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The Influence of Soil Composition on Stormwater Retention and Runoff in Green Roofs at Portland State

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Introduction: Green roofs have been gaining popularity due to their positive impact on the environment and the community. By incorporating vegetation on rooftops, green roofs help reduce urban heat island effect, improve air quality, and create habitats for wildlife. The purpose of this experiment was to test how soil changes over time and find the best composition of soil that will most effectively retain water and mitigate stormwater runoff.

BACKGROUND

Green roofs, composed of vegetation and a growing medium planted over a waterproofing membrane, offer numerous environmental benefits, including reduced stormwater runoff, energy conservation, and mitigation of the urban heat island effect. One of the most common variables studied is soil and substrate composition. Researchers can decide the best composition for retaining stormwater and reducing runoff by studying many different soil types (Buccola 2008).

Hypotheses involving layered soil and/or heterogeneous mixtures were common, especially when compared to homogeneous or single soil types. In most cases, layered soil mixtures outcompeted their single soil counterparts, and a low porosity soil stacked on top of a highly porous substrate retained water better than any of the other mixtures (Wang et al. 2021). With that in mind, the goal of this study is to determine what soil composition is best for the green roofs at Portland State, to see how the current soil mixture compares to the original substrate used, and to see how the green roof's soil composition can be improved in the future.

Green roofs have been identified as effective systems for improving water quality, primarily through the filtration and adsorption of contaminants by the soil media and plants. Studies, such as the one by Vijayaraghavan and Joshi (2014), have demonstrated their capacity to significantly reduce metal ion concentrations in runoff, suggesting a broader potential for filtering other contaminants like nitrates, nitrites, and phosphorus. Sakson (2023) concluded that substrate should be considered the most important factor affecting the quality of runoff. The interaction between green roof components and runoff water can lead to a reduction in harmful contaminants.

Despite the promising findings, several gaps remain in the literature, particularly regarding long-term performance and the specific mechanisms through which green roofs affect different water quality parameters. The variability in green roof designs and local climate conditions also poses challenges to drawing general conclusions, highlighting the need for further targeted research.

FIGURE 1 - The green roofs at Portland State

METHODS

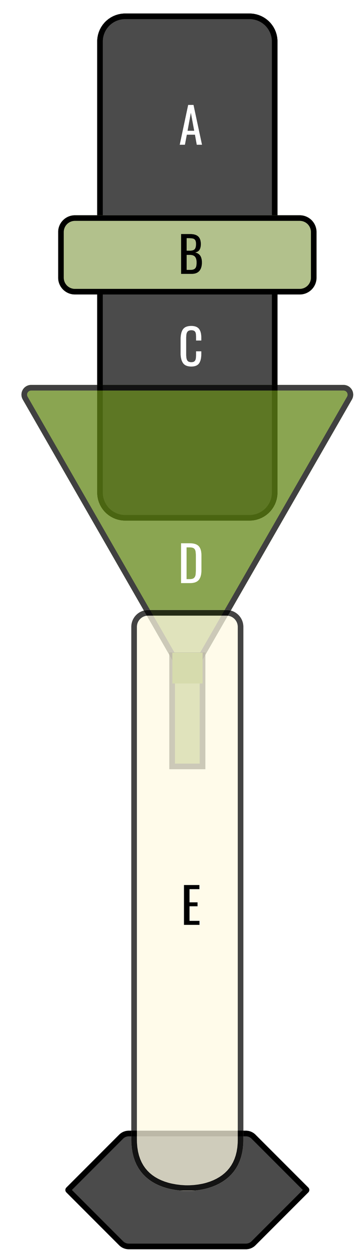


FIGURE 2

We tested the original and current soil of Portland State's green roof and compared them to a layered mixed, solid mixed, and potting soil. Using the pictured setup, we simulated high and low intensity rainfall (in/hr) for a predetermined time (10min for high application and 20min for a low application rate) with a rainfall simulator (Figure 2). We simulated rainfall by pouring 1,000mL of water into a container (A) placed upon a rock sieve (B) and letting it drain into a given soil mix (C). The water would then drain out of the soil mix and into a funnel (D), where the water would then be collected in a graduated cylinder (E). All data was recorded in an online spreadsheet. The pot's surface area remained constant at 30.8 sq. in., and the application rate was determined by timing the water reaching successive 100mL marks on the graduated cylinder. Conversions were made from mL to cu. in, and seconds to hours to standardize application rate.

To examine the impact of green roofs on water quality, our experiment utilized standardized testing equipment to measure key parameters:

- Nitrate/Nitrite (Hach Model NI-12, Cat No. 14081-00)
- Conductivity (Vernier Software Conductivity Probe "CONBTA")
- Orthophosphate (Hach 0-45mg/l, Model PO-14, Cat No. 1475-00)
- pH levels (Whatman Indicator Papers Type CF, Cat No. 2614-991).

Collaborating with our "Water retention team" we collected water samples twice weekly, every Tuesday and Thursday, during class hours. All data gathered was recorded and organized into a comprehensive spreadsheet.

RESULTS

FIGURE 3 - Average application rates

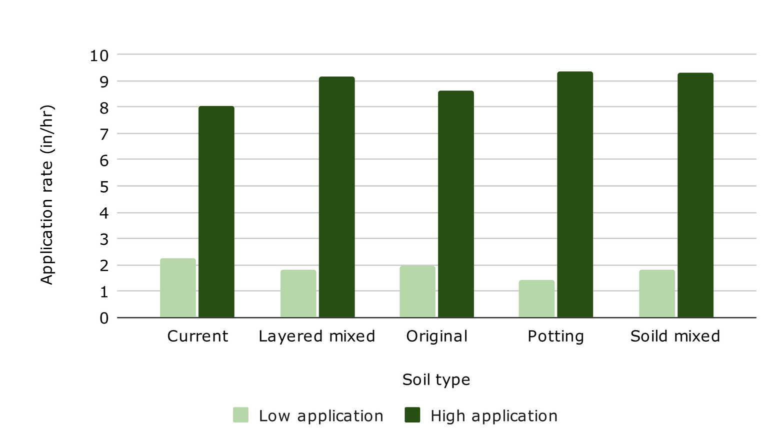


FIGURE 4 - Water retention

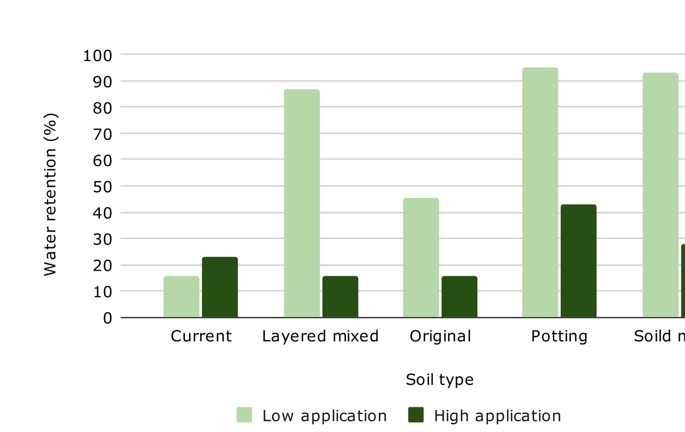


FIGURE 5 - Input vs. output rate

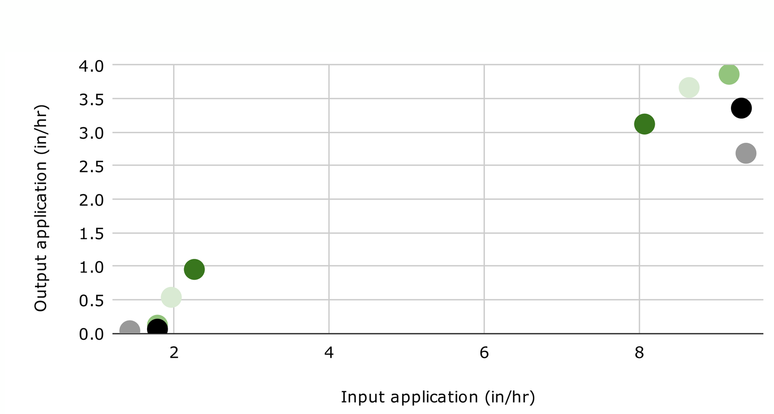
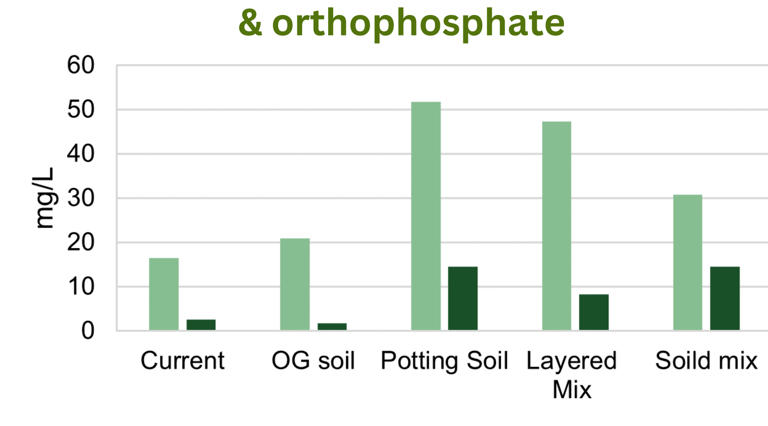


FIGURE 6 - Average nitrate & orthophosphate



RESULTS (CONTD.)

Figure 3 illustrates how various soil types (current, layered mixed, original, potting, and solid mixed) retain rainwater under high and low application conditions. The results show that in low application conditions (≤2.25 in/hr of simulated rainfall), layered mixed, potting, and solid mixed soils all retained 85% or higher of the water input into its substrate under low application conditions. In contrast, the current and original soil retained less than 50% of the water input into its substrate under the same conditions. The results show that — under a low application rate — potting, layered mixed, and solid mixed soils had a substantially higher rate of water retention than its current and original counterparts.

Figure 4 illustrates the rate of retention (as a percentage) of the same soils under high application conditions (≥7 in/hr of simulated rainfall). The results demonstrate that layered mixed and original soils retained <20% of the water input into its substrate, compared to much higher rates of retention (>20%) found in the current, potting, and solid mixed soils.

Figure 5 compares the experimental soil types under different application rates (low vs. high) to the total stormwater runoff collected (in/hr). In terms of grouping, the lower left cluster displays the experimental soils under low application conditions, and the upper right cluster displays the experimental soils under high application conditions. Under low application conditions, less than 0.11in/hr of simulated rainfall was collected in the layered mixed, potting, and solid mixed soils. Under the same conditions, the original and current soils resulted in a collection of ≥0.5 in/hr of simulated stormwater runoff. In terms of a high application rate, >3in/hr of simulated stormwater was collected in all of the experimental soils with the exception of potting soil alone having an average of 2.6in/hr of collected simulated stormwater.

Figure 6 compares the current and original soil concentrations of nitrate and orthophosphate in the runoff water. The findings show that the current and OG soil have the least amount of contaminates in the water runoff.

CONCLUSION

To enhance stormwater management, Portland State could consider rotating the soil in their green roofs to minimize runoff and maximize retention. We found that adding a layer of potting soil on top of the existing soil could provide similar benefits, as demonstrated by the efficacy of layered mixed soil in retaining water and mitigating runoff.

Our experiment underscores the potential of green roofs as natural filters for stormwater, suggesting that with the right soil mix, they can effectively reduce common pollutants. The evolved current soil, enriched by natural processes, exhibits a lower contamination rate compared to the original soil. This progress highlights the role of green roofs in reducing the amount of stormwater runoff and improving runoff water quality. Further research into soil substrate optimization could establish green roofs as a standard in urban environmental management.

BIBLIOGRAPHY

All sources for this experiment can be found by scanning the QR code.