Testing predictions used to build an agrivoltaics installation on a small-scale educational model

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Introduction

Education and scientific research use small scale models as tools for gaining science skills and understanding larger systems. Biosphere 2, a model of our Earth, is one such model where the dual goals of education and scientific research are achieved. A new model of agrivoltaics (agriculture+photovoltaics) is currently being built at Biosphere 2. This novel man-made system has the potential to transform the way we utilize land spaces by combining solar energy with native plant restoration or agricultural food production. I built a mini-agrivoltaic model to test this system as a tool for education and scientific research. The objectives of this project were:

1. To investigate the predictions used to plan construction of the large-scale project, including the claims that:
   i. Plant productivity will increase when grown in shade
   ii. Plants will cool an overhead solar panel via transpiration
2. To evaluate the educational value of a small scale model by:
   i. Engaging students in testing predictions
   ii. Using "low-tech", classroom friendly methods for scientific experimentation

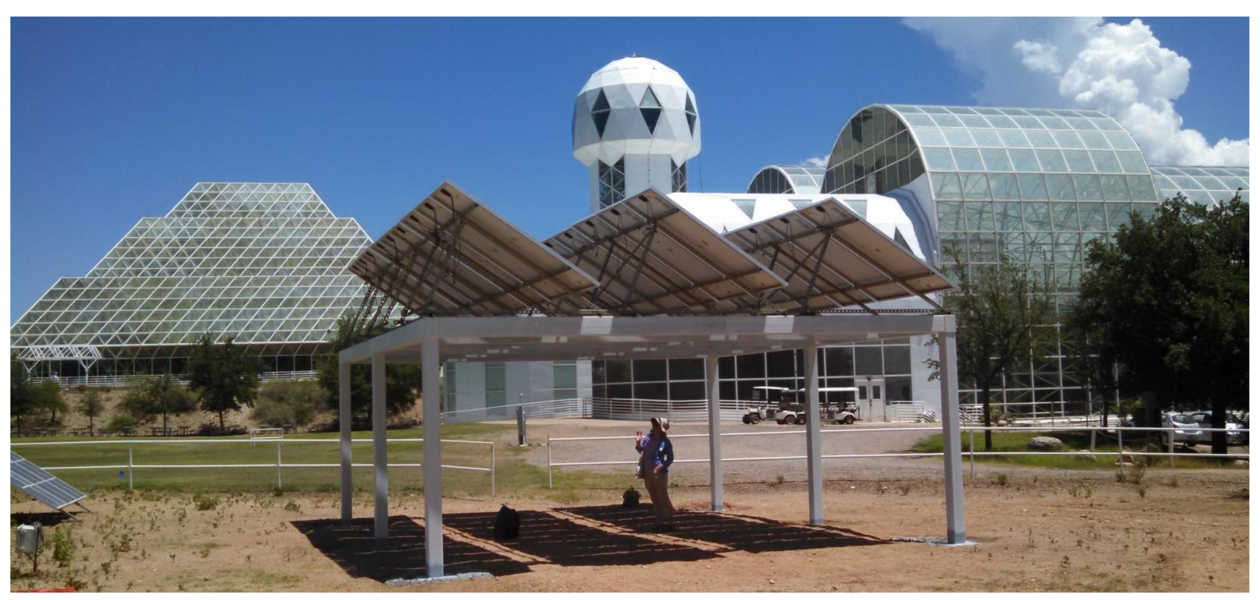


Figure 1: Large agrivoltaics installation in the solar field in front of Biosphere 2.

Methods

Experimental Set-Up

The experimental set up involved an angled solar panel, facing south, that shaded eight pots. Four of those pots contained plants and four contained soil. Eight duplicate pots were placed in the sun (Figure 2). Our resulting experimental groups are: 1) shaded plants, 2) shaded soil, 3) unshaded plants, and 4) unshaded soil.

Plant Productivity

- Scientific predictions: Plant productivity was measured with moisture loss measurements and leaf and soil temperature measurements.
- Educational value: Low-tech measurements were used to gather the data. Moisture loss was measured by adding 500 mL of water once to each of the sixteen pots. The weight was recorded at two hour intervals for eight hours.

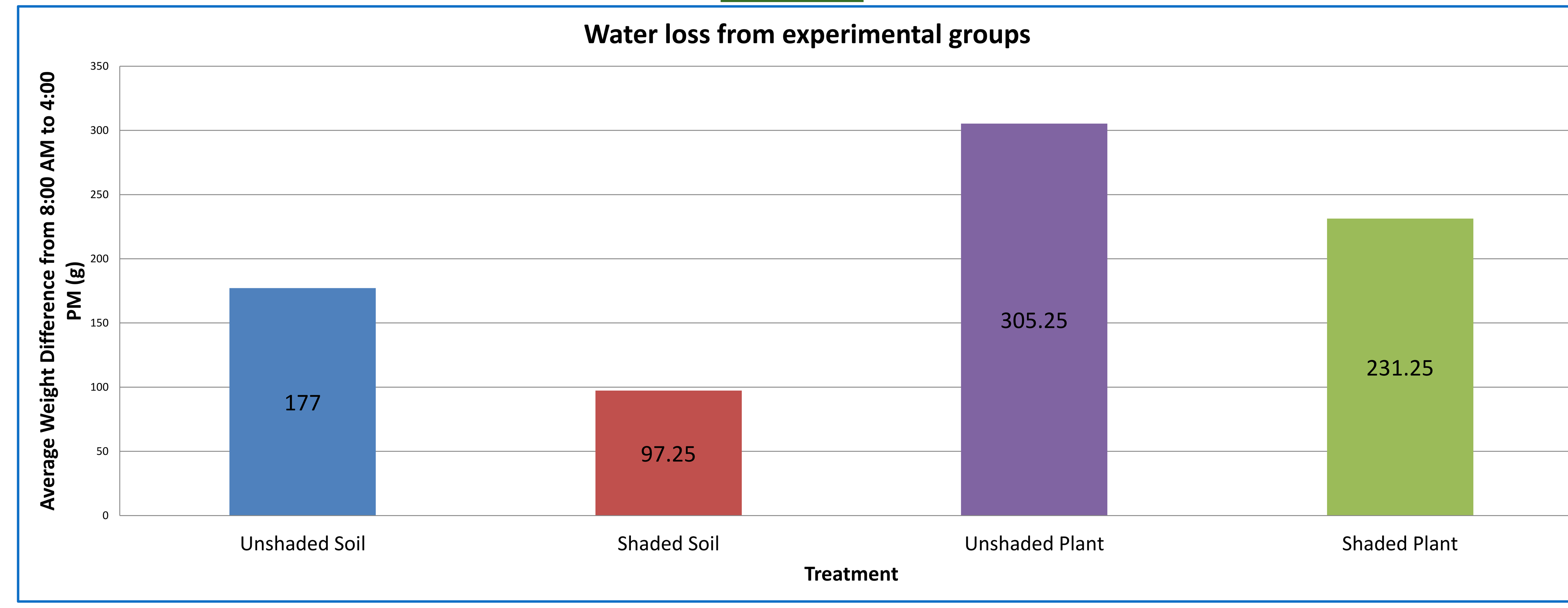
Panel Cooling

- Scientific predictions: The effects of plants on panel temperature and air temperature were measured using an infrared gun and HOBO pendant light and temperature sensors (Figure 3).
  - The HOBO pendants recorded data every 30 minutes for 24 hours. The HOBO sensors were placed in one of the four pots in each treatment on a PVC stake.
- Educational value: Infrared guns used to take air and panel temperature are readily available at low-cost from hardware stores. HOBO pendants are a high-tech instrument with multiple applications with the benefit of being readily available through grant funding or a teacher budget. HOBO software adds an extra technology component.

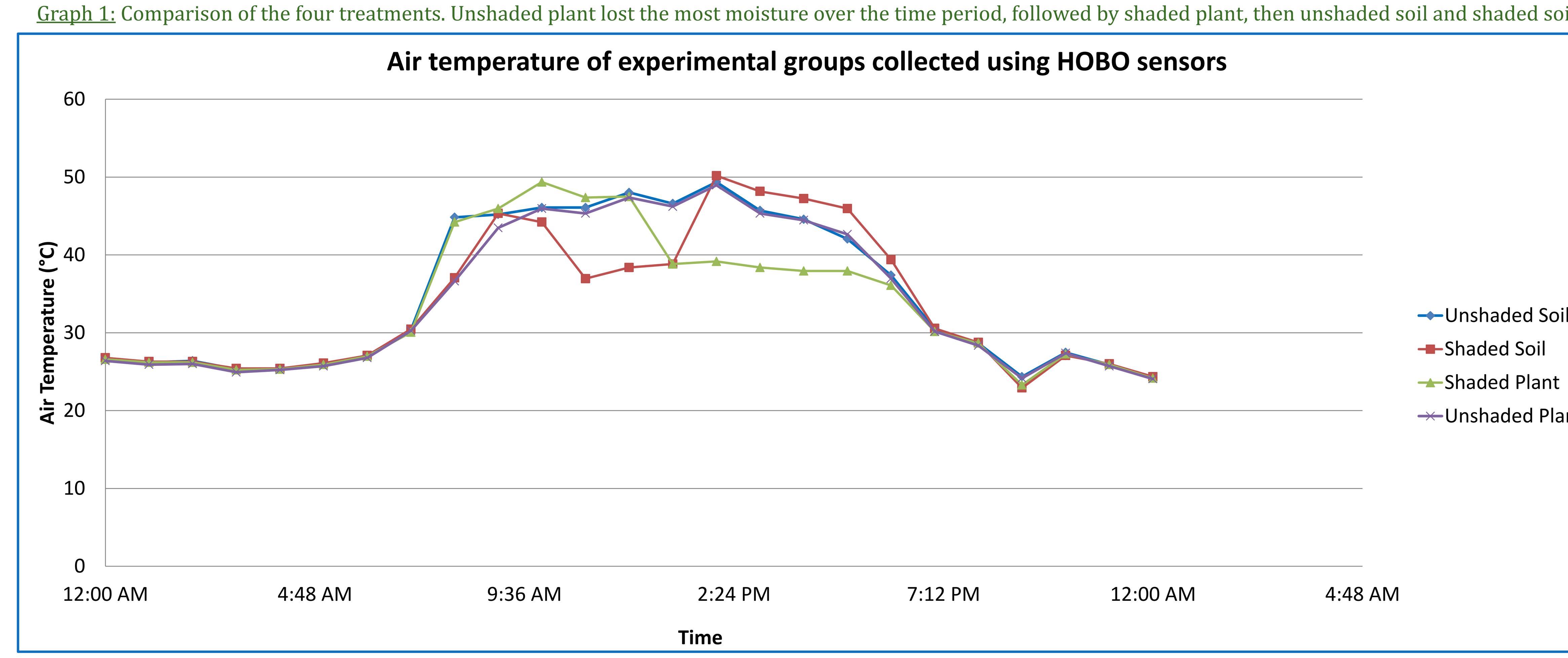
Figure 2: Experimental set-up. Photo is taken facing north. Shaded plants are on the right side of the photo underneath the panel; shaded soil is on the left. Unshaded plants and soil are in the foreground.

Figure 3: HOBO pendant light and temperature sensors.

Results



Graph 1: Comparison of the four treatments. Unshaded plant lost the most moisture over the time period, followed by shaded plant, then unshaded soil and shaded soil.



Graph 2: Average air temperature collected over 24 hours. The highest temperature for all treatments was the same, although it was reached at different points throughout the day. Note the "edge effect" occurring around noon where the temperature of shaded plants drops and the temperature of shaded soil rises.

Conclusions

Plant Productivity

- Plants lose more water than bare soil, possibly due to transpiration (Graph 1)

Panel Cooling

- Highest recorded air temperature was not significantly different over plants or soil (Graph 2)

As a scientific tool

- Introduces previously unseen "edge effect" where the position of the sun influences the temperature of treatments under the panel (Graph 2)
- These observations inform plans for the larger agrivoltaic system

As an educational model

- Introduces students to a novel system, allowing for increased engagement in science and technology through real-world application
- Exposes students to data collection, unique tools, mathematical applications, formation of arguments and critical thinking
- Creates opportunities for students and educators to face a unique design challenge with engineering components

Acknowledgements

This project has been made possible with support from the National Marine Sanctuary Foundation (www.marinesanctuary.org) and the California State University STEM Teacher Researcher Program in addition to contributions from the University of Arizona, Biosphere 2, and the National Science Foundation. Special thanks to Biosphere staff, including Jimmy, Bob, Yadi, John A., Steve L., Tony C., Patrick, Kevin B., and Ali H.