



# Thermal Flux of Residential Green Roof Systems

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## Abstract

Green roofs have been demonstrated to reduce the thermal flux of a building, thus reducing energy demand and the need for space conditioning. In order to determine the thermal performance 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 roof models. 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. 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*. Temperatures of the undersides of each of the eighteen roof decks were monitored at midday once a month for 13 months. We have determined that the green roofs were significantly cooler than the control roofs for each month during this study period. In addition, there are thermal differences due to roof slope in the control and green roof models.

## Introduction

Green roofs are roofs that have been modified to support plant growth. Benefits of green roof technology include mitigating storm water runoff, increasing the lifespan of a roof, adding to the aesthetics and biodiversity of an urban area, reducing the urban heat island effect, and reducing the energy use of a building (Liu and Baskaran, 2003). Much of the scientific research involving green roofs has been focused on commercial and industrial buildings, however, residential buildings can experience the benefits of green roofs as well.

One major concern for homeowners is rising energy costs. Installing a green roof has been shown to reduce the energy demand of a building by moderating the thermal fluctuation (Liu and Baskaran, 2003). In our research, we are evaluating the thermal performance of a modular green roof system designed for residential roofs.

## Methods and Materials

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 (Figures 1 and 2). Each replication includes two roofs at each slope angle, one of which is fitted with a green roof module 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 an 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.

After planting the roofs, we began recording the temperatures of the undersides of the roof decks on a weekly basis using an infrared thermometer. Temperatures were recorded for each of the roofs once every week at midday for thirteen months (September 2009 – September 2010). For this analysis, we used one of the midday observations from each of the thirteen months.

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.

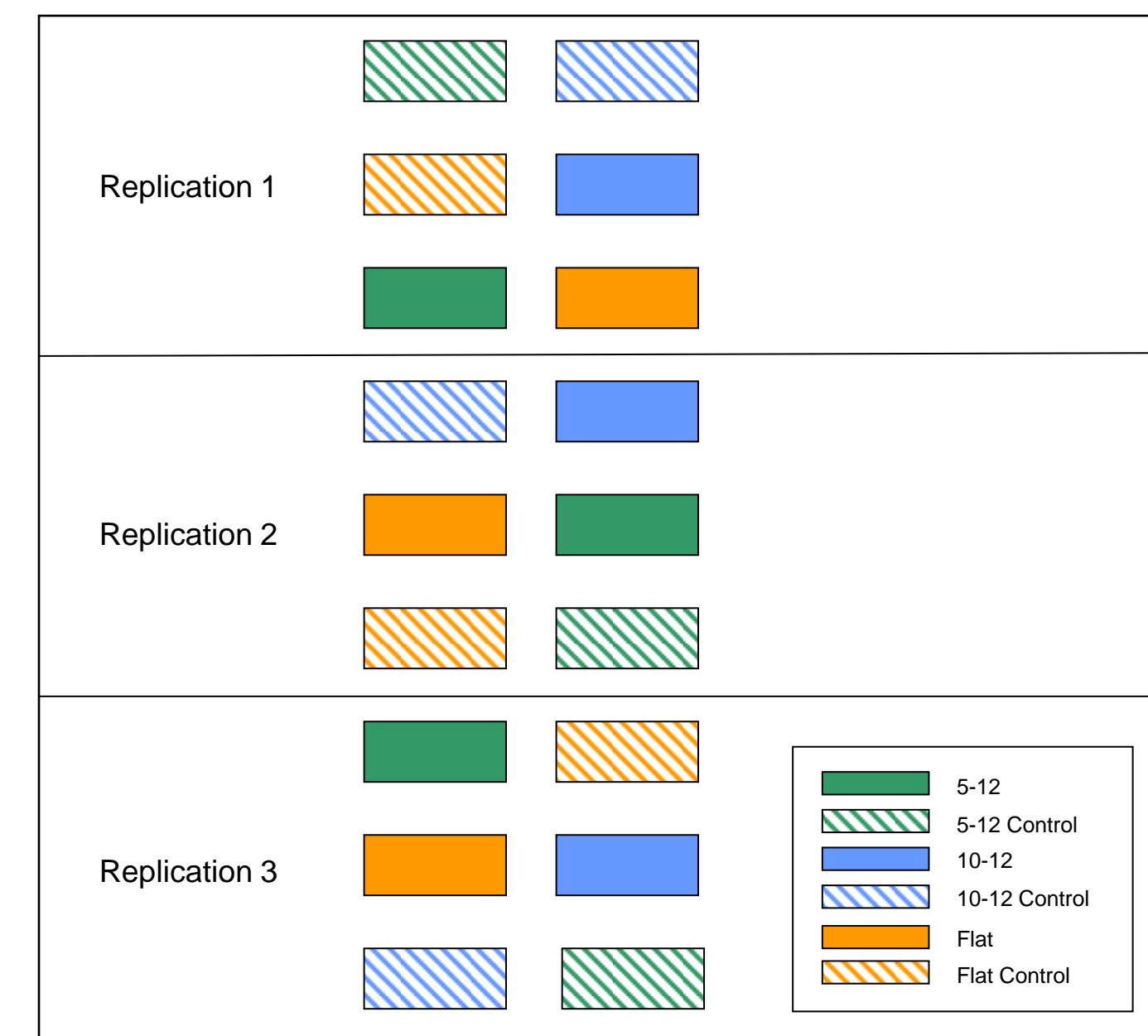


Figure 1. Experimental layout of residential roof models.

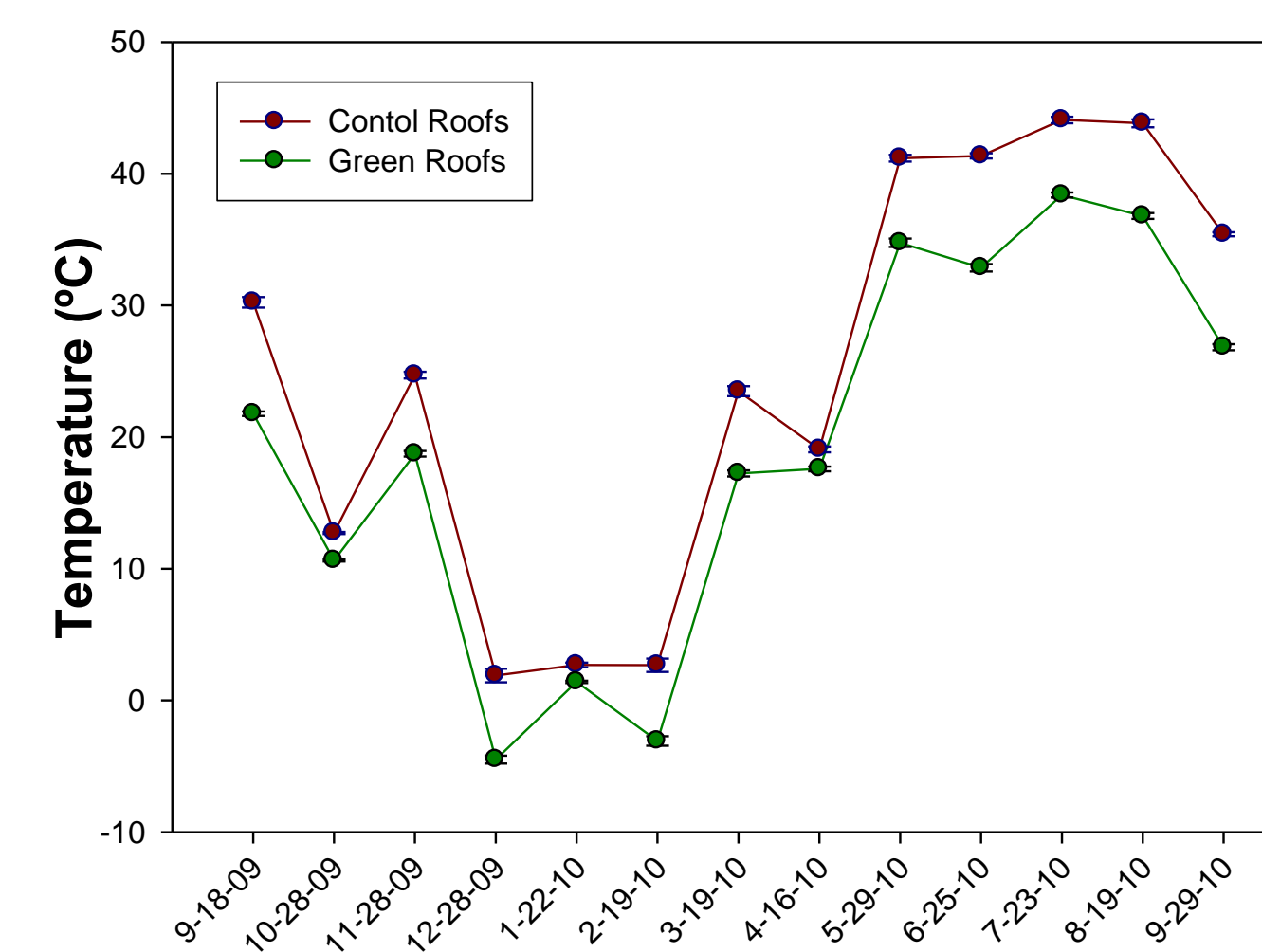


Figure 3. Mean temperatures of the undersides of the shingled roof decks and green roof decks at midday for a single monthly measurement, September 2009 – September 2010. All data points are significantly different at p<0.05 level.

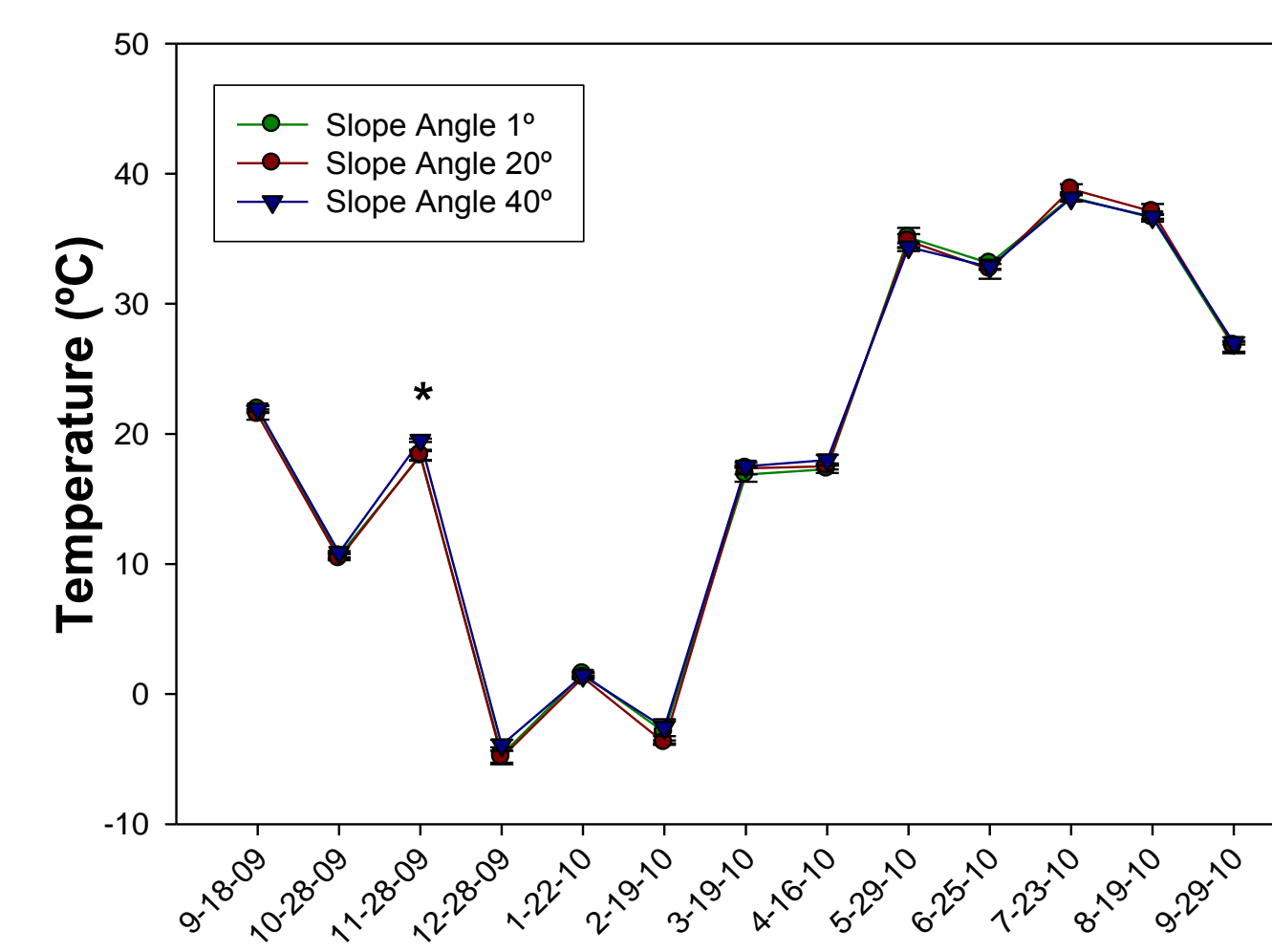


Figure 4. Mean temperatures of the undersides of the green roof decks of each slope angle at midday for a single monthly measurement, September 2009 – September 2010. \* indicates data points significantly different at p<0.05 level.

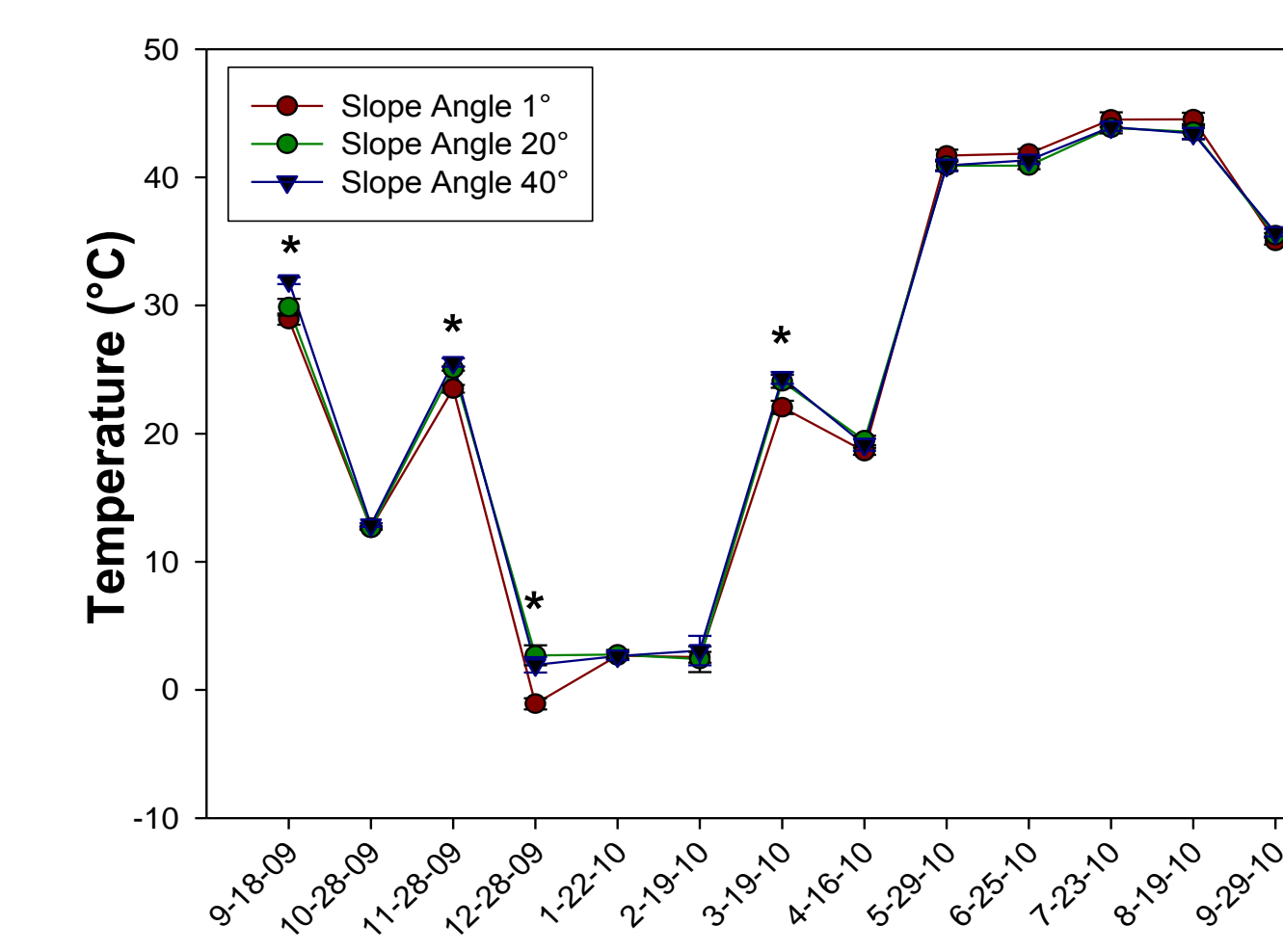


Figure 5. Mean temperatures of the undersides of the control roof decks of each slope angle at midday for a single monthly measurement, September 2009 – September 2010. \* indicate data points significantly different at p<0.05 level.



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

## Discussion

The results demonstrate that the undersides of the green roof decks were significantly lower in temperature compared to the undersides of the control roof decks for each of the thirteen observations (Figure 3). This suggests that the green roof modules have an insulating effect on the roofs. Because the temperatures were taken at midday, the green roof modules may also be mitigating a warming effect as temperatures rise from sunrise to midday, which has been demonstrated in other studies where green roofs were shown to maintain a more consistent temperature during a 24 hour period compared to conventional roofs (Sidwell *et al.*, 2008).

When comparing the slope angles of the green roofs, a significant difference in temperature of the undersides of the roof decks was exhibited in only one observation: the flat roof and the 20° roof in the November observation (Figure 4). When comparing the three slope angles, the undersides of the control roof decks showed significant differences in temperature in four out of the thirteen months (Figure 5). In each case, it was the flat roof (1° slope angle) that was significantly cooler than the two pitched roofs. These differences in temperature were expected because all the roof models in the experiment face South, allowing roof decks with larger pitches (20° and 40°) to receive a greater intensity of sunlight compared to the flat roof decks and thus causing the undersides of the roof decks to become significantly warmer. The green roofs, however, appeared to maintain a more consistent temperature regardless of pitch.

## Conclusion

The newly planted Steep Paks® residential green roof modules were shown to reduce the temperature of the undersides of the model roof decks at all three slope angles, 1°, 20° (5/12 pitch), and 40° (10/12 pitch).

When comparing slope angles, the undersides of the decks of the 1° slope angle (flat roof) was significantly cooler in four out of thirteen observations for the control roofs and one out of thirteen observations for the green roofs.

These results suggest that Steep Paks® residential green roof modules help maintain cooler roof temperatures which could result in energy savings for a homeowner during warm months. It should be noted that since the roof temperatures were cooler in the winter months as well, this could mitigate energy savings. Further research would need to be done to estimate overall energy use on an annual basis to see if the thermal effectiveness of the green roof system would be cost effective.

## References

- Liu, K. and Baskaran, B. Thermal performance of green roofs through field evaluation. Institute for Research in Construction. 1-15. (2003).
- Sidwell, A., Gibbs-Alley, J., Forrester, K., Jost, V., Luckett, K., Morgan, S., Yan, T., Noble, B. and Retzlaff, W. 2008. Evaluation of the thermal benefits of green roof systems.