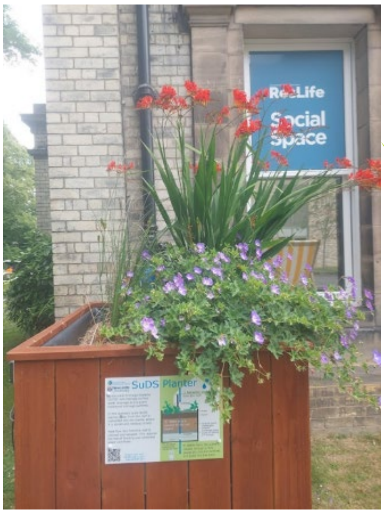

Figure 1 SuDS Planter

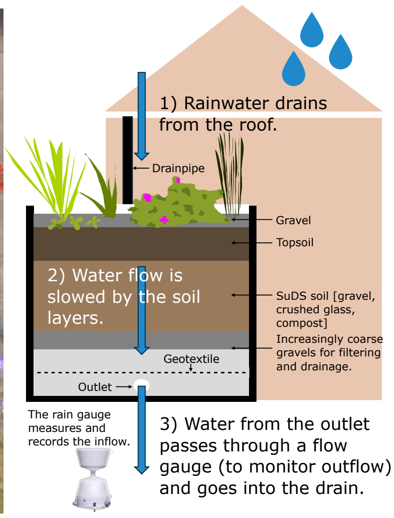

Figure 2 SuDS Planter Diagram

The inflow and outflow of the SuDS planter is being actively monitored to understand the impact these systems can provide. Data collected from rain gauges in the local area, including immediately on-site, are used to estimate the inflow (roof runoff). The outflow of the planter is monitored using a tipping bucket flow gauge connected to the outlet below the planter. The compared inflow to outflow data collected demonstrates a reduction in peak flows. The reduced peak is achieved because of flow being distributed over time (attenuated). The change in flow characteristic means that the traditional, piped drainage system can accommodate the rate of flow, which reduces surface water flood risk in the local area. At this time, as data is continuously collected, the relationship between weather conditions and performance (i.e. inflow:outflow) can be explored opportunistically. The extent of impact presence of the planter has on the reduction in surface water flooding is ultimately unknown without an identical, contemporaneous control setup; however, further monitoring allows validation of the model which will enable this to be understood more confidently. It is expected that the overall impact of a SuDS planter depends on its context of application. The monitored, domestic scale planter would need to be scaled to manage larger inflows.

3 EMPIRICAL BASIS FOR TREES IN SURFACE WATER MANAGEMENT

Citywide initiatives, like BGN, are known to encourage the introduction of trees via SuDS, based on enhancing the appeal and function of urbanised spaces. Trees are believed to provide multiple benefits including helping to manage surface water, providing cooling and improving biodiversity. To better constrain the extent to which trees mitigate surface water flood risk, a monitoring campaign across Newcastle upon Tyne has been commissioned. Sensors are to be placed on and around multiple urban and peri-urban trees to gather evidence in order to understand their contribution. These sites will encompass trees of various ages, species and at different site contexts (e.g. tree pits and peri-urban parkland) aimed at capturing the impact these changes have on soil-water-tree interactions. Examples of further trees expected to be monitored from spring 2026, include 'whips' and mature trees on a peri-urban green space, confined tree pits and trees within a small (enclosed) urban green space. Since projects that will most benefit from this evidence, including BGN, have many stakeholders, exploring a wider range of site types is beneficial.

One such tree currently monitored is located at the (UK) National Green Infrastructure Facility (NGIF, 2025), an outdoor lab featuring a range of research-orientated SuDS features, including a raingarden (bioretention cell) hosting a Alnus glutinosa Imperialis (Cut Leaf Alder), planted in summer 2017, and other recommended SuDS planting. To understand the hydrologic conditions across the site, the following sensors have been employed: A 100 ml/tip, tipping bucket flow gauge located at the experimental plot outfall, soil-water potential sensors (TEROS 21, Meter Group) to constrain plant available water and volumetric water content sensors (TEROS 12, Meter Group). Additionally, an ICT International SFM1 sap flow meter (ICT International, 2025) is used to better understand the water demand of the tree and thus, its role in dynamic water storage capacity of the SuDS. Three needles (1.3mm diameter) are inserted into the tree, the central needle injects a small pulse of heat while neighbouring probes simultaneously measure temperature changes above and below the heated needle. The change in temperature allow the flow of sap up and down the tree to be established which can be correlated to water demand given trunk geometry parameters. The sap flow data seen within Figure 3 shows a period of 112 days and captures the diurnal cycle, with flow rates increasing during the daytime and decreasing at night. This reflects typical tree transpiration behaviour, where sap rises in response to the demand for water in the leaves as water is lost due to evaporation from stomatal pores.

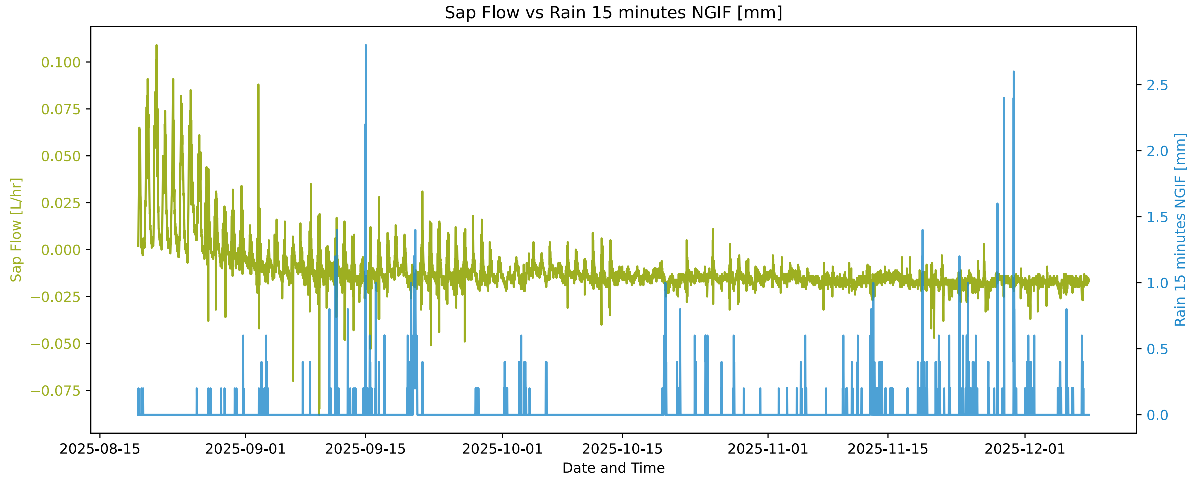

Figure 3 Preliminary Sap Flow Data Shown in the Context of Contemporary Rainfall Conditions.

The transpiration rate is affected by light levels and temperature, meaning sap flow can also be used to understand the relationship between weather conditions and ultimately, root water uptake. The monitored tree water demand is considered in context of meteorological data including rainfall, seen within Figure 3 which will help to understand the trees impact on the surface water. Once the relationship between light and sap flow is accounted for, this graph shows evidence of increased sap flow during dry periods. Collecting data overtime allows for the seasonal response of the tree and the rain garden to be captured, during autumn and winter, deciduous trees are expected to have lower water demand due to the loss of leaves resulting in reduction of transpiration. This means such species are expected to have a lesser impact on flood risk in winter. Data collected during this time is expected to be mainly 'noise', a product of needle misalignment during installation, yet this can be useful in the removal of noise from actively transpiring periods.

4 COMBINED SUDS PLANTER – TREE SYSTEM SCENARIO

The monitoring campaign explores both SuDS planters and trees allowing for the relationship between them, the urban setting and surface water flood risk to be understood. The different sites cannot be explored in isolation to fully understand their impact so they will be compared and evaluated against each other. It is expected that all sites (trees and SuDS planter) will have an impact, but the scale of this impact will depend on variables including site location and type. However, they are not expected to be able to prevent surface water flooding alone especially within the winter months when trees are dormant. Therefore, next steps of this research aim to investigate the possibility of a SuDS planter to tree connection, where the outflow of the planter is directed to a tree rather than the traditional drainage system. Giving the opportunity to explore disconnection of buildings providing a larger impact by appropriately managing more water outside of the traditional drainage systems. The SuDS planter to tree connection will be explored by modelling the scenario ensuring that this is a viable solution. Once the planter is constructed, for the scale of expected inflow, the site will be monitored to reflect the monitoring of alternative sites. This will evidence the performance and impact of the intervention and is designed to encourage the disconnection of other sites. To best support projects like BGN, evidence-based guidance targeting specific stakeholders in communities will be developed. Developing guidance, with targeted recommendations and with links to policy, ensures that findings and data become accessible. Helping stakeholders to introduce more of these systems affectively which reduces surface water flooding and the impact of rainfall events while improving the area for communities.

5 CONCLUSION

By researching the best way to optimise the inclusion of trees and SuDS planters as well as the connection of them, this project will support city-wide greening projects, like BGN, designed to reduce surface water flood risk. Improving the management of surface water within urban spaces is important as traditional systems are struggling to manage water, and these areas are experiencing more severe flooding events. Findings so far show that the SuDS planter slows water directed from a roof and distributes it over time. Sap flow rates increase during dry, daylight hours and is negatively influenced by cool (typically cloudy) rainfall days. Both systems are not expected to have a significant impact on larger events, especially in the winter months, therefore next steps will monitor a SuDS planter to tree connection. This will be paired with an upscaling monitored tree sites within Newcastle upon Tyne city limits. This will ensure the project evidences the performance of various trees allowing the research to reflect the dominant species and ages of the trees possible within the given region. Overall, this research provides a pathway for projects like BGN to lead in climate-resilient urban design where nature becomes an active part of the city's drainage network.

Acknowledgements

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