Role of vegetation maintenance in nature-based stormwater solution: short-term plant succession in a rain garden in Estonia

Rôle de l'entretien de la végétation dans les solutions fondées sur la nature pour les eaux pluviales : succession végétale à court terme dans un jardin de pluie en Estonie

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RÉSUMÉ

La végétation des jardins de pluie joue un rôle essentiel dans la régulation hydraulique, l'absorption des polluants, l'évapotranspiration et la stabilisation des sols, influençant directement la performance à long terme des solutions naturelles de gestion des eaux pluviales. Cependant, le fonctionnement continu de ces systèmes dépend fortement d'un entretien régulier. Afin d'évaluer la rapidité avec laquelle la structure de la végétation peut évoluer en l'absence d'entretien, cette étude examine la dynamique des communautés végétales d'un jardin de pluie aménagé sur un parking, âgé de cinq ans et auparavant bien entretenu, après l'arrêt de cet entretien pendant une saison de croissance. La végétation a été inventoriée durant l'été 2025 et comparée à la plantation initiale afin d'évaluer la persistance des espèces, les déplacements spatiaux et les schémas de succession émergents. Les résultats montrent un déclin marqué d'une espèce initialement plantée sur onze, contrastant avec l'expansion de trois espèces et l'établissement de 29 espèces locales spontanées. Globalement, l'étude souligne l'importance d'intégrer des stratégies de gestion continue de la végétation dans le fonctionnement des solutions naturelles de gestion des eaux pluviales afin de garantir un fonctionnement écologique résilient et une performance durable en matière de régulation hydraulique et de traitement de l'eau.

ABSTRACT

Vegetation in rain gardens plays a central role in hydraulic regulation, pollutant uptake, evapotranspiration, and soil stabilization, directly influencing the long-term performance of nature-based stormwater solutions. However, the continued functioning of these systems depends strongly on routine management. To assess how quickly vegetation structure may change under unmaintained conditions, this study examines plant community dynamics in a previously well-maintained, five-year-old parking-lot rain garden following the cessation of maintenance for one growing season. Vegetation was surveyed in summer 2025 and compared to the initial planting to evaluate species persistence, spatial shifts, and emergent successional patterns. The results show a marked decline in one originally planted species out of 11, contrasting with the expansion of three species and the establishment of a total of 29 spontaneous local species. Overall, the study highlights the importance of integrating continuous vegetation management strategies into the operation of nature-based stormwater solutions to ensure resilient ecological function and sustained hydraulic and water treatment performance.

KEYWORDS

Bioretention, blue-green infrastructures, performance evaluation, plant community, urban runoff

1 INTRODUCTION

Healthy and well-structured plant communities are central to the optimal performance of nature-based stormwater solutions (also called blue-green infrastructures, sustainable urban drainage systems), as vegetation regulates hydrological processes, supports pollutant removal, and contributes to ecological and aesthetic functions in the urban environment (Beral et al., 2023; Dudrick et al., 2024). Previous research has demonstrated that rain garden vegetation enhances runoff retention, nutrient uptake, and biodiversity, reinforcing its multifunctional role in nature-based stormwater solutions (Read et al., 2009). However, the continued functioning of these solutions depends strongly on routine management. Without essential maintenance activities, such as weeding, mulching, debris removal, and plant replacement, invasive local species can outcompete designed plant communities, and plant stress can diminish performance, including evapotranspiration rate and pollutant-removal efficiency (Champagne-Caron et al., 2024). These maintenance-related vulnerabilities have been highlighted in earlier studies on rain garden design and operation (Dudrick et al., 2024; Virahsawmy et al., 2014).

The primary objective of this study was to investigate short-term changes in plant community composition and plant succession in a previously well-maintained, five-year-old parking-lot rain garden following the cessation of maintenance during one growing period. Our specific objectives were: 1) to determine the general species performance of planted species by comparison of the initial planting schematic with the summer 2025 plant community; 2) to evaluate the plant performance of planted species; 2) to monitor the changes in plant community compositions after cessation of maintenance.

2 MATERIALS AND METHODS

The studied rain garden was built in 2020 in a public parking lot (Randvere tee 18) in Viimsi municipality, Estonia. This rain garden was built as a pilot example of the LIFE UrbanStorm project (LIFE17 CCA/EE/000122). This rain garden (length 37.5 m, width 3 m; total area of 160 m^2) has a shallow ditch-like structure (slopes 1:2 to 1:1) with stormwater entering as sheet flow from two sides. This rain garden is filled with substrate (depth: 40 cm) and equipped with a bottom drainage pipe (Ø 160 mm). Substrate is covered with limestone gravel (Ø 32-64 mm). This rain garden was planted with selected ornamental plants as clustered cover (Fig. 1). The rain garden has been well-maintained by the Viimsi municipality. At the beginning of each season, the herbaceous plants were cut back, and all weeds and other unwanted vegetation (e.g., tree seedlings) were removed from the rain garden.

From spring 2025, a study was conducted, as a part of the European Biodiversity Partnership in the context of the BioReStorm project (GA No. 101052342) under the 2023-2024 BiodivNBS joint call, to understand the short-term changes in the plant community present in a well-maintained rain garden when the plant maintenance was stopped for one vegetation season. At the peak of the growing season, in early August 2025, the plant survey was conducted. For detecting changes in the plant community and succession, the rain garden was divided into 13 quadrats (each 3 × 3 meters in size). In the summer of 2025, the plant community was compared with the initial planting schematic (Fig. 1).

To evaluate plant performance, the following parameters were monitored: species persistence, spatial shifts, vegetative cover, plant height, and general health condition. Each quadrat was photographed from above, and all plant species were listed per quadrat. Plant cover was denoted according to predetermined abundance classes (0% = 0; 1-5%=1; 5-10% = 2; 10-15% = 3; 15-25% = 4; 25-50%=5; 50-75%=6; 75-100%=7; 100%=8). Both prevalent ground (i.e., gravel, rock) cover and coverage of each species were detected. The average height of each species per quadrat was measured and assigned to three height strata: 1 – high (60 cm and above), 2 – medium (less than 60 cm), and 3 – low (less than 20 cm). The general health of initially planted species was assessed (i.e., 0 = non-existent, 1 = very low, 2 = low, 3 = intermediate, 4 = optimal). According to the scores of the cover and health classes, the species performance indexes were assigned (i.e., classes range from 0 to 2 = “low”, 2 to 4 = “average”, 4 to 6 = “high”, and > 6 = “very high”). Furthermore, site disturbances (e.g., erosion, litter, damage) in each quadrate were documented when present.

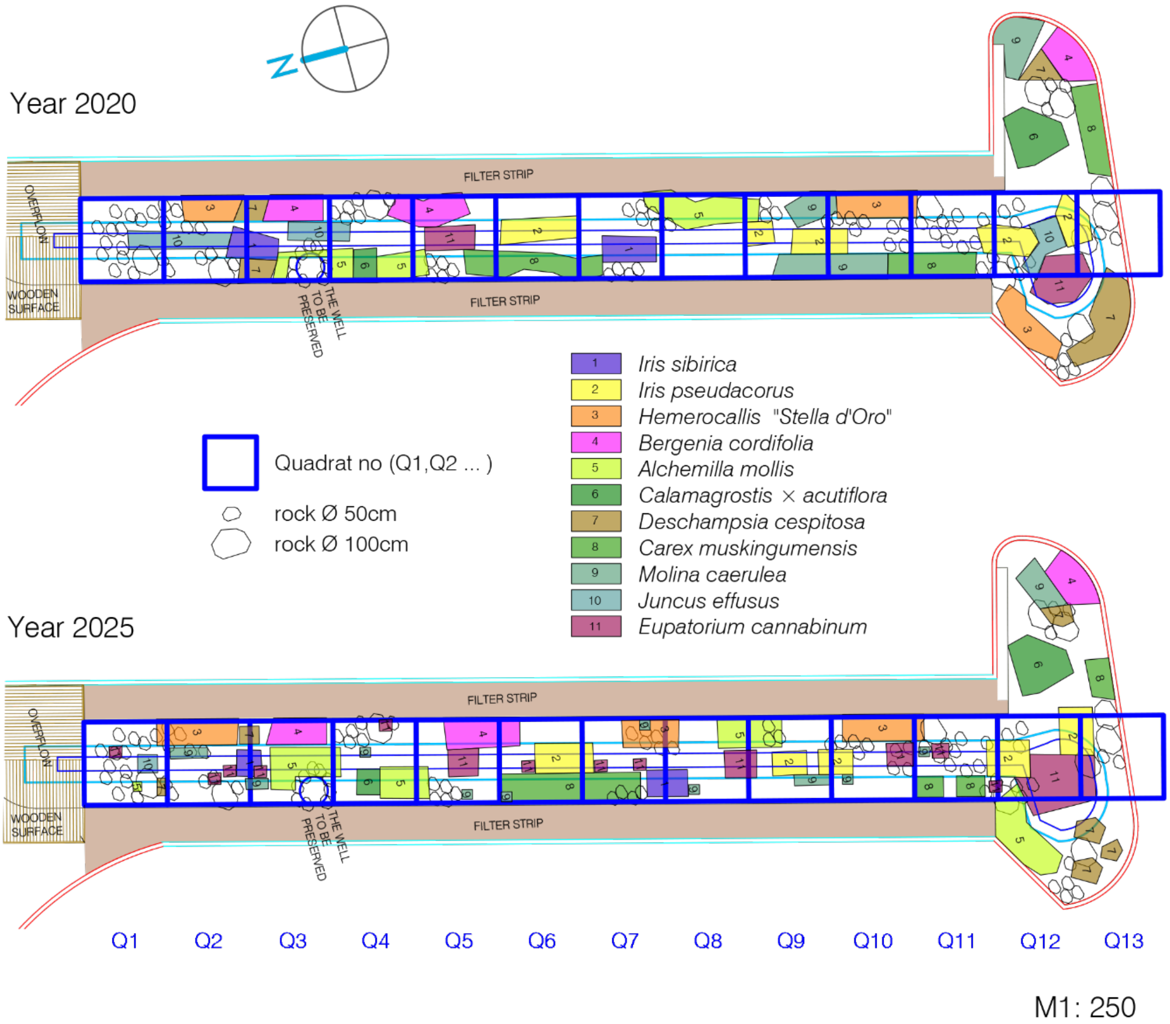

Figure 1. Spatial distribution of planted species according to the original project planting plan (year 2020) and during summer 2025.

Table 1. Plant performance table for the originally planted species after a year of no maintenance.

Species	Present in quadrats (year 2025)	Strata (0 - 20 cm = 1; 20 - 60 cm = 2; > 60 cm = 3)	Cover class (1-8)	Health class (0-4)	Plant performance index (low; average; high; very high)
Gravel cover	ALL	NA	5-6	NA	NA
Iris sibirica	2, 3, 7, 8	2-3	1-2	3	AVERAGE
Iris pseudacorus	6, 7, 9, 10, 11, 12, 13, 15	3	3-4	4	HIGH
Hemerocallis "Stella d'Oro"	1, 2, 7, 8, 10, 11	2	2	4	AVERAGE
Bergenia cordifolia	3, 5, 6, 15	2	4-5	4	HIGH
Alchemilla mollis	1, 3, 5, 8	2	4	4	HIGH
Calamagrostis × acutiflora	4, 15	3	4	4	HIGH
Deschampsia cespitosa	1, 2, 3, 14, 15	3	3	4	HIGH
Carex muskingumensis	6, 7, 11, 15	3	4	4	HIGH
Molina caerulea	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15	2	1-2	4	AVERAGE
Juncus effusus	1	3	2	3	AVERAGE
Eupatorium cannabinum	ALL	3	2	4	AVERAGE

3 RESULTS AND CONCLUSIONS

A comparison of the original planting plan and the spatial distributions and cover of 11 planted ornamental species five years after planting shows clear differences (Fig. 1). In some quadrants, several species originally planted are missing or present in reduced numbers. Notably, the species adapted to constantly wet conditions like *Juncus effusus* appears to have decreased the most, possibly due to unfavourable, mostly dry and well-drained rain garden conditions. In contrast, some vigorous and fast-spreading species have expanded beyond their intended boundaries, spreading over the entire rain garden (e.g., *E. cannabinum, M. caerulea*, and *Hemerocallis*).

Ruderal species typical of urban environment appeared within the 2025 growing season without maintenance. A total of 29 new plant species established spontaneously within the rain garden. Common local species (e.g., *Taraxacum officinale*, *Erigeron canadensis*, and *Trifolium repens*) have also appeared in large numbers, especially in the upper edges (inlet zones), where nutrient loads are also the highest and conditions are the driest. Furthermore, there are some ornamental species and trees, like *Rhus typhina* and *Alnus glutinosa,* that have colonized the rain garden from nearby areas.

The plant performance estimation, based on the plant survey (Table 1), indicates that all planted species were in good health, and most of them exhibited high abundance in the planted locations. This plant survey resulted in generally high plant performance (Table 1).

Monitored changes in the plant community structure and succession clearly illustrate the importance of continuous and proper maintenance. Overall, the comparison shows that a lack of maintenance, even during only one growing season, can lead to rapid and spontaneous colonisation by local species. Further studies during the next growing season on plant performance, soil composition, and hydraulic performance will provide more information about the factors affecting plant succession and performance in the rain garden.

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