Storm Water Runoff on Residential Green Roof Systems

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Abstract

Green roofs have become a popular mechanism of reducing storm water runoff. In order to determine the runoff retention potential of a residential green roof system, eighteen shingled roof models were constructed at three different slope angles, 1˚, 20˚ (5/12), and 40˚ (10/12). A modular green roof system designed for residential roofs was installed on nine of the roofs. The roof models were divided into three replications in a completely randomized design. Each replication includes two roof models at each slope angle, one of which is fitted with a green roof and the other is a conventional shingled roof model. The green roof models were planted with mixed plantings of seven *Sedum* species: *S. kamtschaticum*, *S. reflexum*, *S. sexangulare*, *S. album*, *S. spurium*, *S. floriferum* 'Weihenstaphaner Gold', and *S. immergrunchen*. Gutters were installed on each of the roof models, and barrels were placed at the ends of the gutters in order to collect storm water runoff. After each precipitation event, the amount of runoff in each barrel was measured, and the amounts collected for each roof model were compared. Out of the fifteen dates sampled initially in this study, more runoff was collected from the control roofs on nine of the dates compared to runoff from the green roof models. In addition, storm water runoff was different between different roof pitches on five of the monitoring dates.

Introduction

Urban areas are faced with numerous environmental challenges, especially as they increase in size and become more populated. One challenge is the management of storm water. Due to the large area of impervious surfaces common to urban areas, storm water is largely unable to infiltrate back into the ground and is instead directed into local waterways, carrying various pollutants with it and increasing flood risks. New technologies have been developed in order to help alleviate this problem. Green roofs, which are rooftops that have been modified to support plant growth, are an example of such a technology.

Much research has been done demonstrating the benefits of green roofs on commercial and industrial buildings. Green roofs have been demonstrated to reduce storm water runoff as well as reduce the thermal flux of a building (Laar and Grimme 2006). New green roof studies are now being directed towards residential buildings. In our research, we are evaluating a modular green roof system designed for residential roofs in order to determine its ability to retain storm water runoff.

Methods

Eighteen shingled roof models (8 feet by 4 feet) were constructed at three slope angles, 1˚, 20˚ (5/12 pitch), and 40˚ (10/12 pitch). Each roof is replicated three times in a completely randomized design (Figure 1). Each replication includes two roofs at each slope angle, one of which is fitted with green roof modules and the other left as a conventional shingled roof. The green roof modules are high-density polyethylene knit fabric bags called Steep Paks®, which were designed by Green Roof Blocks™, a company based in St. Louis, Missouri. The bags measure 10 inches by 32 inches and are filled with a blended expanded clay medium (arkalyte). Mixed plantings of seven *Sedum* species (*S. kamtschaticum*, *S. reflexum*, *S. sexangulare*, *S. album*, *S. spurium*, *S. floriferum* 'Weihenstaphaner Gold', and *S. immergrunchen*) were planted in the Steep Paks® in early September 2009.

Gutters were installed on each of the roof models in August –September 2010. Eighteen 55-gallon barrels were cut in half, fitted with plywood lids, and placed at the ends of each of the gutters in order to collect runoff (Figure 2). Two glass rain gauges were installed at the site to monitor the amount of precipitation. After each precipitation event, a meter stick was used to measure the amount of water in each barrel. A regression line was constructed to convert the runoff measurements into liters. This analysis includes fifteen measurements taken between September 24, 2010 and January 30, 2011 (Figure 3). A one-way ANOVA for a completely randomized design was used to test for differences between the roof decks. A Tukey's post-hoc test was used to rank the differences at an alpha level of 0.05 (Proc GLM, SAS version 9.2). SigmaPlot version 8.0 was used to graph the results.

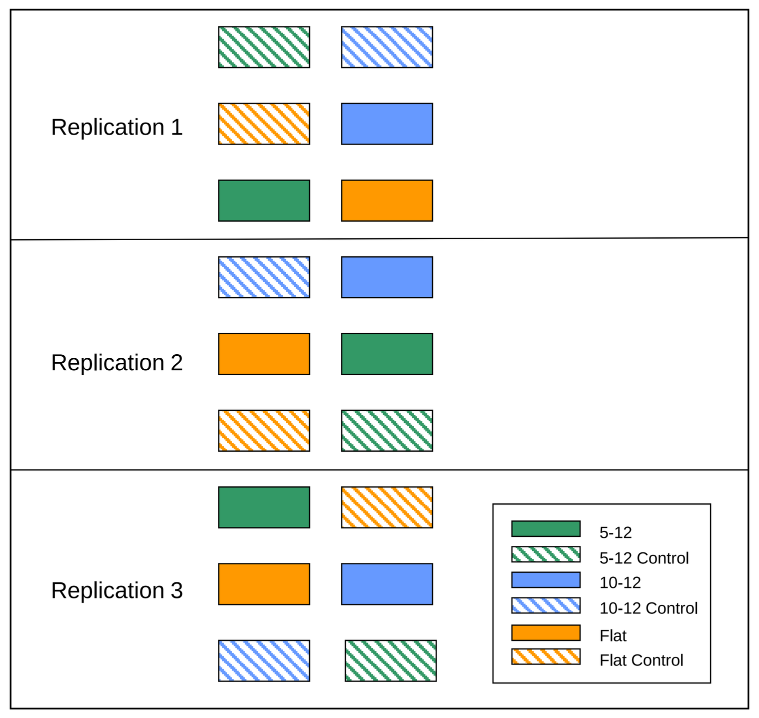

Figure 1. Experimental layout of residential roof models.

Figure 2. Residential green roof models at SIUE Environmental Science field site.

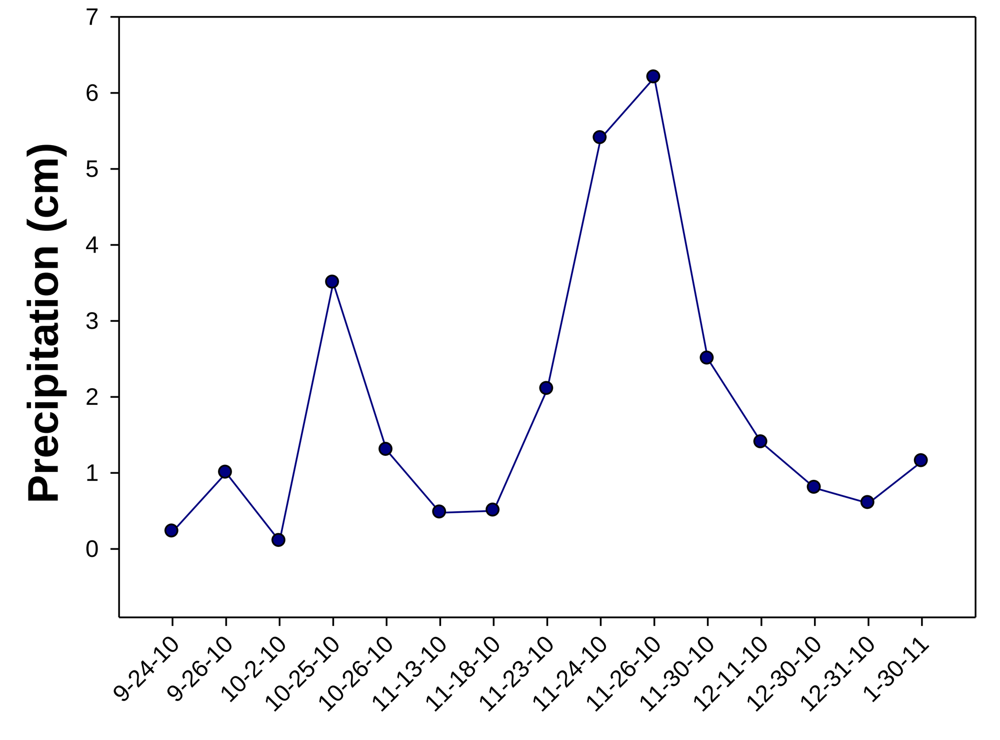

Figure 3. Precipitation measurements taken at the field site before each storm water runoff measurement.

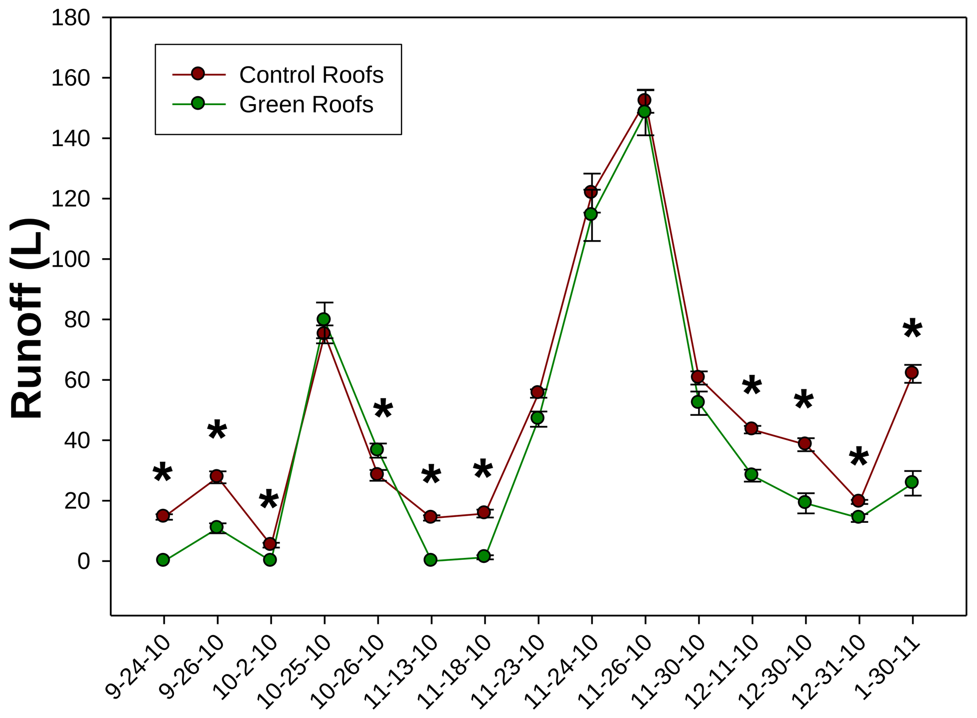

Figure 4. Mean amounts of storm water runoff (L) collected from green roofs and control roofs for fifteen precipitation events. (*) indicates a significant difference between roof types at p<0.05 level.

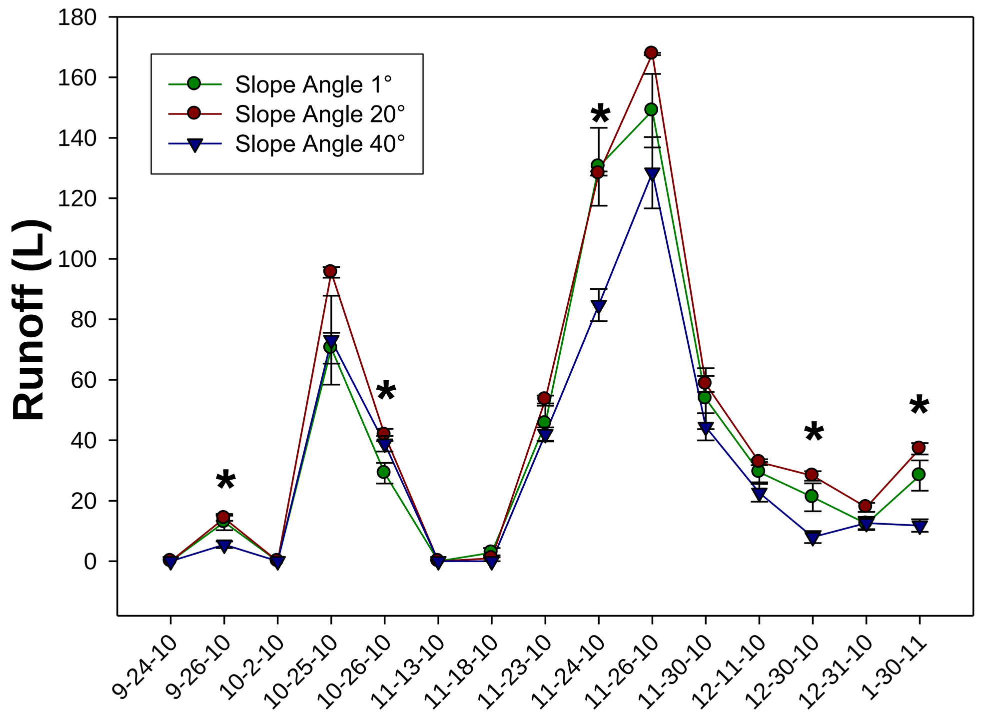

Figure 5. Mean amounts of storm water runoff (L) collected from green roofs for fifteen precipitation events. (*) indicates a significant difference between slope angles at p<0.05 level.

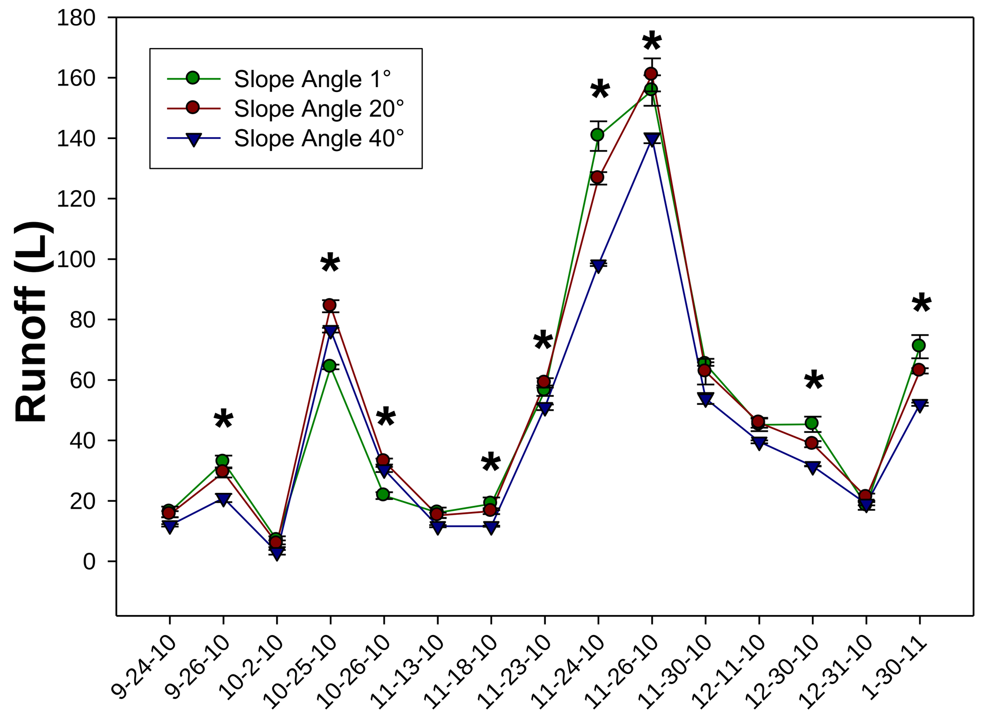

Figure 6. Mean amounts of storm water runoff (L) collected from control roofs for fifteen precipitation events. (*) indicates a significant difference between slope angles at p<0.05 level.

Discussion

Significantly less runoff was collected from the green roofs compared to the control roofs on nine of the fifteen dates (Figure 4). On October 26, significantly more water was collected from the green roofs compared to the control roofs. This could be because the Steep Paks® may not have finished draining from the rain event that occurred before the previous measurement (October 25); furthermore, their ability to retain water may have been reduced due to saturation. This is further evidenced by the fact that the five measurements where there was no significant difference between roof types were taken after rain events greater than 2 cm (Figure 3). Thus, once the Steep Paks® become saturated, they are less effective at reducing runoff. Similar studies have found that the ability of a green roof to retain storm water is reduced with increasingly heavier rainfalls (VanWoert, *et al.* 2005).

When comparing the slope angles of the green roofs, differences between the amount of runoff collected between the slope angles occurred on five of the measurement dates (Figure 5). On three of these dates, more runoff was collected from the 20° slope angle compared to the other two slope angles. On the other two dates, more runoff was collected from the 1° and 20° slope angles compared to the 40° slope angle. This is different from what has been demonstrated in other studies in which storm water retention decreased as slope angle increased (Getter *et al.* 2007). This may be partially explained by comparing the slope angles of the control roofs, in which there were significant differences between the slope angles on nine of the measurement dates (Figure 6). On seven of the nine dates, the least amount of runoff was collected from the 40° slope angle, which suggests that it may be intercepting less precipitation due to its steep angle. As Getter *et al.* (2007) point out, the horizontal area upon which precipitation falls is reduced by increasing slope angle. In addition, rainfall direction, intensity, and duration, as well as the initial moisture content of the growing medium all play a role in the storm water retention rate of a green roof system (Bliss, *et al*. 2009).

Conclusion

The Steep Paks® residential green roof modules were demonstrated to retain more storm water during nine of fifteen precipitation events compared to control roof models. The amount of runoff collected from the Steep Paks® was similar to the amount of runoff collected from the control roofs after rainfalls greater than 2 cm. When green roof slope angles were considered, the 40° slope angle retained the least amount of storm water on four out of fifteen dates. The 40° slope angle was also demonstrated to retain the least amount of storm water on seven of the fifteen dates for the control roof models. This suggests that the steeper slopes may be intercepting less storm water. In conclusion, the Steep Paks® residential green roof modules are an effective mechanism of reducing storm water runoff, especially during light rain events.

References

Bliss, D.J., R.D. Neufeld, and R.J. Ries. 2009. Storm water runoff mitigation using a green roof. Environmental Engineering Science 26:407-417.

Getter, K.L., D.B. Rowe, and J.A. Andresen. 2007. Quantifying the effect of slope on extensive green roof stormwater retention. Ecological Engineering 31:225-231.

Laar, M. and F.W. Grimme. 2006. Thermal comfort and reduced flood risk through green roofs in the tropics. PLEA2006: 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland. September 2006.

VanWoert, N.D., D.B. Rowe, J.A. Andresen, C.L. Rugh, R.T. Fernandez, and L. Xiao. 2005. Green roof stormwater retention: Effects of roof surface, slope, and media depth. Journal of Environmental Quality 34:1036-1044.