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Green Roofs in the Desert: Comparing Grass with Lavender

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Abstract

Green roofs are an exciting development in modern architecture. Although they have been used throughout history, they are seeing a resurgence as a way to aid in insulation in buildings passively. Since they are a fairly new topic of modern research, there is little information on different plant types for green roofs in desert climates. This paper measures and compares differences between two types of plants for green roof application, grass, and lavender. These two plants will be tested in multiple categories to determine their strengths and weaknesses compared to each other. This paper shows the benefits of choosing one type of plant over another by thoroughly analyzing multiple variables. The tested variables are interior temperature, water use, drought tolerance, initial cost, soil loss, growth, and potential future growth. This paper identified soil as the primary component of insulation in green roofs. Grass and lavender are evenly split on advantages and disadvantages. However, lavender would be a better choice in a desert climate due to its higher drought tolerance and lower water use.

Introduction

Green roofs are an effective way to reduce solar gain on the roof of a building, which can lower its energy costs by lowering the change in temperature required for a building to stay at a comfortable temperature. There are many different styles of green roofs to choose from, for example, whether they are fully covered in plants, what type of plants, or if they are walkable and serve as a patio. In many cities, a lack of greenery is noticeable. There is no room for parks or other green spaces, so we turn to the only available space left, the roof. There are many benefits to green roofs other than reducing energy consumption. Green roofs also clean the air, provide pleasant scenery, aid in resting places for animals and pollinators, provide storm runoff, and cool the area around the building, reducing the urban heat island effect. Green roofs in arid climates are rare, and the few built are typically sparsely planted and act more as rooftop yards. Grass roofs in arid climates may not be the wisest choice due to grass' high water consumption and short lifespan. The harsh summer sun might also burn the grass blades, preventing further growth and requiring reseeding multiple times a year. Roofs with lavender or other arid tolerant species might work better for projects meant to last longer. Lavender also has other added benefits, such as providing pollen and shelter to native animals.

Research Questions

This research paper aims to answer the question of what type of plant is best for green roofs in desert conditions and how effective green roofs are. What plant keeps the temperature lower during the day and warmer at night? What is the difference in temperature between a building with and without a green roof? What plant uses less water and is more resilient to drought? What plant holds soil better? Will plant growth need to be managed?

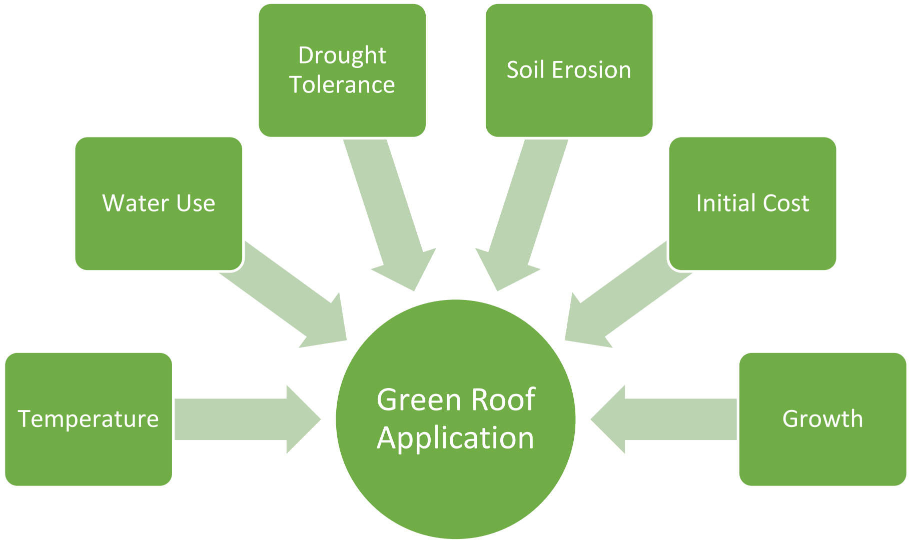
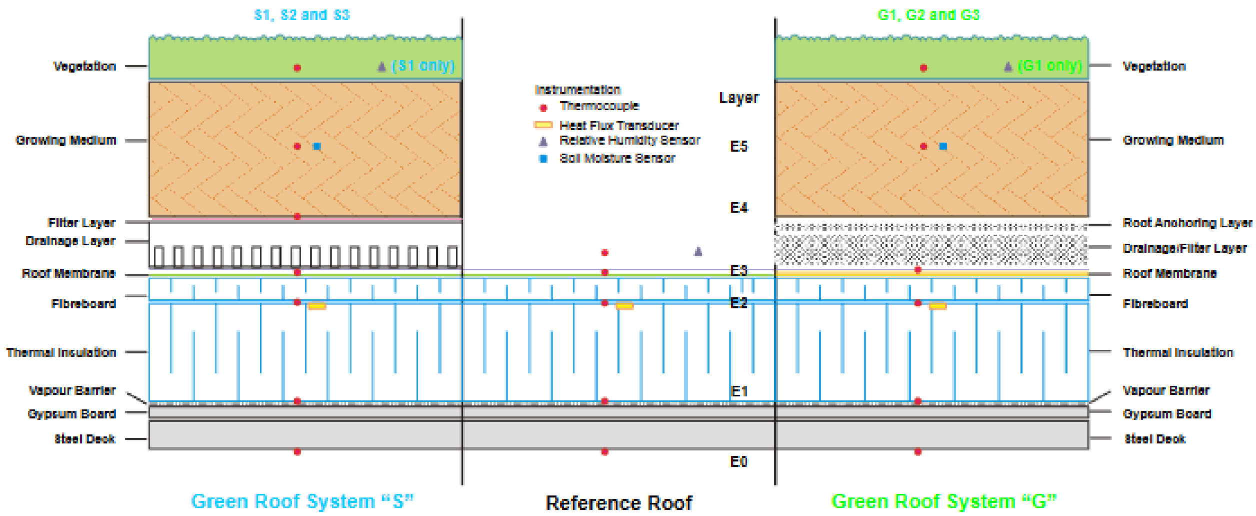


Image 1: Conceptual framework of variables to measure when looking into green roof creation.

Literature Review

Performance Evaluation of an Extensive Green Roof

In Toronto, Canada, green roofs were installed and measured compared to a standard roof. They were equipped with several advanced sensors and measured over an extended period. The green roofs "reduced the heat flow through the roof by 70-90% in the summer and 10-30% in the winter" (Liu). The roofs used different plant mediums. The lighter-colored medium functioned better in the summer, reducing temperatures drastically. In contrast, the second medium was more beneficial in the winter because it had higher insulation values due to its darker coloration. This finding can also be seen in modern buildings in desert cities. Often the rooftops are a light color to help reflect solar gain. On top of this, the researchers suggested that green roofs could reduce aging and thermal stress in buildings, helping them last longer without repairs or maintenance. The ultra-violet waves from the sun would have difficulty penetrating the deep growth medium and reaching the exposed rooftop.



Literature image 1: shows the vast amount of detail and sensors that went into this project (Liu)

Analysis of the green roof thermal properties and investigation of its energy performance

In this study, researchers investigated how green roofs dissipate thermal energy compared to standard roof materials. They used infrared imagery to see the temperature difference between the green roofs and insulated or non-insulated roofs. The green roofs lowered the maximum air temperature inside the building by 2 degrees Celsius (Niachou). The green roofs provide excellent insulation for buildings without insulated roofs and are still useful for already insulated roofs. The researchers concluded, "The surface temperature of the green roof varies according to the different kind of vegetation, which exists in the various places. Lower temperatures are measured in the spaces, which are covered by thick dark green vegetation and higher in the spaces, which are covered by sparse red vegetation or only soil" (Niachou).

Performance evaluation of green roof and shading for thermal protection of buildings

This research evaluated the effectiveness of various aspects of the green roof. Foliage height and thickness directly correlate to canopy air temperature, which in turn leads to a cooler roof temperature and a cooler internal temperature during the day. "Heating flux entering green roof with a foliage height of 0.6 m is 1.94 Wh m−2 (6984 J) and this increased further by nearly 4 times (14,400 J) Wh m−2 for the bare roof" (Kumar). Even a small height in canopy cover, just under 2 feet, is enough to massively reduce the heating flux of a roof. The green roofs in this study reduced indoor temperatures by an average of 5.1 degrees Celsius.

Invertebrates on green roofs

Green roofs can support other native life, such as pollinating bugs or arthropods to keep unwanted pests away. Flowering plants are more commonly seen with invertebrate life than typical grass roofs. The roofs also provide a large and diverse habitat. They are a way to help mitigate habitat loss through urban expansion, though "green roofs do not compensate for habitat lost at ground level when a building is constructed" (MacIvor). Invertebrates can colonize green roofs virtually, whether by already being in the soil or plant material, flying, climbing, or wind. These creatures enhance the local food web, benefiting the community. As invertebrate populations increase due to more green roofs being constructed, insectivores such as lizards and frogs will also become more prevalent in the community. Biophilia is the innate human love for nature. Humans also grow happier passively by increasing the food web and green space. However, this requires a large connection of green roofs to achieve, and there needs to be green space on the ground for these other animals to survive.

Adapting a Green Roof in Tucson, Arizona

Because of Tucson's, desert climate, green roofs are challenging to implement. With an average precipitation of 11.9 inches and large temperature fluctuations throughout the seasons, finding a plant that can survive in these with only 4-12 inches of soil is difficult (Cutter). Many plants were listed in this research, including red yucca and plains prickly pear. The yucca has a large profile and would effectively reduce the heat in an area, but its wide root system would hinder other plants on the roof. Prickly Pear also seems like a wise choice, but the fruit that it grows would need to be removed else it would rot and potentially poison the green roof since it is an isolated 'island' that does not have many ways for harmful material to be removed.

Application of a Green Roof on the College of Architecture, Planning, and Landscape Architecture

This research focuses on the cost and energy savings of green roofs. "Extensive roofs have a thin layer of soil, may grow succulents, mosses, and other vegetation, and are self-sustaining" (Horn). The extensive green roof is the ideal style of green roof for Arizona. The thin soil can work well with drought-resistant vegetation. However, the energy savings from insulation might not balance out with the cost of a green roof, so public benefits such as a place to hang out, biophilia, and environmental benefits will need to be used for potential green roofs. Since green roofs are a rarity in desert climates, these benefits will need to outweigh the water use. Highly drought-tolerant plants should be used in future green roof projects.

Methods

Three plywood boxes were constructed using screws and hinges as connecting points. The boxes measure 1ft by 1ft by 1.5ft. The front and back panels of the box are 1ft x 1ft squares of plywood, approximately 1/8 inch thick. The back is screwed into place and immovable, while the front is attached to the left side panel by a hinge, allowing the entire front panel to swing freely like a door. The side, top, and bottom panels measure 1ft x 1.5ft. However, the top of the box, or the roof, is set down approximately 4 inches from the top of the walls, creating a pocket for soil to be placed. This pocket slopes down ¼ of an inch as it heads towards the back of the box, helping to drain the water used for the plants. Thermometers are placed in all three boxes, and a fourth thermometer is placed on the ground nearby. Since this is a short-term project, waterproofing the boxes was unnecessary, so no tarp or rubber paint was used. The boxes are placed 2 feet apart from each other, and they are orientated so that the door faces east to minimize the solar exposure to the long sides. They are placed in the middle of a large yard without any shade other than the yard’s walls, so they currently receive around 10 hours of sunlight a day.

The soil was poured into two of the boxes until it reached the top of the walls. This is approximately .5 cubic feet of soil per box. The soil used was a raised garden bed soil due to its water-absorbing capabilities. The cost of the soil is around $5 per cubic foot. The plants used were a fast grass seed, costing around $1 per square foot, and lavender plants, costing $12 per square foot. Lavender was chosen to see if there was a difference in temperature for flowering, low water plants that are more beneficial to the environment versus standard grass. Also, lavender is a lighter color and has a drastically different profile than grass, which was thought to lead to different temperatures. Ideally, a plant called Ruschia ‘Nana’, also known as Dwarf Carpet of Stars, would be a better drought-tolerant comparison against the grass. However, I could not find it in Tucson, and it takes far longer to establish fully.

The temperature of each thermometer was measured three times a day, in the morning, afternoon, and after sunset. These measurements were put into an excel file and charted against each other. The temperatures were measured over 31 days to ensure temperature trends were captured accurately.

Image 2 and 3: the soil and grass seed that were aquired for the project

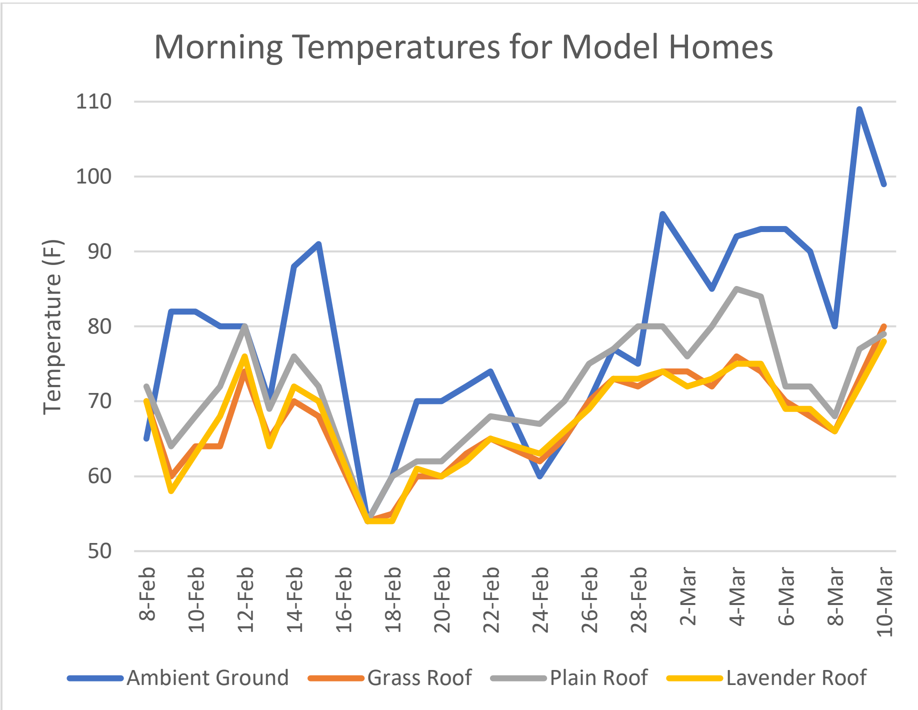
Image 4: Photo of the model homes

Image 5: photo of the grass roof before growth

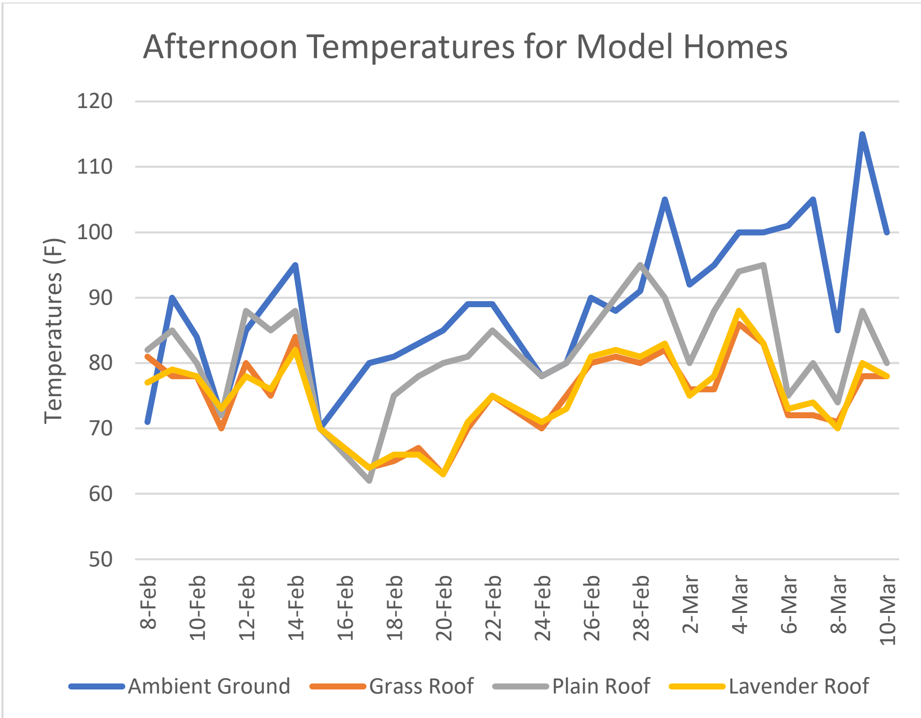
Image 6: Photo of the lavender roof

Data and Results

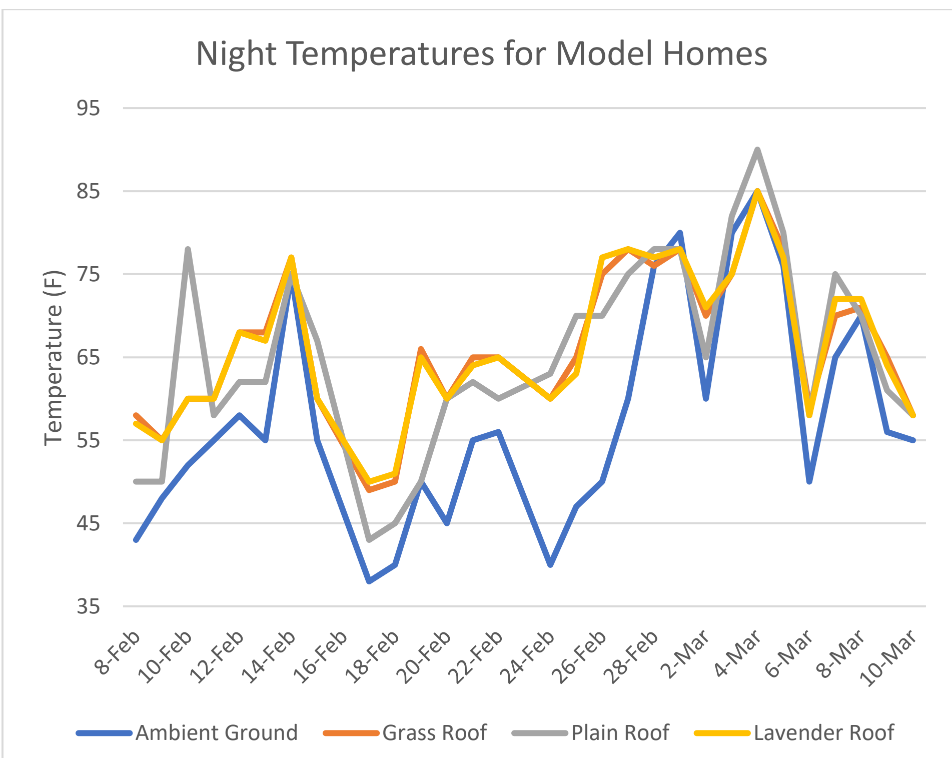
Graphs 1 through 3 show the temperatures taken during the morning, afternoon, and evening through the 31 days. It rained on two days during the test, so February 16 and 23 are omitted from the data. As seen in the graphs, the grass and lavender roofs are insulated at around the same rate, often having the same temperature and never deviating more than 2 degrees Fahrenheit. A key plot on these graphs is the plain roofline. It is almost always above the two green roofs during the morning and afternoon and deviates sharply from its day temperatures at night. The green roof temperatures changed less throughout the day, proving that the insulating features of green roofs is true. Further below in this section, the raw data is listed in temperature tables.



Graph 1: Morning Temperatures of model homes compared to ambient temperature

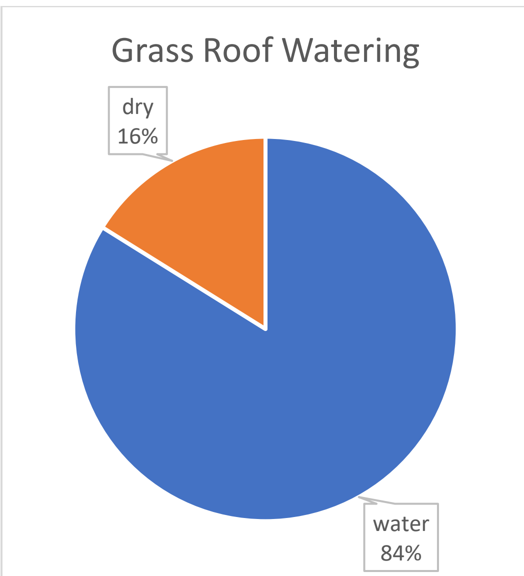


Graph 2: Afternoon Temperatures of model homes compared to ambient temperature



Graph 3: Nighttime Temperatures of model homes compared to ambient temperature

As seen in the charts below, lavender was watered far less than the grass was. The grass was watered every day until it was established and then was watered 6 out of 7 days of the week. If the grass went for more than one day without water, it would visibly be folding and yellowing. It only lasted one week without water. This may be because of the cheap grass used, but most grasses are not drought tolerant and require a lot of water. The lavender plants functioned much better without water, and were only watered on every 4th day. After the temperature measurements were completed, the lavender went over a week without water and bounced back after two days of consistent watering. It only started changing visibly on the 7th day of the drought.



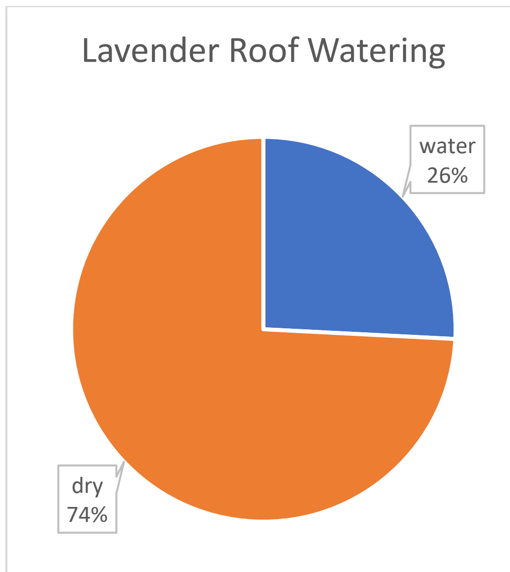


Chart 1 and 2: Percentage of days where the plants received water

The cost of the green roofs differed drastically, with the lavender green roof costing 12 dollars per square foot and the grass roof only costing 1 dollar per square foot. This initial heavy cost can be offset by the water saved with a drought-resistant plant such as lavender.

The grass roof lost no soil over the month since the grass covers all the soil with a protective net of blades. The grassroots also start much higher in the topsoil and act like anchors, keeping the soil in place. The lavender plants lost around half an inch of soil to wind over the month. Lavender roots are deeper, and since the plants were more spread out, more soil was left unanchored and exposed. A solution to this problem would be to purchase mesh netting to keep the soil in place.

The grass grew to a total height of 3 inches. It then fell over itself and got tangled. The lavender grew to a total height of 8 inches, growing 4 inches in a month. The lavender has also started to flower, attracting pollinators to the roof.

Ambient	Morning	Afternoon	Night
8-Feb	65	71	43
9-Feb	82	90	48
10-Feb	82	84	52
11-Feb	80	72	55
12-Feb	80	85	58
13-Feb	70	90	55
14-Feb	88	95	75
15-Feb	91	70	55
16-Feb			
17-Feb	54	80	38
18-Feb	60	81	40
19-Feb	70	83	50
20-Feb	70	85	45
21-Feb	72	89	55
22-Feb	74	89	56
23-Feb			
24-Feb	60	78	40
25-Feb	65	80	47
26-Feb	70	90	50
27-Feb	77	88	60
28-Feb	75	91	76
1-Mar	95	105	80
2-Mar	90	92	60
3-Mar	85	95	80
4-Mar	92	100	85
5-Mar	93	100	76
6-Mar	93	101	50
7-Mar	90	105	65
8-Mar	80	85	70
9-Mar	109	115	56
10-Mar	99	100	55

Table 1: Ambient ground temperature

Grass	Morning	Afternoon	Night
8-Feb	70	81	58
9-Feb	60	78	55
10-Feb	64	78	60
11-Feb	64	70	60
12-Feb	74	80	68
13-Feb	65	75	68
14-Feb	70	84	77
15-Feb	68	70	60
16-Feb			
17-Feb	54	64	49
18-Feb	55	65	50
19-Feb	60	67	66
20-Feb	60	63	60
21-Feb	63	70	65
22-Feb	65	75	65
23-Feb			
24-Feb	62	70	60
25-Feb	65	75	65
26-Feb	70	80	75
27-Feb	73	81	78
28-Feb	72	80	76
1-Mar	74	82	78
2-Mar	74	76	70
3-Mar	72	76	75
4-Mar	76	86	85
5-Mar	74	83	78
6-Mar	70	72	59
7-Mar	68	72	70
8-Mar	66	71	71
9-Mar	73	78	65
10-Mar	80	78	58

Table 2: Grass Roof interior temperature

Plain	Morning	Afternoon	Night
8-Feb	72	82	50
9-Feb	64	85	50
10-Feb	68	80	78
11-Feb	72	72	58
12-Feb	80	88	62
13-Feb	69	85	62
14-Feb	76	88	75
15-Feb	72	70	67
16-Feb			
17-Feb	54	62	43
18-Feb	60	75	45
19-Feb	62	78	50
20-Feb	62	80	60
21-Feb	65	81	62
22-Feb	68	85	60
23-Feb			
24-Feb	67	78	63
25-Feb	70	80	70
26-Feb	75	85	70
27-Feb	77	90	75
28-Feb	80	95	78
1-Mar	80	90	78
2-Mar	76	80	65
3-Mar	80	88	82
4-Mar	85	94	90
5-Mar	84	95	80
6-Mar	72	75	58
7-Mar	72	80	75
8-Mar	68	74	70
9-Mar	77	88	61
10-Mar	79	80	58

Table 3: Plain Roof Interior Temperatures

Lavender	Morning	Afternoon	Night
8-Feb	70	77	57
9-Feb	58	79	55
10-Feb	63	78	60
11-Feb	68	73	60
12-Feb	76	78	68
13-Feb	64	76	67
14-Feb	72	82	77
15-Feb	70	70	60
16-Feb			
17-Feb	54	64	50
18-Feb	54	66	51
19-Feb	61	66	65
20-Feb	60	63	60
21-Feb	62	71	64
22-Feb	65	75	65
23-Feb			
24-Feb	63	71	60
25-Feb	66	73	63
26-Feb	69	81	77
27-Feb	73	82	78
28-Feb	73	81	77
1-Mar	74	83	78
2-Mar	72	75	71
3-Mar	73	78	75
4-Mar	75	88	85
5-Mar	75	83	77
6-Mar	69	73	58
7-Mar	69	74	72
8-Mar	66	70	72
9-Mar	72	80	64
10-Mar	78	78	58

Table 4: Lavender Roof Interior Temperatures

Conclusion

This study analyzed the impact of different green roofs- using grass, lavender, and a control- on build temperature, water use, and cost. Small model homes were constructed and planted with different materials to do so. These models were compared in multiple aspects to determine the best green roof plant material.

While measuring the temperatures of the green roofs and comparing the grass building to the lavender building, no significant temperature difference was recorded. The two plants would vary by a couple of degrees, with some days the grass building being cooler, and other days the lavender building was cooler. However, they were both far cooler than the building without the green roof.

For cost, the grass roof costs far less to set up than the lavender roof. The lavender roof is 12 times the cost of the grass roof to set up. However, this cost can be offset over time with the lower water use of the lavender plant.

Both roofs were tested for water use and drought resistance at the end of the temperature measuring cycle. They were both left without water for a week. The grass had almost all died, while the lavender was only slightly worse off than before the week. After a week of trying to revive the grass, no success was had. The lavender became as green and lively before the drought with only one watering.

General water consumption was much higher for the grass building than lavender. The grass building needed water every day or two, while the lavender roof was only watered every 3-4 days, and was capable of going longer, as shown in its drought tolerance test.

When looking at soil stability during windy conditions, the grass building lost almost no soil. Under the same conditions, the lavender building lost a decent amount of topsoil, almost half an inch before the roots of the plants were able to hold the soil. To compensate for this soil loss, a mesh or netting would need to be installed to lock in the soil.

In terms of plant growth over the 2 months of testing, the grass grew to a total height of 3 inches before getting tangled with itself and matting over. The lavender grew approximately 4 inches taller than when it was planted, to a total height of 8 inches on average. The lavender could grow to 2 feet tall with enough time, so pruning it would be recommended.

Both green roofs have their respective strengths and drawbacks. Considering water use to be the highest value variable next to temperature, the lavender green roof performed far better, and similar flowering and drought-resistant plants should be considered in future projects.

Limitations and Recommendations

Future research could utilize the same scale model methodology for a longer-term analysis. Additionally, pruning and care methods could be studied. For example, there may be ways to keep the grass from tangling with itself with minimal care, staying unmatted without constant pruning and management. Longer-term studies could also determine the impact of lavender or other flowering plants on the number of pollinators that visit the roof. Anecdotally, there has been a slight increase in bees and other insects at the site, but that could be due to the warming temperatures. Ruschia ‘Nana’ could be studied for this experiment, as it may have more desirable impacts than lavender, but due to limitations in time and funding, it could not be acquired, nor was it feasible to test due to its lengthy growth time.

In general, this study demonstrates that utilizing lavender for green roof planting is a more cost-effective strategy than native grass and provides the best benefits for reducing building temperatures while utilizing less water. Implementing lavender or other low-care green roofs in Tucson could be a way to reduce energy costs for some buildings. This is an exciting avenue for future research that can impact our building comfort and energy usage.

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