Testing the Water Holding Capacity of Living Wall Plants

Consultancy Report for Flora Fanatica

Conducted by

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Summary

- Four species of evergreen climbers, suitable for use as living wall vegetation, were tested for their water retention capacity
- Plants retained the most water during the first three minutes of rainfall, but continued to retain water for the full 30 minutes of the simulation
- *Trachelospermum jasminoides* and *Hedera algeriensis* were best at retaining water, relative to their growing footprint
- *T. jasminoides,* the best performing plant, reduced stormwater by 21%
- Leaf number was a good predictor of water retention for *T. jasminoides*
- Plant footprint was a good predictor of water retention for *Hedera colchica* and may have been for *H. algeriensis*
- There was a suggestion that introducing a leaning angle for *H. algeriensis* could improve water retention further
- When the effect of soil was included water retention improved by 60%

Introduction

Vegetation can be utilised in urban planning to alleviate pressures caused by stormwater runoff. Overloaded storm drains can cause localised surface flooding (Plate 1) which in turn can cause problems such as traffic collisions and disruption of local services. Trees, shrubs and other plants intercept water, retaining it on their leaves where it is either released more steadily to the ground-level, absorbed by the plant for incorporation into plant tissue or evaporated back into the atmosphere[1]. As such, vegetation is increasingly incorporated into Sustainable Drainage Systems (SuDS). SuDS planting ranges from the use of near-natural systems, such as tree planting, to vegetation specifically designed for civil engineering, such as green roofs and living walls.

Plate 1. Flash flood in Chepstow UK, 2004 (Kennedy, 2004)

Little is known, to date, about the quantity of water retained by plants in this way and whether there are species specific differences in water retention. Plugging this knowledge gap will enable civil engineers and architects to optimise planting regimes to fulfil SuDS criteria and to predict water retention rates, aiding SuDS planning.

This mini-research project aims to quantify the water retention capabilities of four evergreen climbers used by the living wall company Flora Fanatica.

[1] Wang, J., Endreny, T. A. and Nowak, D. J. (2008) Mechanistic simulation of tree effects in an urban water balance model. Journal of the American Water Resources Association, 44; 76-88

Method

Three to five individuals of four evergreen living wall species were tested under a rainfall simulator. The selected species were*, Trachelospermum jasminoides, Holboellia latifolia, Hedera algeriensis* '*Gloire de Marengo*' and *Hedera colchica* '*Dentata Variegata*'. The rate of rainfall applied was approximately 40mm/hour, which is considered a "heavy shower" (Met Office[2]). The effect of soil within the plant pot was excluded by tightly wrapping the pot in plastic film. Each plant was placed in a tray measuring 50 cm by 50 cm and simulated rain applied for 30 minutes. During this 30 minute period, water remaining in the tray was measured every three minutes. This value was subtracted from the average volume of water expected with a plantless run[3].

These data are presented both in raw format (ml of water retained) and standardised to leaf number and plant footprint. Plant footprints were assumed to be circular. The maximum width of each plant was measured from four different angles and the mean these was used for the circles diameter. Comparisons between species retention capacity relative to plant footprint are expressed in mm/hour to enable comparison with UK rainfall data.

One plant species, *H. algeriensis*, was tested for its ability to retain water when soil was included. Pots contained approximately four litres of soil. For this test the same method as above was used, excluding plastic film.

[2] *www.**metoffice**.gov.uk/media/pdf/f/c/Fact_sheet_No._3.pdf*

[3] This mean value was obtained by performing 10 rainfall simulations without plants, using the same tray as used for plant experiments.

Results

Greatest water retention was achieved within the first three minutes of rainfall for *H. latifolia, H. colchica* and *H. algeriensis*. After the initial three minutes, plants continued to retain water, but at a steady and lower rate. This is evident in Fig 1. The exception to this rule was in the case of *T. jasminoides*, for which water retention levels were high for the first six minutes, before levelling off to a lower level. All four species continued to retain a small amount of water throughout the 30 minute period, though both *T. jasminoides* and *H. latifolia* slowed in their retention rate toward the end of the thirty minute period, suggesting these species were nearing the threshold of their water retaining capacity.

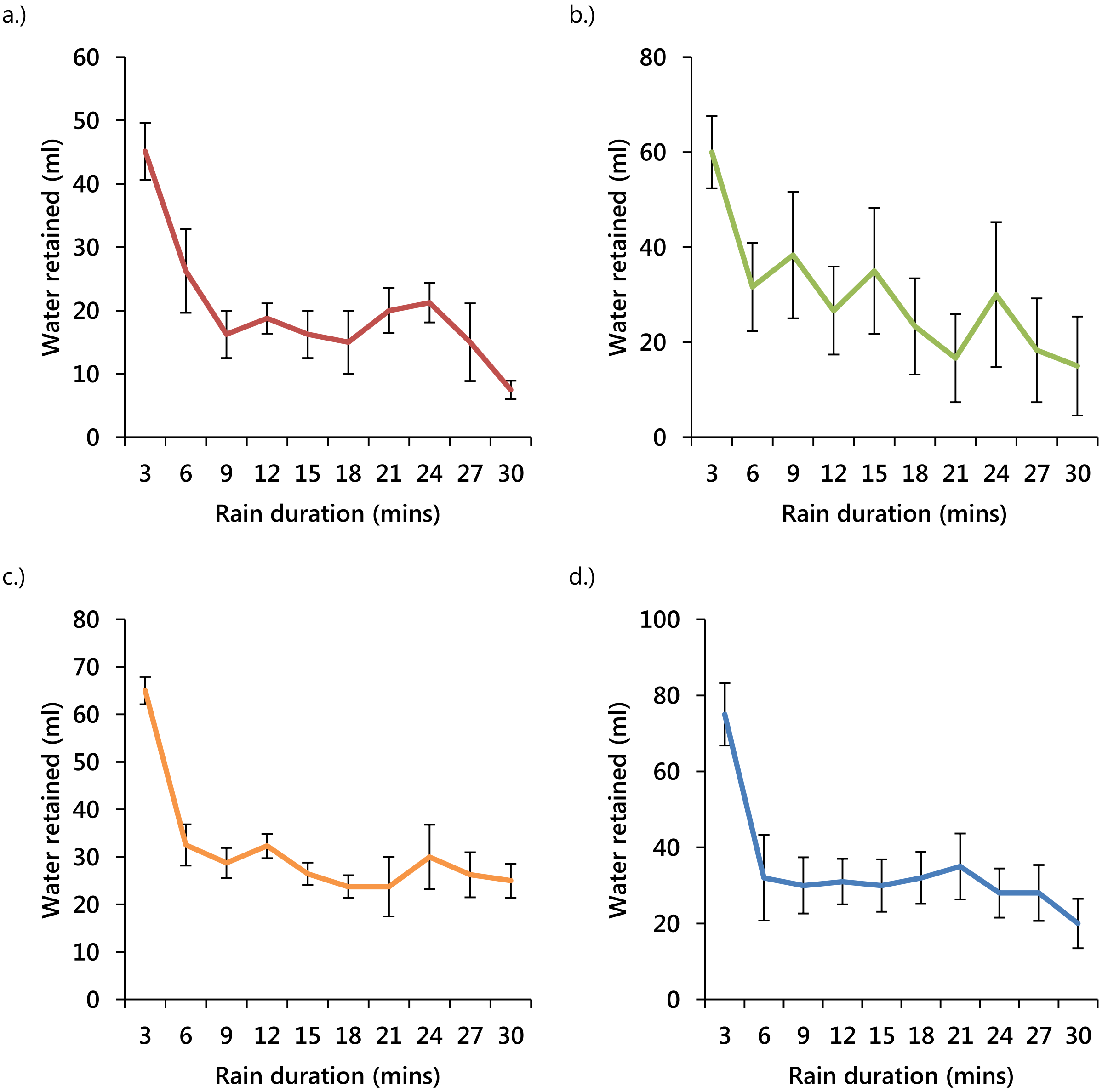
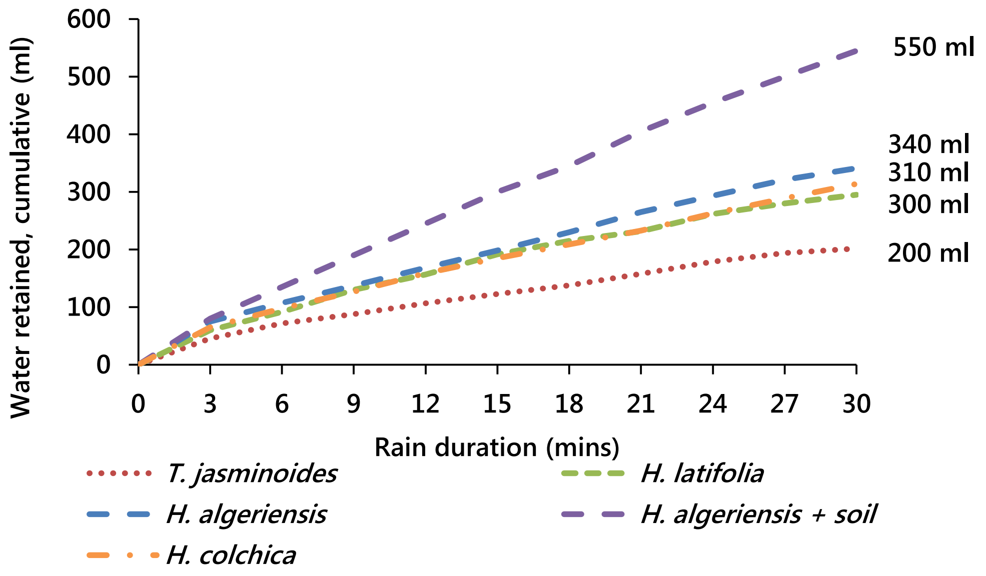


Fig 1. Mean water retained (ml) since last measurement, at each 3 minute interval over 30 minutes under a rainfall simulator. Error bars represent the standard error of the mean (a measure of statistical accuracy, based on variation between samples and number of individuals tested). a.) *T. jasminoides*, b.) *H. latifolia*, c.) *H. colchica* and d.) *H. algeriensis*

Overall, *H. algeriensis* retained the highest average volume of water over the thirty minute period, storing approximately 340 ml of water. *H. colchica* and *H. laterifolia* retained lower levels, but only slightly (310 and 300 ml respectively). *T. jasminoides* retained the least amount of water by the end of the thirty minutes period (200 ml).

a.)



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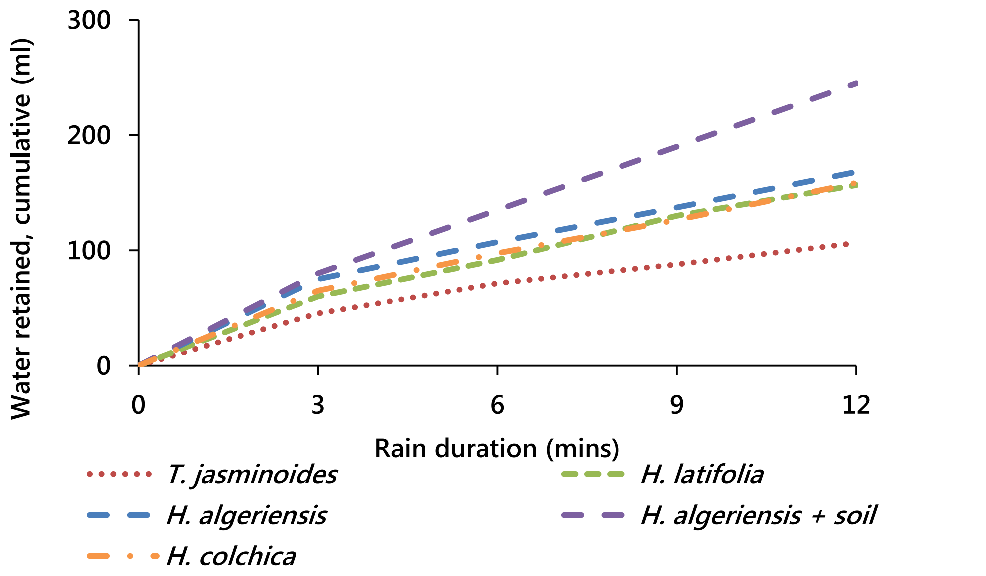


Fig 2. Cumulative mean water retained (ml) over the 30 minute period under a rainfall simulator, measured every 3 minutes. a.) Total period and b.) first 12 minutes

When standardised by plant footprint, *T. jasminoides* retained the most water relative to its footprint, saving an average of 8.7 mm of water per hour, or 22% of the total rainfall that would have fallen in the absence of the plant. *H. colchica* retained the least, saving an average of 1.4 mm per hour (Fig 3).

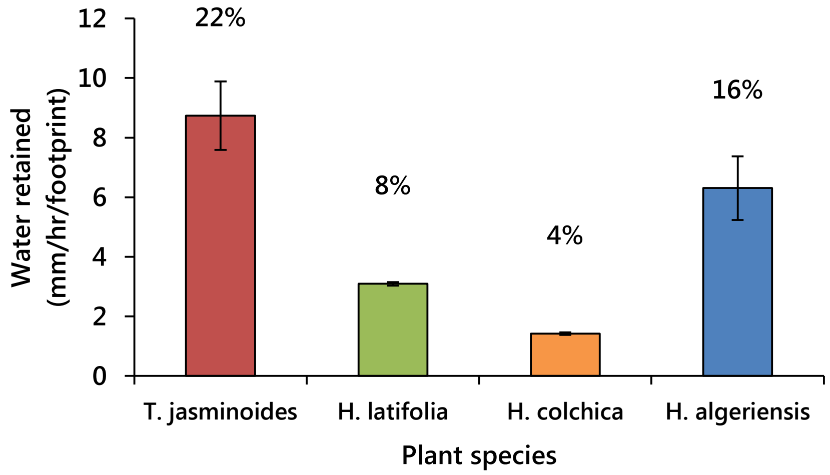
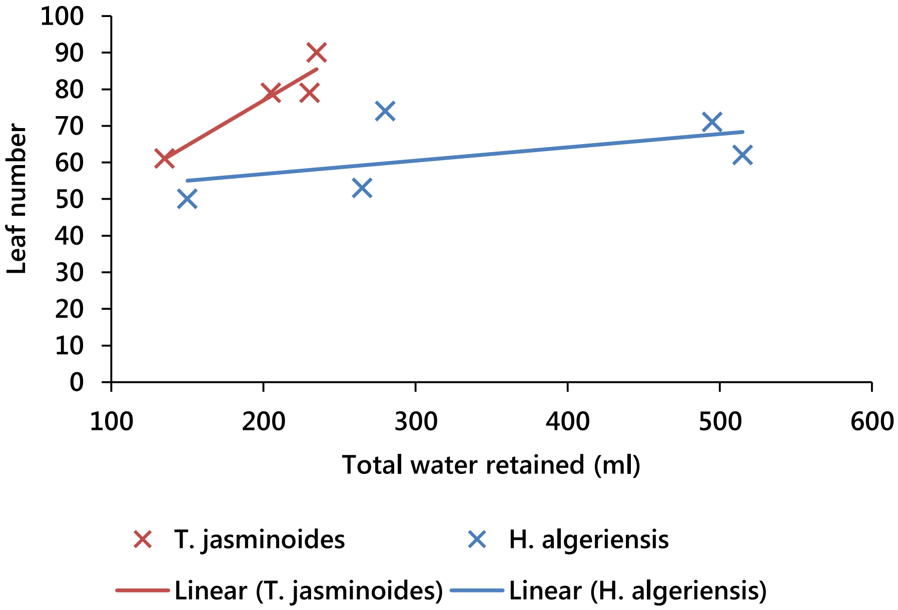


Fig 3. Mean water retained relative to total plant footprint. Per cent values denote % water saved per footprint. Error bars represent the standard error of the mean (a measure of statistical accuracy, based on variation between samples and number of individuals tested).

The contribution of soil, when tested in combination with the species *H. algeriensis,* was substantial. Approximately 550 ml of water had been retained by the end of the 30 minute period, over 200 ml more than when the plant was tested alone. Furthermore, cumulative water retained was still increasing at a steady rate towards the end of the 30 minutes, suggesting this plant and soil combination could have continued to store more water, beyond the 30 minute period. Within the first three minutes of sampling, *H. algeriensis* with and without soil retained a similar volume of water.

a.)



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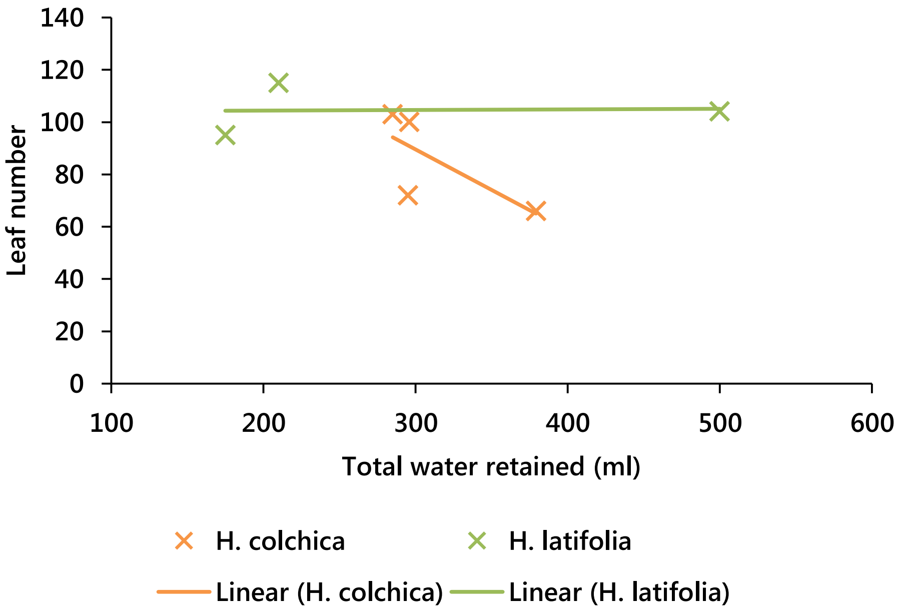
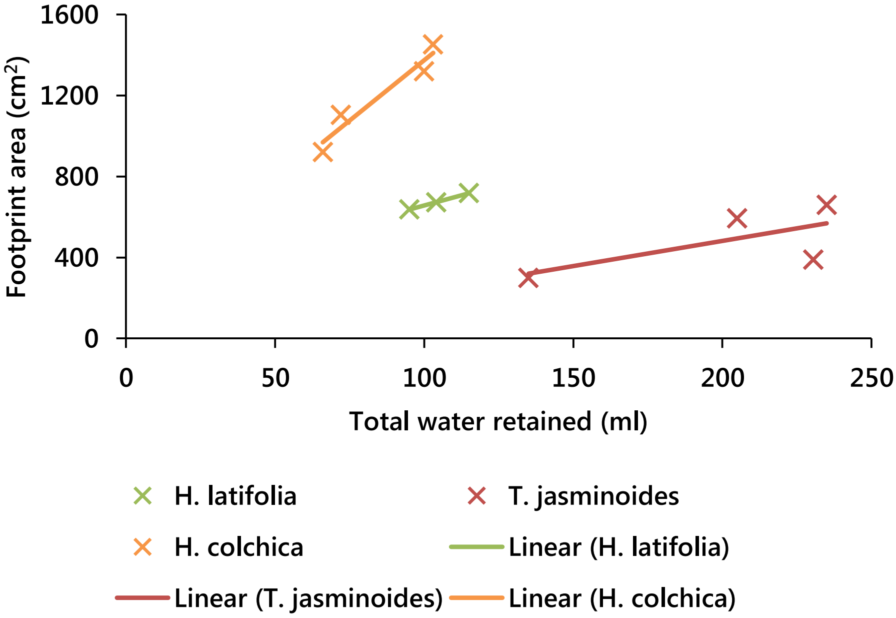


Fig 4. Relationship between total number of leaves counted per plant and the total water retained (ml) over the 30 minute period.

There was a strong positive relationship between leaf number and volume of water retained for *T. jasminoides* and a weak positive relationship for *H. algeriensis* (Fig 4a). *H. latifolia* and *H. colchica* (Fig 4b) did not display this relationship.

a.)



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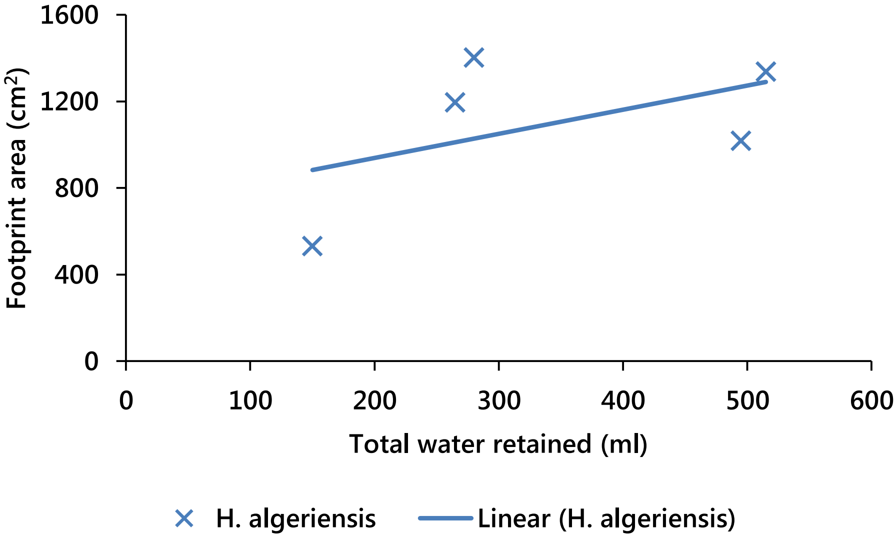

Fig 5. Relationship between footprint (cm^2) per plant and the total water retained (ml) over the 30 minute period.

For all species, there was a positive relationship between plant footprint and water retention capacity (Fig 5). For all species except *H. algeriensis*, trend lines were a good approximation of the data. The relationship for *H. algeriensis* was not as good a fit. It is possible that *H. algeriensis* displays two trendlines, with individuals on the right of Figure 5aretaining more water per their footprint than other individuals, but sample sizes are too small to draw significant conclusions.

Discussion

All four species of climber were successful at retaining water on their leaf surface for the duration of the 30 minute rainfall simulation, so all are suitable as components of SuDS. Particularly encouraging is that, although retention rate slowed significantly after 3 minutes, all plants appeared to continue to retain water for the full 30 minutes tested. This suggests that more water could have been retained over a longer period. Additionally, this simulation replicated a heavy rainfall scenario. It is conceivable that in lighter periods of rainfall, plants could retain a higher proportion of rainfall. However, additional factors, such as rain drop size will also affect this. Larger scale projects should take this into account by testing a range of representative rainfall scenarios likely to be encountered in the UK.

Trachelospermum jasminoides retained the most water compared to its plant footprint, suggesting that it has high potential in planting regimes where space is limited. *Hedera algeriensis* was also efficient at retaining rainfall for its footprint size.

A number of factors affect leaf water retention capabilities, including leaf area index (LAI: the total leaf area per plant compared to its footprint) and physiological factors such as leaf shape or the presence of hairs. In the current study, it is probably that *T. jasminoides* had a higher LAI than the other three species, due to its small, densely packed leaves (Plate 2). This is supported by the positive relationship between leaf number and water retention for this species.

The high performance of *H. algeriensis* is more difficult to explain, particularly in light of the relatively poor performance of its relative, *H. colchica*. Leaf shape between species was different, with *H. colchica* displaying downward curling, convex leaves (Plate 2) and *H. algeriensis* possessing flatter, sometimes concave, leaves. It is easy to imagine that this difference in morphology creates differences in water holding capacity.

The contribution of soil to water retention was significant, emphasising that soil is also a vital component in SuDS programmes. In the context of the current study, soil volume was relatively low, yet still had a notable effect. In Flora Fanatica living walls, it is expected that planters would have a greater overall effect on SuD capability in early years of establishment than the plants themselves, due to their large volume. Future studies should assess how water holding capacity of plants and their associated soil is related to the maturity of the wall. This could inform projections of maintenance programs, ecosystem services calculations and lifecycle analyses prior to installation.

Another interesting result with regards to water retention with and without soil, was that retention levels were the same for both in the first three minutes. This suggests that soil has no effect for the first three minutes of rainfall, with the plant taking the full rainwater load. This exemplifies the important role plants play in urban landscapes, buffering soil from rainwater and thus preventing erosion. Plant roots also contribute to this effect, binding soil together. Thus, both plants and soil form a symbiosis that enhances ecosystem service provision. This has implications for swale development, suggesting that an overlying canopy provides additive value to the water holding ability of soil.

a.) b.) c.) d.)

Plate 2. a.) *T. jasminoides* (Conrado, 2005), b.) example of water pooling in leaf of *H. algeriensis* (Rumble, 2015), c.) *H. algeriensis* (Gálvez, 2008) and c.) *H. colchica* (MPF, 2005)

Leaf number was a poor predictor for water holding capacity for most species, with only *T. jasminoides* displaying a strong positive relationship. For both *H. latifolia* and *H. algeriensis*, water retention varied greatly even when leaf number was the same. For *H. colchica*, leaf number had little effect on water retention ability; leaf number varied but water retained remained constant.

A far better predictor of retention capacity was plant footprint, with all species showing positive relationships between footprint and water retention. This could provide a simple technique for comparing capacity between living walls and assessing the contribution to water retention an individual plant makes over time. Predictive power was weaker for *H. latifolia*. The positive relationship was also fairly weak for *T. jasminoides*, so for this species leaf number may be used instead.

There is a suggestion in the data that there may be two trendlines for *H. algeriensis*. Plants 1 and 4 retained more water relative to their footprint area than other individuals. This is particularly interesting as, anecdotally, these two individuals were the only two plants to significantly lean in their pots. This suggests that these plants may have higher water retention capabilities when grown at an angle, rather than straight up. However, the number of data points was not large enough to draw significant conclusions at this stage. This would be a highly valuable factor to test in future, as it would have strong practical implications for the design of these living wall systems.

Recommendations for Future Research

- Whether plant retention capabilities vary in different rain intensities
- How water holding capacity of plants and their associated soil is related to the maturity of the wall
- The effect living wall angle has on water retention properties

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