Beyond Air Temperature: A Multi-Metric Assessment of Farmworker Heat Stress Under Agrivoltaic Arrays.

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Assessing heat stress in agrivoltaic systems

Agricultural workers are particularly vulnerable to heat stress, which can reduce labour capacity, increase food prices, and significantly threaten the health and safety of individuals [1, 2]. Agrivoltaic systems (AVS) can modify the occupational heat stress risk by changing multiple aspects of the thermal environment simultaneously, including air temperature, solar radiation, and humidity [3]. To quantify the risk of heat stress, over 120 diagnostic metrics exist which vary in their sensitivity to different environmental factors [4]. Different metrics may thus assess the impact of AVS on heat stress differently depending on which environmental factors each metric emphasises in its calculations. To better understand the impact of AVS of heat stress and to develop practical monitoring approaches, this research asks: can AVS consistently reduce heat stress across different metrics; can standard agricultural monitoring equipment reliably capture heat stress changes compared to specialized instruments; and which metrics best characterize AVS microclimate modifications.

Methods and measurements

We collected microclimate data at two AV research sites (Biosphere 2, Arizona; Jack's Solar Garden, Colorado) using both specialised heat stress instruments (wet bulb globe temperature (WBGT) & black globe thermometers) and standard agricultural monitoring equipment (air temperature, photosynthetically active radiation, wind speed, relative humidity). Multiple heat stress metrics were calculated including heat index (HI), globe temperature (Tg), and WBGT. We analysed the sensitivity of each metric to AV-induced environmental changes and compared directly measured values with those calculated from standard meteorological data. Differences between AV and control plots were assessed hourly to characterize temporal patterns in heat stress reduction (Figure 1).

Heat stress findings

Analysis revealed that AVS consistently reduced heat stress across all metrics. Radiation-inclusive metrics (Tg, WBGT) showed the largest AV-Control differences (up to 21% decrease) due to their sensitivity to shade effects, while temperature-humidity only metrics, e.g., HI, showed more modest reductions (6%). Humidity inclusive metrics sometimes demonstrated smaller AV-Control differences due to changes in evaporative cooling potential. Standard agricultural equipment successfully estimated thermal stress metrics when properly calibrated. WBGT can be calculated accurately from standard meteorological data and demonstrates high sensitivity to AVS microclimate changes. These findings demonstrate both the effectiveness of AVS heat mitigation and establish protocols for its practical assessment using commonly available monitoring equipment.

Figures

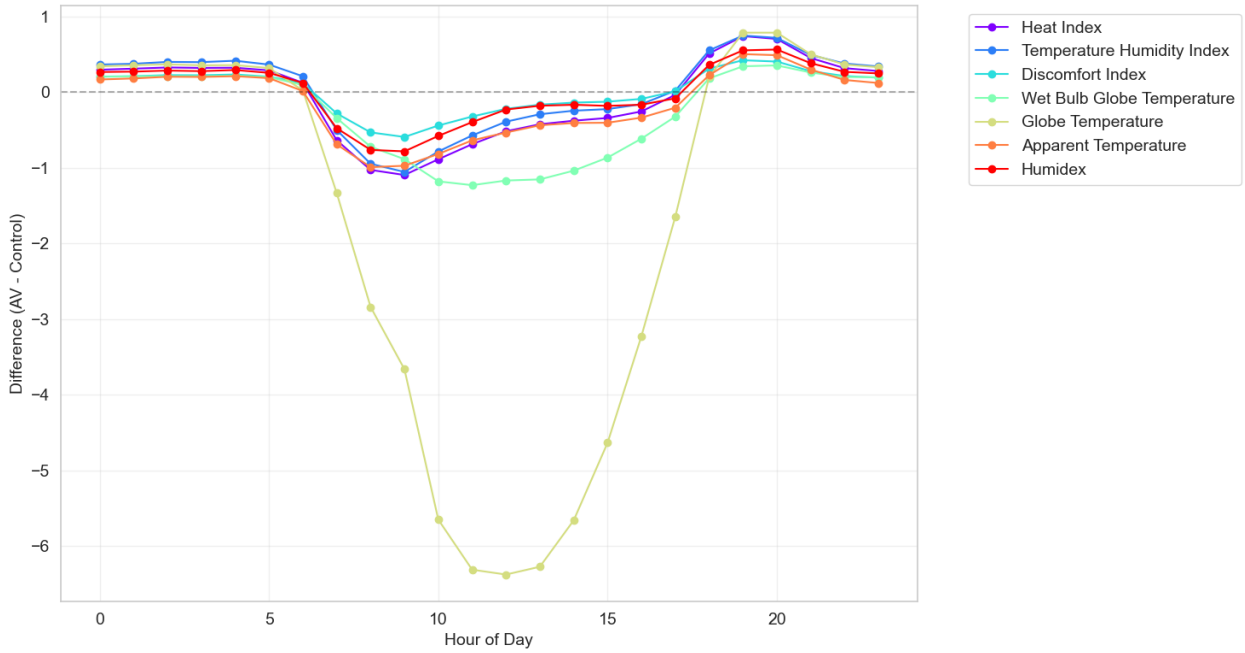

Figure 1: Mean hourly difference in heat stress metrics between agrivoltaics (AV) and control (C). Mean values are calculated across all months from data ranging from 2019-2023.

References

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