Agrivoltaics Effect on the Environment and Natural Resources 2 Building: Rooftop Heat Island Effect

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I. Abstract

The combination of Photovoltaics (PV) and Agriculture brings fourth an innovative urban agriculture system called Agrivoltaics (Hall, 2023). The increased usage of human-made materials has led to an increase in ambient temperatures in urban settings, which is one of the main contributors of the urban heat island effect, especially larger cities (EPA, 2022). There is a research gap in understanding the potential of Agrivoltaics to mitigate the UHI effect in urban areas. While there has been some research on the benefits of green roofs and walls in reducing urban heat, there is limited research on the combined benefits of Agrivoltaics and green infrastructure. The relationship between Agrivoltaics and urban heat was studied using primary quantitative data collected from the Environment and Natural Resource 2 Building located on the main University of Arizona campus in Tucson, Arizona. The findings of this study indicate that the Environment and Natural Resource 2 Building rooftop Agrivoltaics system has the potential to improve the conditions of the surface area by cooling the surrounding ambient temperature. Future research should examine the economic viability of Agrivoltaics and urban heat island mitigation strategies. This will entail evaluating the costs and benefits of implementing a and identifying potential barriers to their adoption.

Keywords: Photovoltaic (PV), Urban Agriculture, Agrivoltaics, Urban Heat Island Effect, Rooftop

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II. Introduction

In recent years, the urban heat island effect has emerged as one of the most significant climate concerns in urban areas. The use of artificial or human-made materials in the structures of many cities contributes the urban heat island effect because they absorb and retain heat unlike organic materials that release heat (Stache et al, 2022). An innovative urban agriculture system that combines photovoltaics (PV) and agriculture has been becoming more popular in sustainable research in Tucson, Arizona, such system is called Agrivoltaics. Agrivoltaics allows the generation of clean energy and the cultivation of native vegetation in one system (Stache et al, 2022). The question this study set to answer was: How does the installation of the Agrivoltaics system on the rooftop of the Environment and Natural Resource 2 Building affect the surface temperature of the rooftop?

III. Literature Review

Agrivoltaics is an innovative approach to agricultural land use that has gained more attention due to its potential to provide sustainable land productivity and energy solutions. Increased agricultural productivity is one of the primary benefits of Agrivoltaics. By shading crops with solar panels it reduces water loss through evaporation and minimizes temperature fluctuations, thereby producing a more stable environment for plant growth (Barron, 2019). In addition, solar panels can shield crops from harsh weather conditions such as heat or reducing the risk of crop loss (Barron, 2019). While Agrivoltaics can increase land productivity, the implementation of solar panels requires a larger quantity of space, which can reduce the land available for crop cultivation (Hall, 2023). Due to the heat island effect, solar-powered systems in urban areas have decreased efficiency as they retain more heat. This poses a problem for the mitigation of urban heat. Benefits of Agrivoltaics include providing shade, capturing vapor moisture, and reducing thermal damage to crops (DOE, 2022).

IV. Methods

The University of Arizona Environment and Natural Resource 2 (ENR2) building rooftop was used for primary data collection. Tucson’s hot and dry environment makes this research ideal for determining the pattern of the urban heat island effect on the ENR2 roof.

Furthermore, Tucson’s built environment contains an abundance of artificial materials that absorb and retain heat. The ENR2 rooftops host an Agrivoltaics system with 21 square plots of natural desert plants in its installation. Six plots were used in my data collection. They were located on the east side of the system, three of which are fully exposed to sunlight with no PV panels, and three of which were fully exposed to sunlight but were positioned beneath PV panels.

This study consisted of three data collection measurements. It was ideal to collect all three measurements on the same day around the same time to control for weather. The average time I spent taking and recording data took was about two hours, which typically started around 12pm when the sun was at its peak. The optimal condition for this investigation was a day with clear skies and no precipitation. This indicated that the six plots were all visited and collected under stable weather conditions.

Measurement 1: The ground temperature of two plots were measured in the initial data collection. The first plot that was collected from was Plot 1 which was fully exposed to sunlight with no PV panels, and eight ground temperatures were measured using an IR Heat gun that was purchased from Home Depot, two measurements on each side of the plot. The second plot that was utilized was Plot 4 and was positioned beneath the PV panels but was fully exposed to sunlight and adjacent to the plot with no PV panels, eight ground temperatures were measured, two measurements on each side of the plot as seen in (Figure 1). For Plot 1 and Plot 4, each ground temperature measurement on the plot (indicated by red dots) was collected at the IR heat gun distance of about four inches away from the soil. This accumulated a total of 16 temperatures from plots 1 and 4.

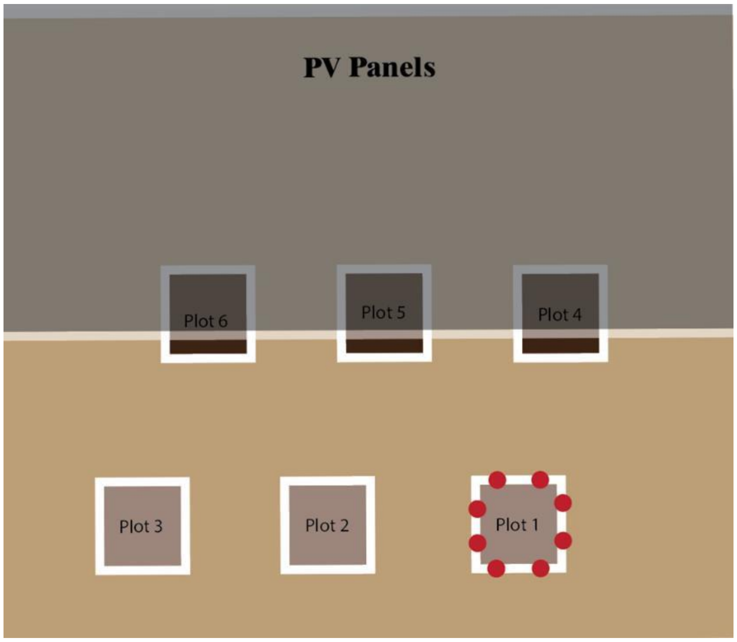

Figure 1: 6 Selected Plot Layout

Measurement 2: The average ground temperature and plant temperature was collected in the second data collection phase for plots 1, 2, 3 & 4, 5, and 6. *Solanum Elaeagnifolium* (Penstemon Perryi) was identified in each data collection plot and was used to collect plant temperatures. Utilizing the same plant with similar characteristics and controlled data variability. The Penstemon Perryi has larger sized leaves compared to its flower, using the IR heat gun at a distance of three inches, I collected the temperature of the leaves, one plant temperature per plot (Figure 2). For ground temperature measurement, I used the IR heat gun at a distance of about four inches away from the soil, one measurement per plot. For plots 1, 2, and 3, there was a total of six measurements, three ground temperatures and three plant temperatures. For plots 4, 5, and 6 there was a total of 6 measurements, three ground temperatures and three plant temperatures. The average ground temperature and plant temperature for plots with no PV panels (1, 2, and 3) was calculated by adding up the tree totals separately and dividing them by 3. The same calculation was applied to the plots with PV panels (4, 5, and 6).

Figure 2: *Solanum Elaeagnifolium* (Penstemon Perryi)

Measurement 3: the last measurement conducted for this research measured the soil moisture of all six plots. The Office of Sustainability at the University of Arizona States that the ENR2 rooftop plots have a soil depth that is eight inches deep (Office of Sustainability, 2023) and soil moisture data was measured using a six-inch soil moisture probe on a scale from one (dry) to 10 (wet). Taking a static collection, I analyzed whether there was a significant difference in soil moisture between 3 plots completely exposed to sunlight (plots 1, 2, and 3) and three plots fully exposed to sunlight and covered with photovoltaic panels (plots 4, 5, and 6).

V. Results

5.1 : Measurement 1

Based on the 8 records of ground temperature from the ENR2 Agrivoltaics, it is observed that plots 1, 2, and 3 (non-PV plots) as shown in Figure 3 have a lower ground temperature compared to plots 4, 5, and 6 (PV plots).

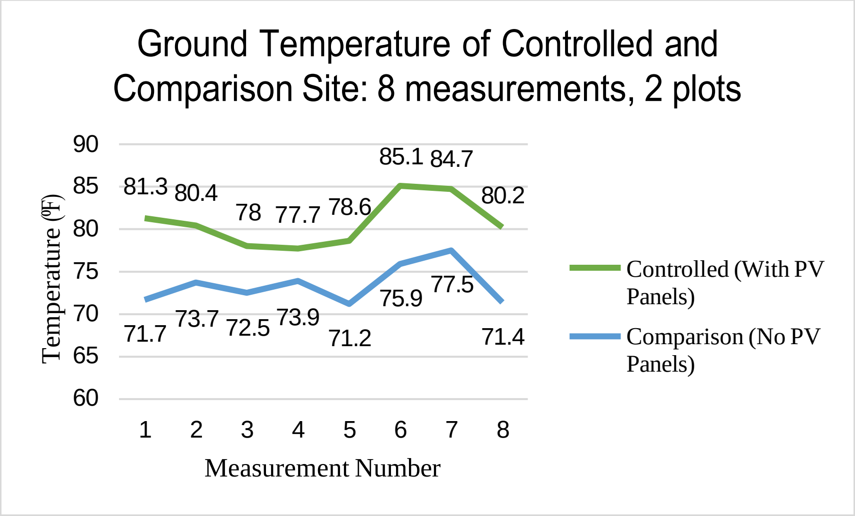

Figure 3: Ground temperature of controlled and comparison sites.

5.2 : Measurement 2

As Figure 4 demonstrates, plots 4, 5, and 6 with PV panels show a higher average temperature difference between plant and ground temperatures compared to plots 1, 2, and 3 without PV panels.. There is a difference of 12 degrees Fahrenheit for the average plant temperature between plots 1, 2, and 3 and plots 4, 5, and 6. Plots without PV panels showed an average ground temperature reduction of 4.24 degrees Fahrenheit.

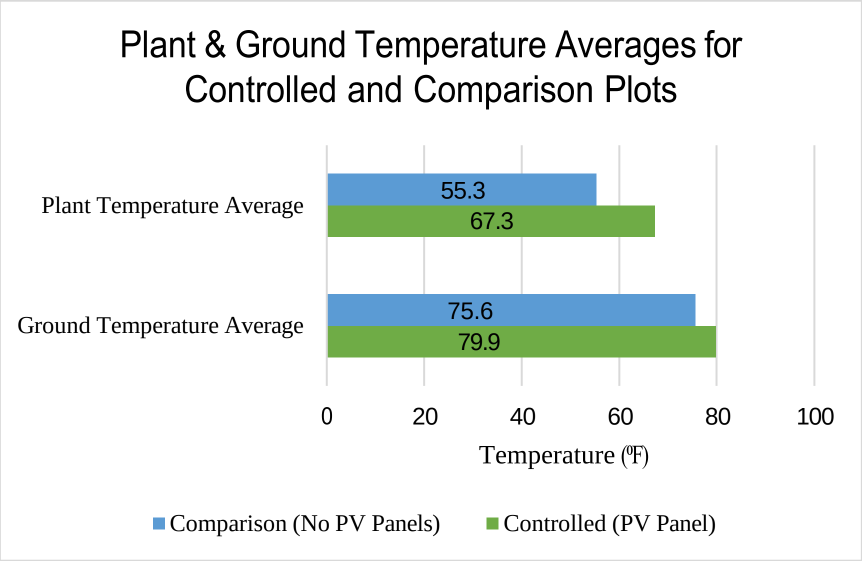

Figure 4: Plant and ground average temperature.

5.3 : Measurement 3

All six plots had nearly identical initial soil moisture. The soil moisture in the plots with PV panels (4, 5, and 6) is slightly drier than plots without PV panels (1, 2, and 3), seen in Table 1.

Controlled Site (With PV Panels)	*Soil Moisture Level*
Plot 1	6
Plot 2	5
Plot 3	7

Key:

Dry: 0-3.5

Moist: 4-7.5

Wet: 8-10

Comparison Site (w/o PV Panels)	*Soil Moisture Level*

Plot 1	6
Plot 2	7
Plot 3	6

Table 1: Soil moisture levels.

VI. Discussion

Based on the result of measurements 1,2 and 3 , the trend that emerge from the plots 1, 2, and 3 that had lower overall heat temperatures compared to plots 4, 5, and 6 which were under the panels. Due to the emission of longwave radiation, the radiation on solar panels continually adds energy to the ground surface which leads to plots 4, 5 and 6 having warmer ground and plant temperatures (Sheppard et al, 2022). I factored in environmental conditions, such as season of weather, when collecting temperature data from Agrivoltaics plots. However, the effectiveness of Agrivoltaics is dependent on the native ecology an geographical location (Mamun et al, 2022).

VII. Conclusion

This study analyzed the effects of Agrivoltaics, the combination of photovoltaics and native vegetation, on urban heat on the Environment and Natural Resource 2 (ENR2) building rooftop. A quantitative study demonstrated that the ENR2 building rooftop Agrivoltaics system reduces the temperature around the PV panel system by absorbing the sunlight but in the process, the PV panels absorb some of the heat from the sun (Rui et al, 2022). While measuring and comparing the soil moisture of the ENR2 rooftop plots with and without PV panels, no significant difference in soil moisture was found. The average ground temperature for plots 1, 2, and 3 decreased by 12 degrees Fahrenheit and a 4.23 degrees Fahrenheit reduction in plant temperature for lots 1, 2, and 3. Limitations to this investigation include the season of which temperatures were collected, the final data was concluded in early March which resulted in cooler ambient temperatures, which I took into account when collecting data. Despite the fact that this area of agricultural research is still in its infancy, the findings of this capstone project can help determine effective ways to mitigate urban heat and create efficient Agrivoltaics systems in more urban communities in Tucson, Arizona.

VIII. Work Cited

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