From Invader to Insulator: Buffelgrass-Based Roofing for Sustainable Desert Architecture

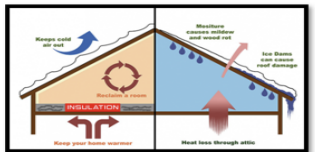
Background Research

Buffelgrass as a sustainable Insulation Material

Natural fibers are sustainable insulation alternatives with lower environmental impact. Buffelgrass, an abundant invasive plant, could be repurposed into biodegradable insulation, helping reduce its spread while providing an affordable, eco-friendly choice for desert housing. (Western Walls, n.d.).

Importance of Roof Insulation in Desert Environments

Insulation is essential for energy-efficient housing in hot desert areas like Yuma because it reduces heat tran sfer and cooling demand. (U.S. Department of Energy, n.d.). Effective roof insulation can cut energy use by up to 45%, highlighting the importance of exploring sustainable options like buff elgrass. (Bradford Insulation, n.d.).

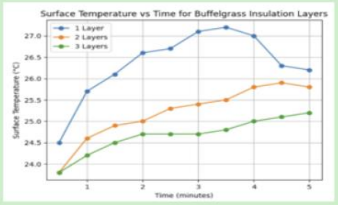


Ecological Impacts of Buffelgrass

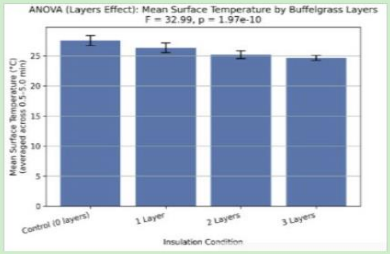
Buffelgrass spreads quickly through seeds and rhizomes, creating dense growth that pushes out native plants and raises wildfire risk (Arizona State Parks, n.d.). Because it is drought-tolerant and regrows rapidly, it is difficult to control, making repurposing it as a building material a valuable management strategy.

RESULTS

Surface Temperature per unit time



ANOVA RESULTS GRAPH



Heating Rate and Insulation Effectiveness

Number of Layers	Initial Temperature (°C)	Final Temperature (°C)	Temperature Change, ΔT (°C)	Heating Rate (°C/min)	Insulation Effectiveness (%)
1 Layer	24.5	26.2	1.7	0.38	0 (Baseline)
2 Layers	23.8	25.8	2	0.44	−17.6
3 Layers	23.8	25.2	1.4	0.31	17.6

ANOVA SUMMARY TABLE

Source of Variation	SS	df	MS	F	p-value
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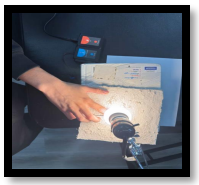
Layers (Columns)	48.1668	3	16.0556	140.0309	1.45×10^{-16}
Error	3.0958	27	0.1147	—	—
Total	65.6878	39	—	—	—

METHODS

Goal 1: Sample collection and Biomass preparation

Goal 2: Composite Panel Fabrication Procedure

Goal 3: Experimental Testing and Material Characterization



DISCUSSION

1. How does the number of Buffelgrass insulation layers affect surface temperature under simulated heat exposure?

The results indicate that increasing the number of Buffelgrass insulation layers leads to lower surface temperatures and slower heating rates. Panels constructed with more layers provided greater thermal resistance, allowing them to absorb heat more slowly. The three-layer panel performed the best, showing the smallest temperature increase ($\Delta T = 1.4$ °C) and the slowest heating rate (0.31 °C/min), demonstrating the strongest insulation capability under simulated heat exposure.

2. Does increasing the thickness of Buffelgrass insulation significantly reduce the rate of heat transfer compared to a single-layer panel?

The findings suggest that increasing insulation thickness substantially reduces heat transfer. Compared to single-layer panels, thicker Buffelgrass panels showed noticeably slower temperature increases. This pattern supports the idea that additional insulation layers improve the material's ability to limit heat movement, enhancing its overall insulating effectiveness.

3. Is Buffelgrass layer thickness a statistically significant factor in reducing surface temperature when analyzed across time using ANOVA?

Statistical analysis confirmed that Buffelgrass layer thickness is a highly significant factor affecting surface temperature. The two-factor ANOVA without replication produced a p-value below 0.001, demonstrating that variations in insulation thickness strongly influence thermal performance. Although surface temperatures increased over time due to continuous heat exposure, layer thickness remained the most influential factor in reducing heat transfer.

https://thafd.bing.com/th/id/OIP.qg64u0g8k0SBmsQov1cMLQHaFk?w=243&h=182&c=7&r=0&o=5&cb=thfvnext&dpr=1.3&pid=1.7

From Invader to Insulator: Buffelgrass-Based Roofing for Sustainable Desert Architecture

Sustainability and Energy Change

Introduction

Context:

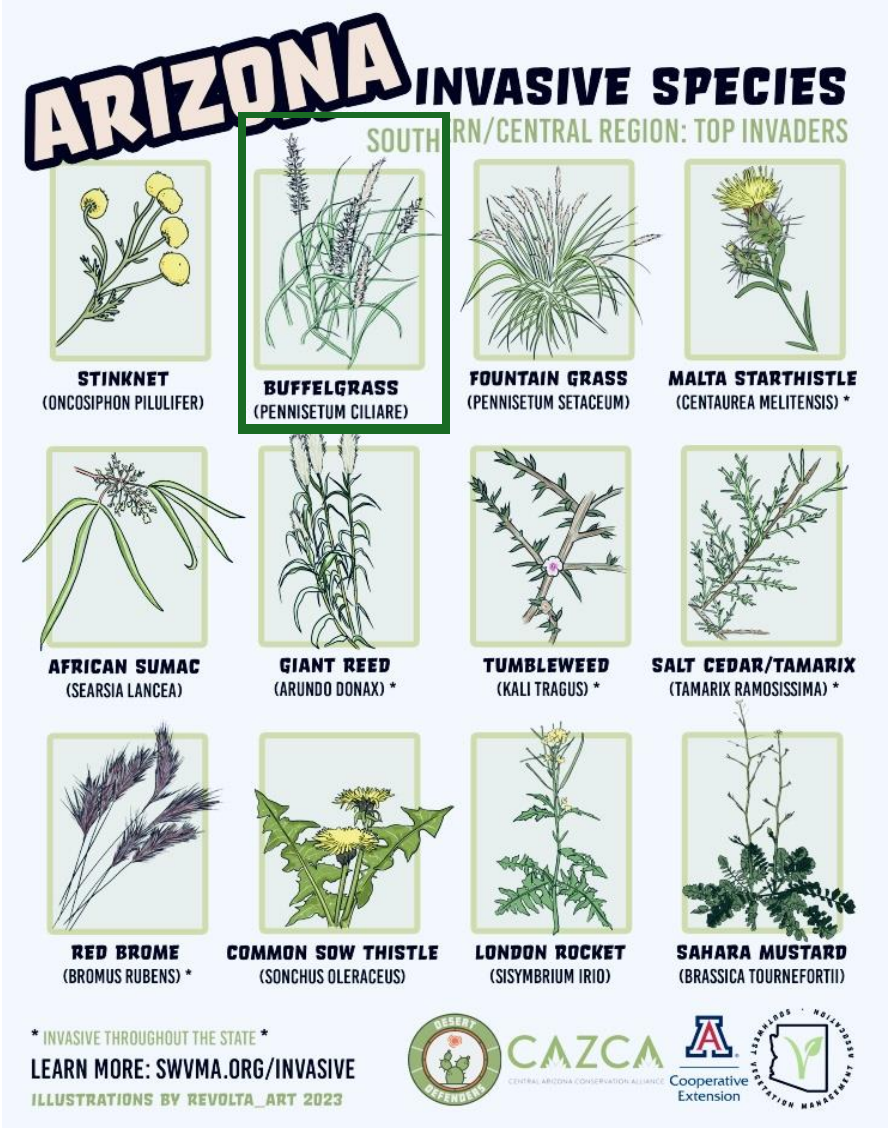
- Buffelgrass (*Pennisetum ciliare*): invasive grass spreading rapidly in Yuma's desert ecosystems.
- Threatens native plants and escalates wildfire frequency and intensity.

Challenges:

- Current control produces excess biomass with no practical reuse.
- Conventional insulation materials contribute to high carbon footprints.

Our Vision:

- Repurpose buffelgrass biomass into eco-friendly thermal insulation panels.
- Create a circular approach linking invasive species control with sustainable building materials.
- Enhance fire risk management and reduce environmental impact in Yuma.



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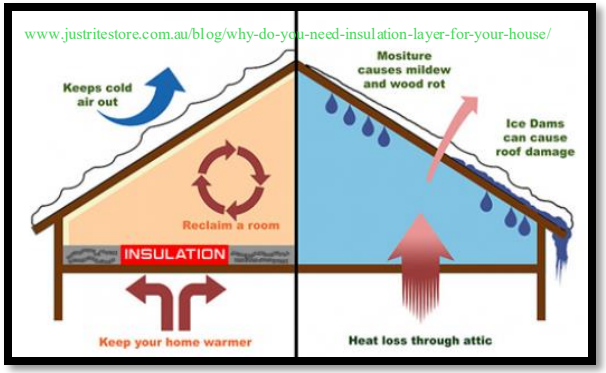

Ecological Impacts of Buffelgrass

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Statement of the Problem

General Problem:
This study examines whether buffelgrass, an invasive species with rapidly increasing distribution, can be repurposed into an effective plant-based roofing insulation material.

Specific Problems:
1. How does the number of Buffelgrass insulation layers affect surface temperature under simulated heat exposure?
2. Does increasing the thickness of Buffelgrass insulation significantly reduce the rate of heat transfer compared to a single-layer panel?
3. Is Buffelgrass layer thickness a statistically significant factor in reducing surface temperature when analyzed across time using ANOVA?

Hypothesis

Null Hypothesis (H_0)
Increasing the number of Buffelgrass insulation layers will have no significant effect on surface temperature or heating rate under simulated heat exposure.

Alternative Hypothesis (H_1)
Increasing the number of Buffelgrass insulation layers will significantly reduce surface temperature and heating rate under simulated heat exposure compared to panels with fewer or no layers.

www.swvma.org/invasive-species/invasive-species/southern-az/

METHODS

Goal 1: Sample collection and Biomass preparation

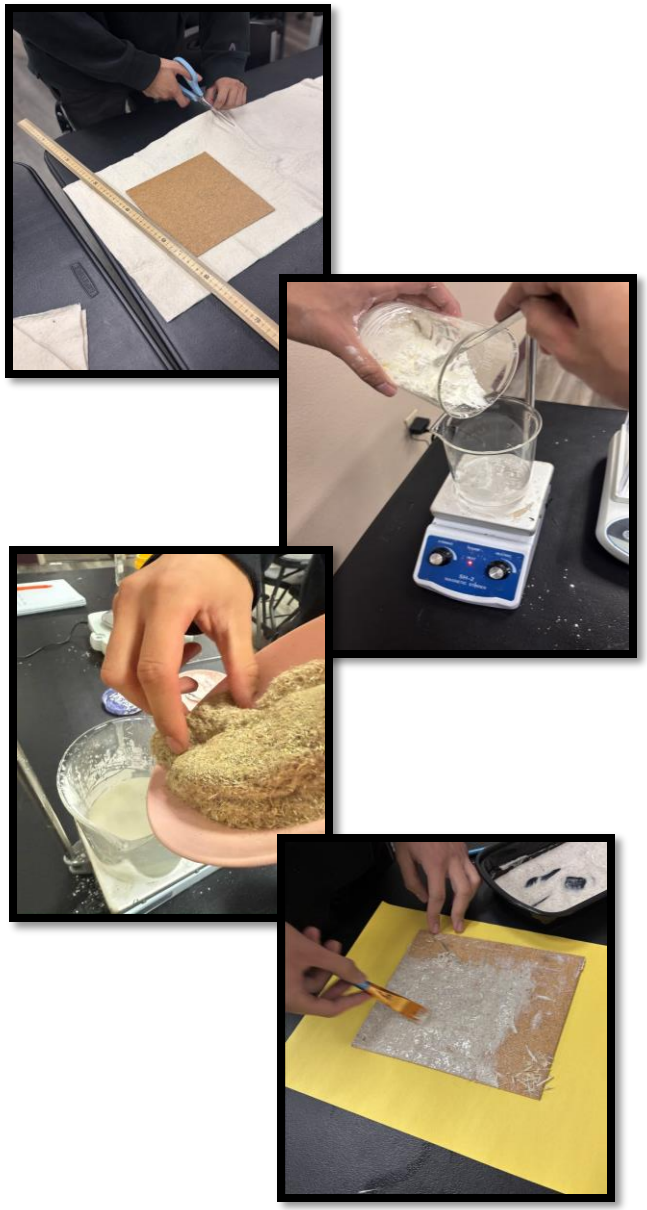
1. Buffelgrass was collected from multiple locations in Yuma County to account for environmental variation.
2. The collected Buffelgrass was air-dried under direct sunlight until no visible moisture remained.
3. Dried Buffelgrass was manually crushed and ground into a fine fibrous material.

Pictures in this slide from:
desertmuseum.org/buffelgrass/learn.php

METHODS

Goal 2: Composite Panel Fabrication Procedure

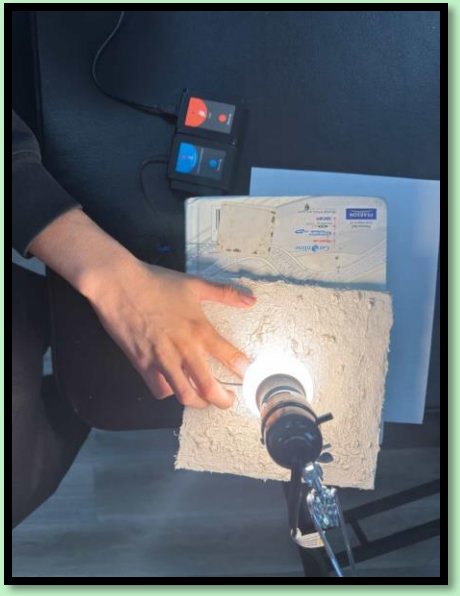
4. A cornstarch binder was prepared by combining 80 g of cornstarch with 100 mL of water and mixing until smooth.
5. The mixture was heated over medium heat while stirring continuously until a uniform paste formed (3–5 minutes).
6. Approximately 2–3 g of salt was added to the binder, which was then cooled to a warm handling temperature.
7. Ground Buffelgrass was placed in a mixing container, and the warm binder was gradually added while mixing by hand.
8. The composite mixture was stirred until all fibers were evenly coated and formed a cohesive insulation material.
9. Standardized substrates were prepared by cutting cloth into 30 × 30 cm sections and wood into uniform 20 × 20 cm panels.

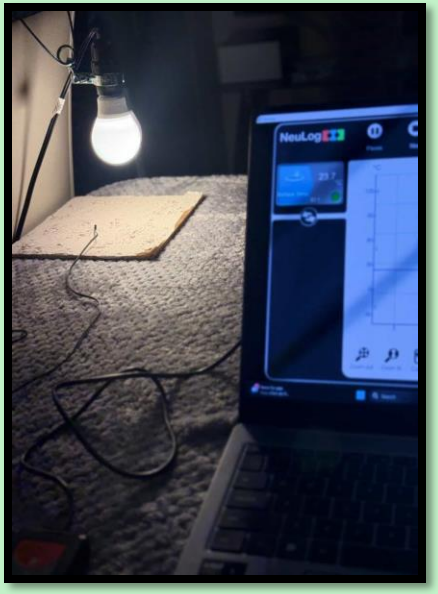


METHODS

Goal 3: Experimental Testing and Material Characterization

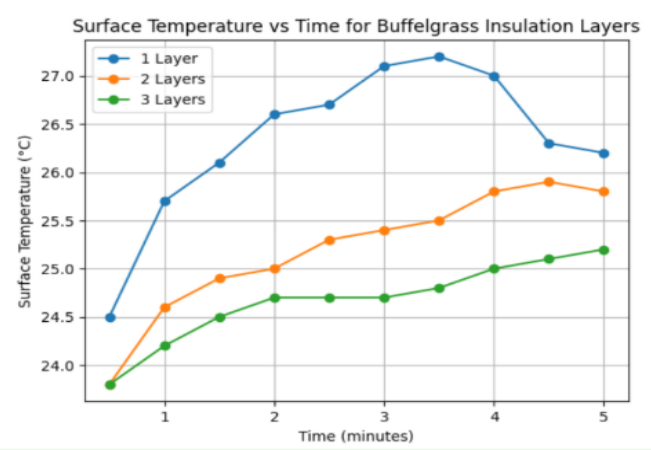
10. The temperature readings were measured and recorded using the NeuLog temperature sensor and organized in a data table for each panel.
11. The experiment was repeated for panels with different numbers of Buffelgrass insulation layers under the same controlled conditions.
12. The collected data was graphed and analyzed to determine how insulation thickness affected heat transfer.





Data analysis

Surface Temperature per unit time



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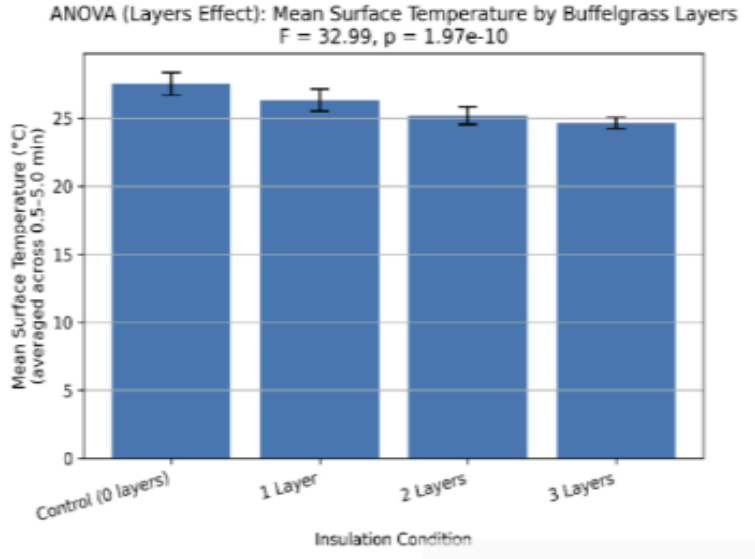

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CONCLUSION

- Panels with more Buffelgrass layers consistently showed lower surface temperatures and slower heating rates compared to panels with fewer layers.
- Quantitative analysis showed that the three-layer panel had the smallest temperature increase ($\Delta T = 1.4$ °C) and the slowest heating rate (0.31 °C/min), showing the highest insulation effectiveness.
- Two-factor ANOVA without replication revealed a highly significant effect of Buffelgrass layer thickness on surface temperature ($p < 0.001$), confirming insulation thickness as a major factor in reducing heat transfer.
- Although temperature increased over time due to continuous heat exposure, insulation thickness had the strongest influence on thermal performance.
- These findings suggest that Buffelgrass, an invasive plant species in Yuma, Arizona, has potential as a low-cost, sustainable insulation material for hot, arid environments, pending further testing on durability, moisture resistance, and fire safety

Recommendation

- Evaluate the long-term durability of Buffelgrass insulation using repeated heating and cooling cycles to simulate real-world conditions. Test the effects of moisture exposure, including humidity and simulated rainfall, on insulation performance and structural integrity. Conduct fire resistance assessments using standardized methods to determine combustibility and identify necessary fire-retardant treatments.

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