Agrivoltaics 2021

Online conference, June 14-16

Improvement of Electrical Efficiency in a PV Solar Farm Utilizing Agriculture

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Annette Penny – Geo Teva - Sustainability

David Meninger – Geo Teva - CEO

Prof. Evyatar Erell – Ben-Gurion University of the Negev

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אוניברסיטת בן-גוריון בנגב
Ben-Gurion University of the Negev

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Acknowledgements

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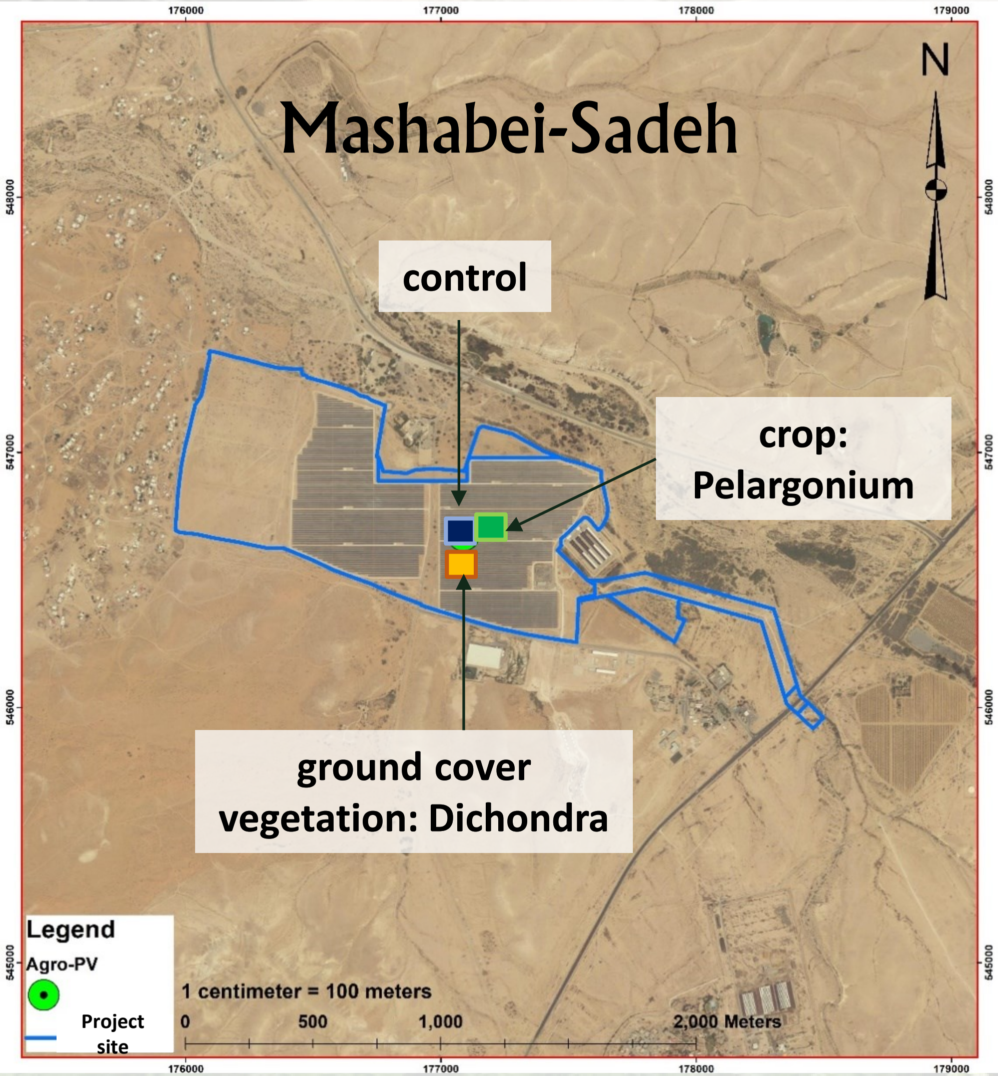
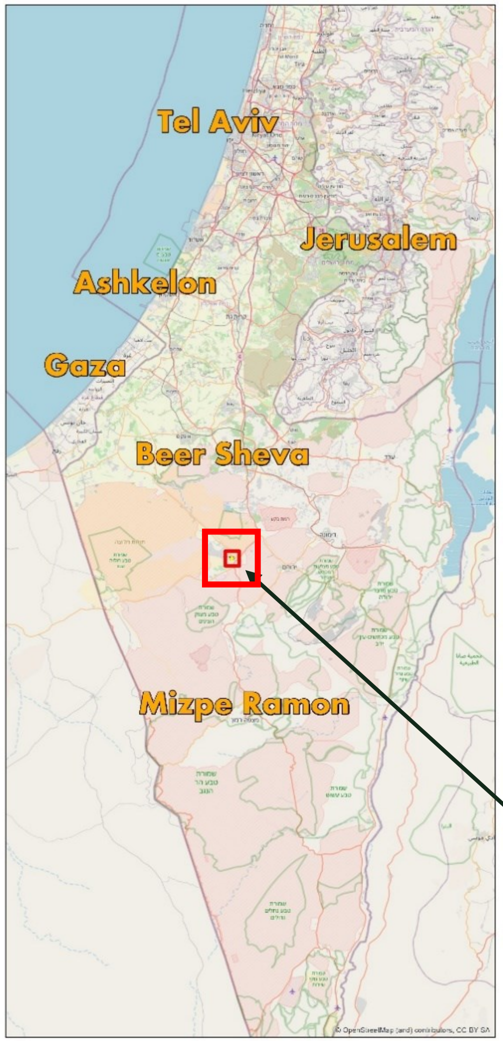
Research objectives

- to deploy a pilot study in an operational commercial solar farm to establish the magnitude of the electricity output premium
- to monitor the microclimatic effects of vegetation in a full-scale solar farm
- to assess the effects of panel shading on crops in a hot dry climate
- to describe the practical difficulties of retrofitting an existing solar farm through the addition of agriculture

Experiment Location & Layout





- Annual insolation 2,250 kWh/m²
- Temperature:
  July 20-35, January 11-18 °C
- Annual rainfall < 100 mm
- 3 test plots, 0.22 hectare (2,200 m²) each
- Fixed panels

Negev Desert, Southern Israel

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Field Preparation

April planting (post-rain, pre-hot season)

Weeding & Plowing

Compost Distribution

Irrigation Installation

Measuring Equipment Installation

Seedling Planting

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From this…

To this!

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Monitoring setup

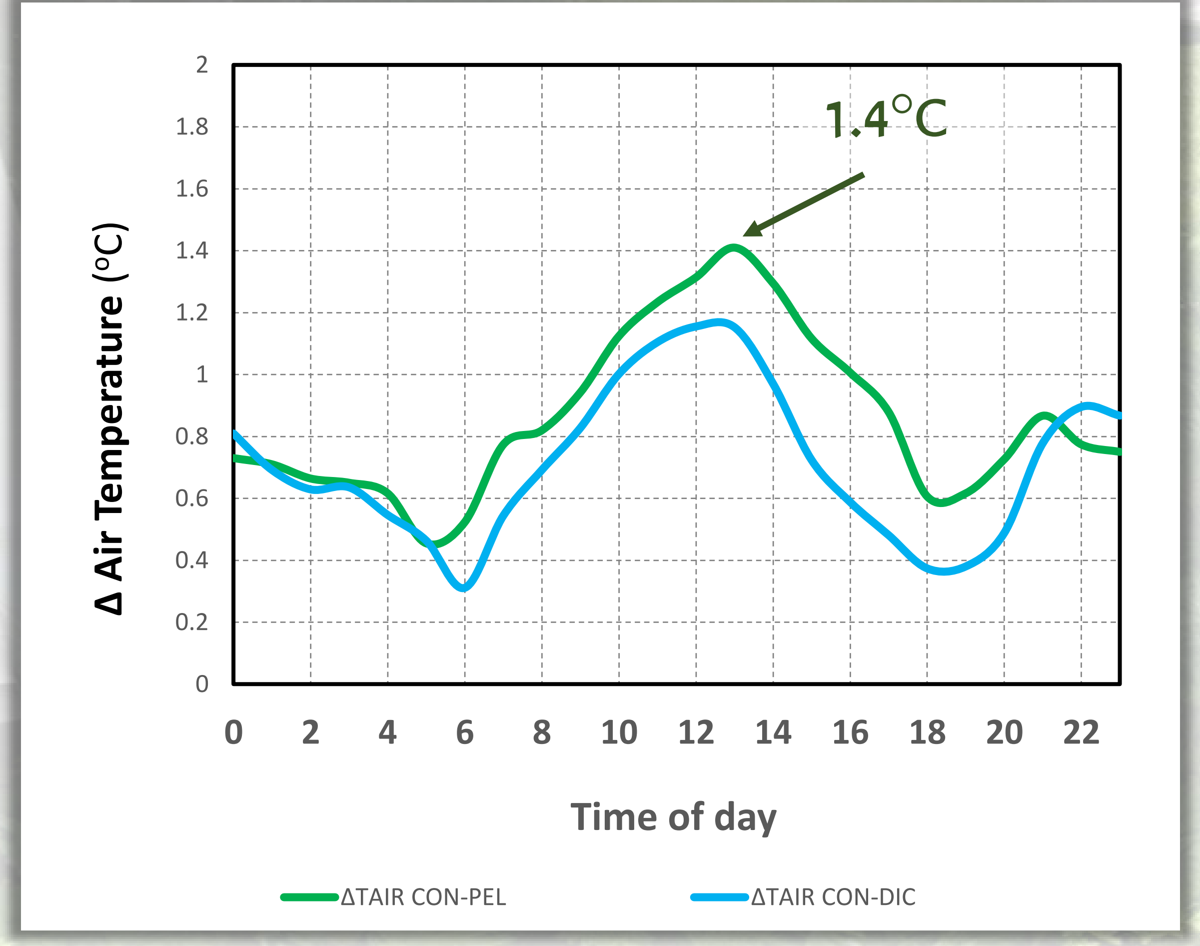
1. Site weather
   - dry bulb temperature
   - relative humidity
   - global solar radiation (at panel tilt)
   - wind speed (at top of panels)
   - wind direction
2. Test plot (below panels)
   - Air temperature
   - Relative Humidity
   - Net radiation
3. Solar panels
   - Panel temperature
   - Voltage
   - Electric current

Data recording and processing

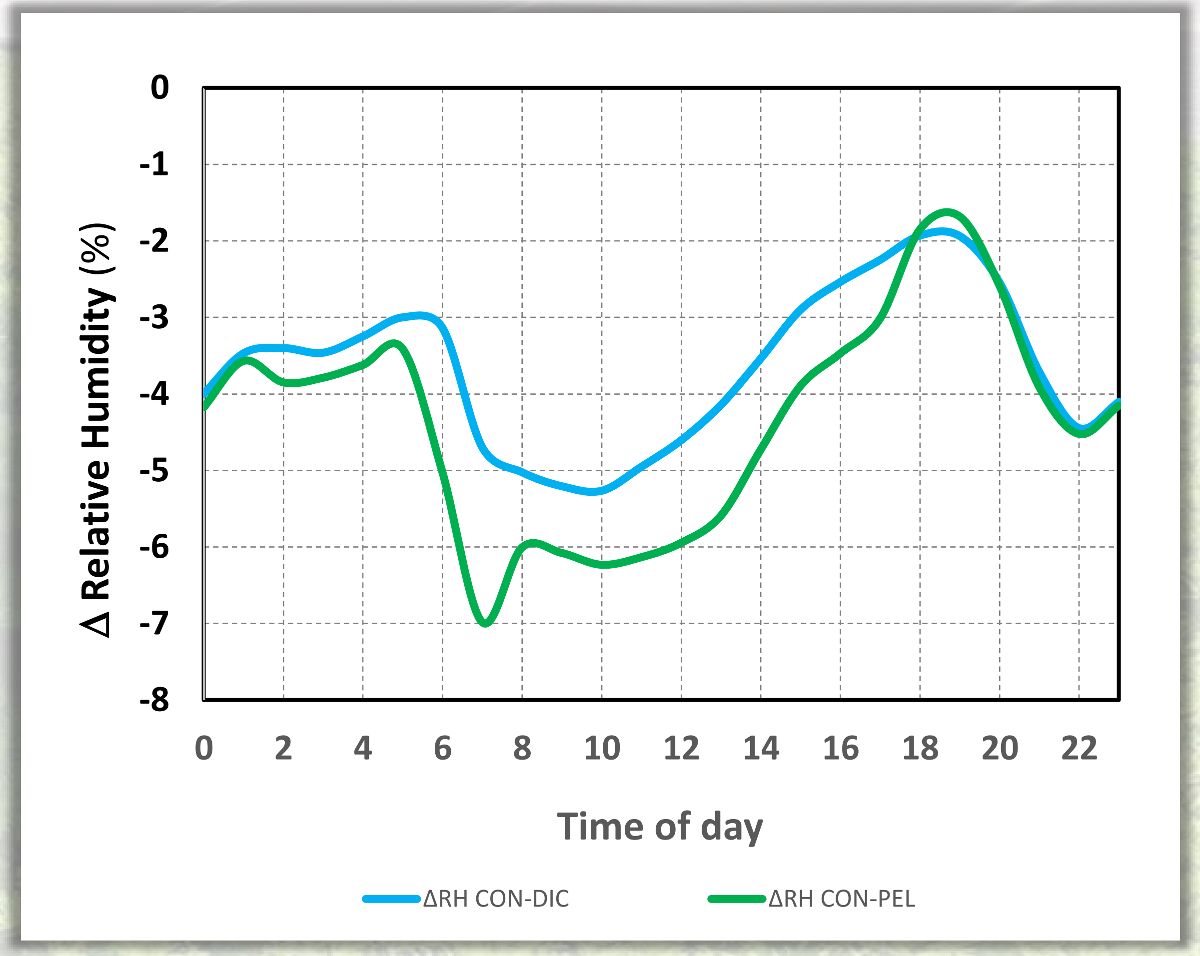
- Data recorded at 1-min intervals on Campbell data logger
- Retrieved remotely
- Processed by Excel

Microclimate

The control plot was warmer



…and drier



Differences between control and test pl0t, August 2020 ensemble

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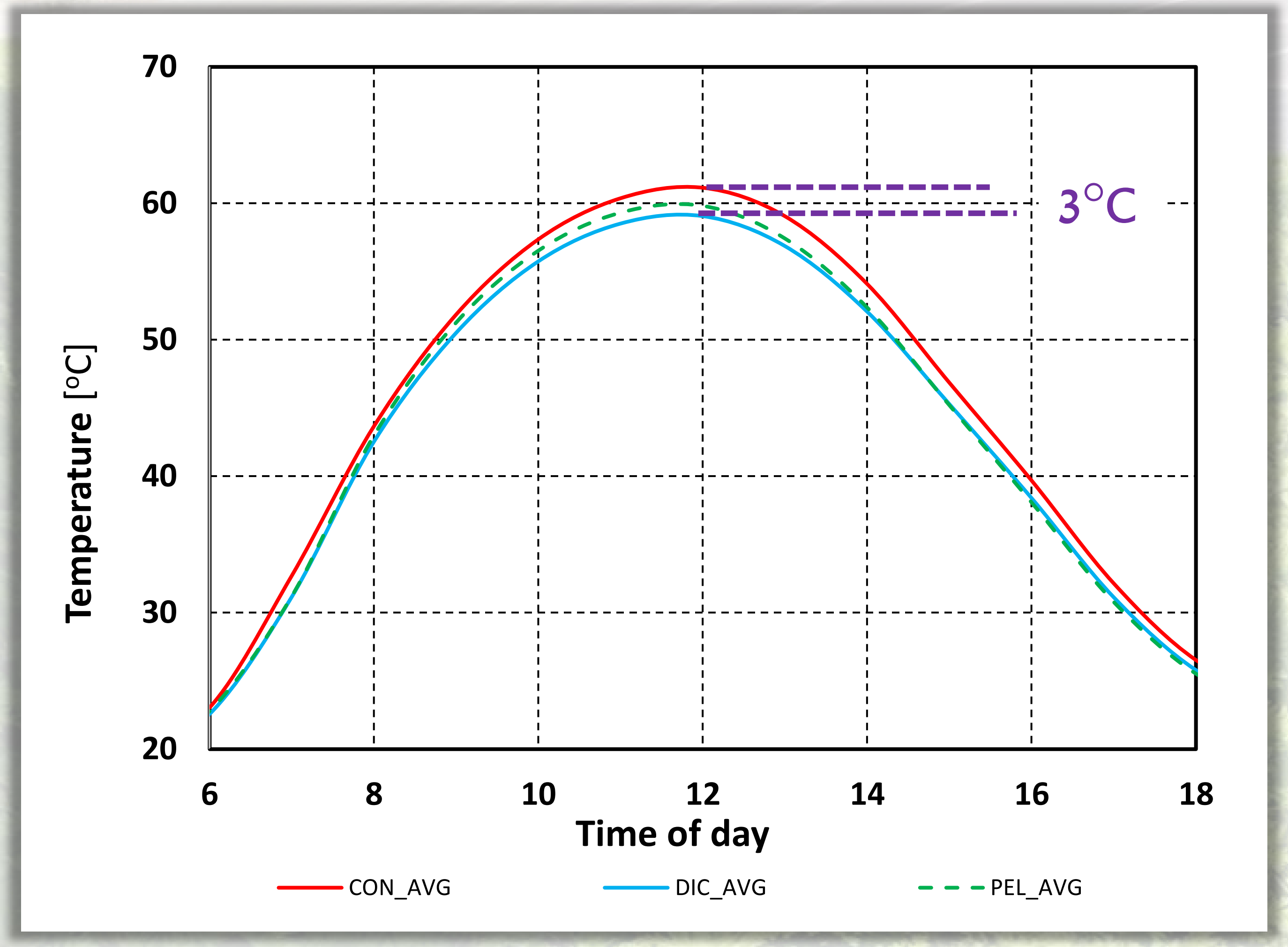
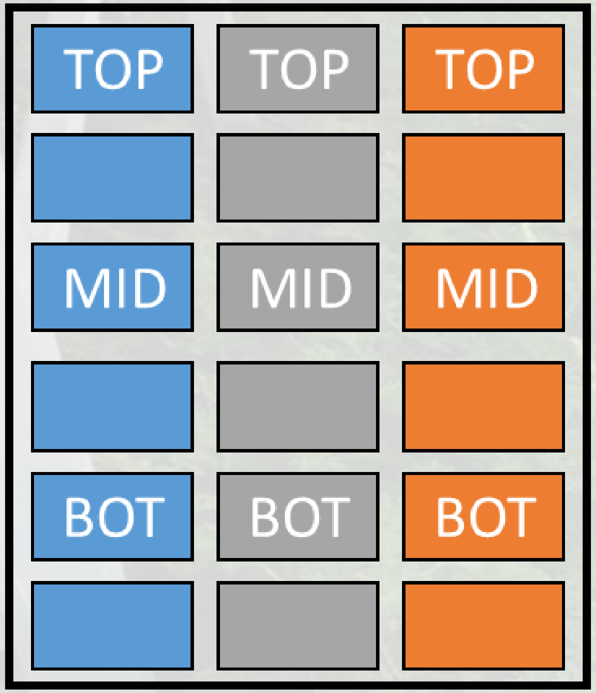
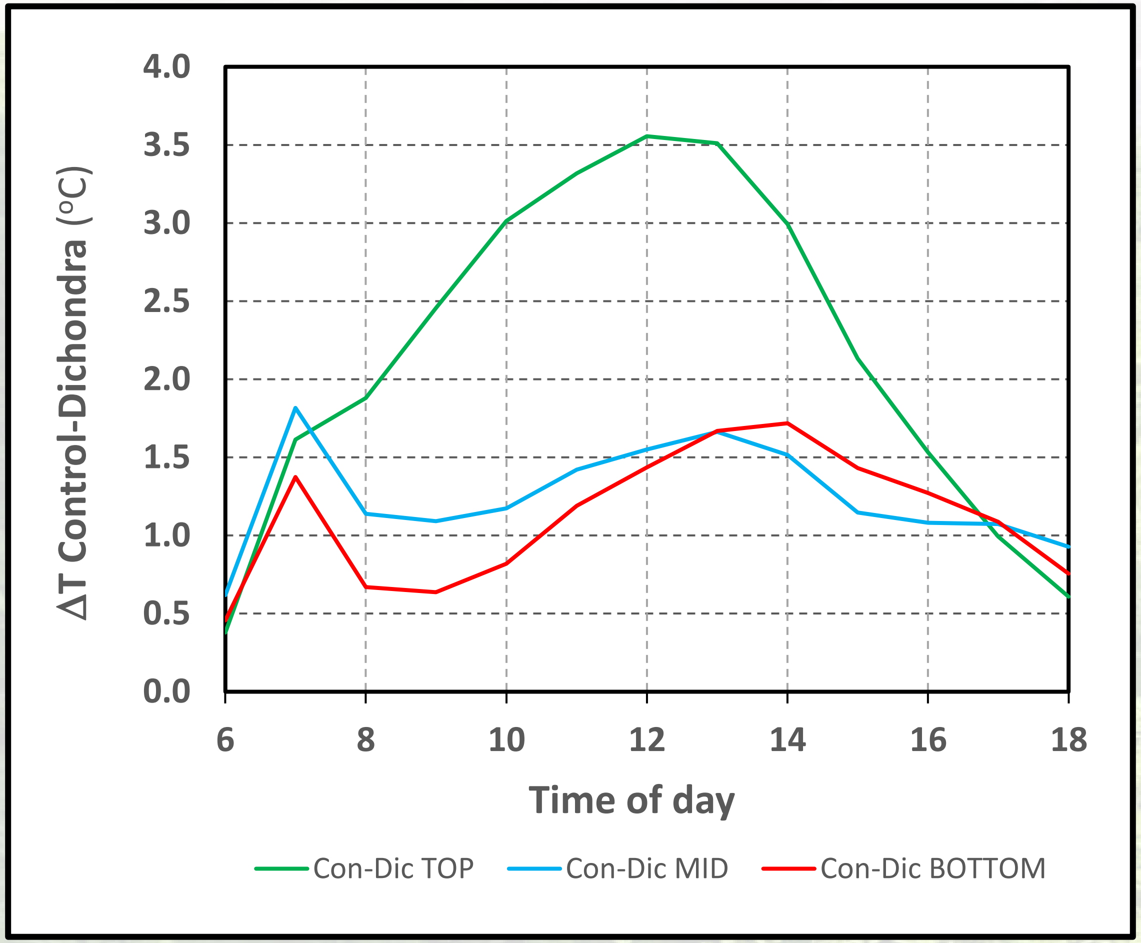
Panel Temperature

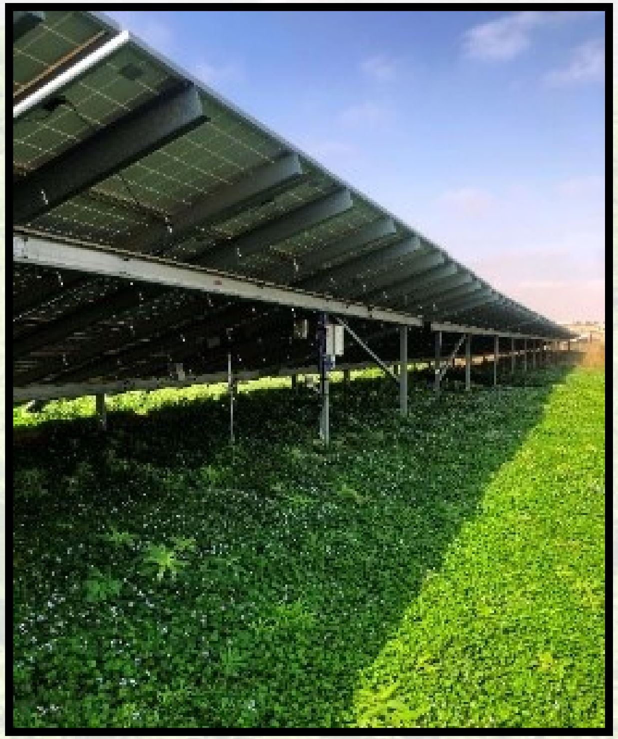


Temperature difference between control plot and test plot

Effect of Height on Panel Temperature



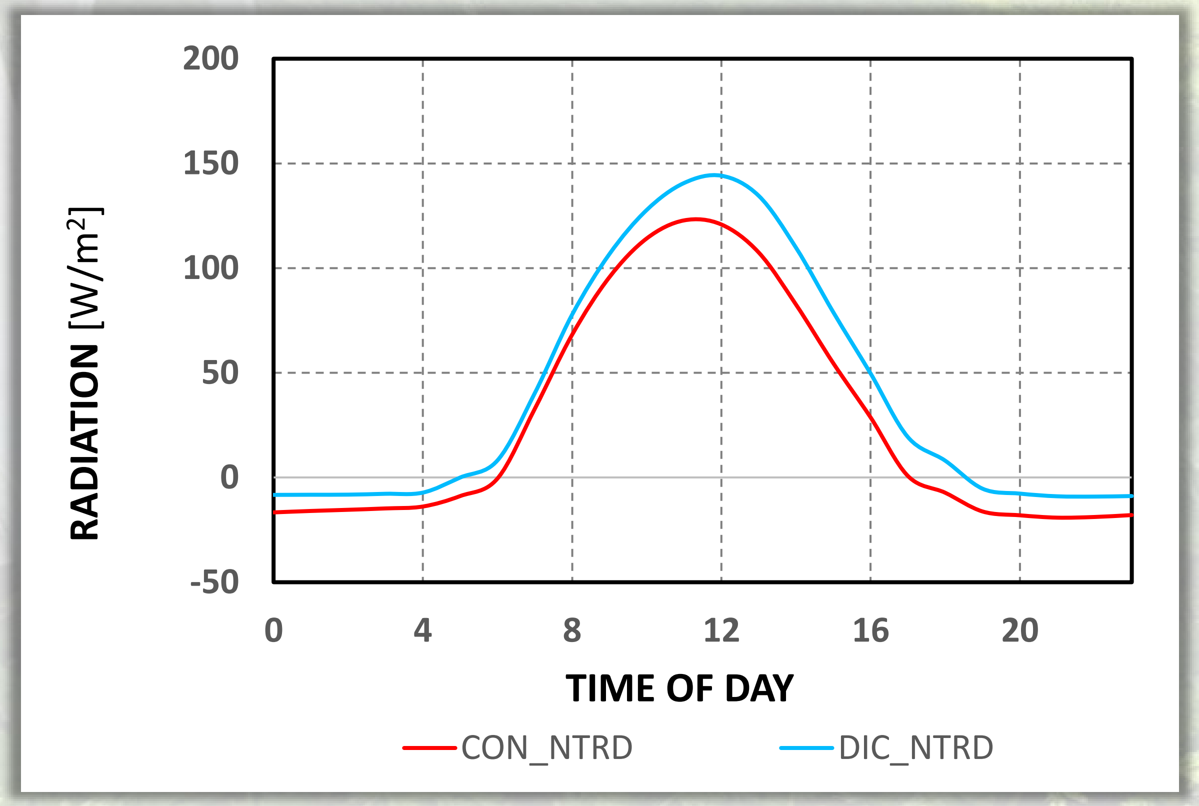




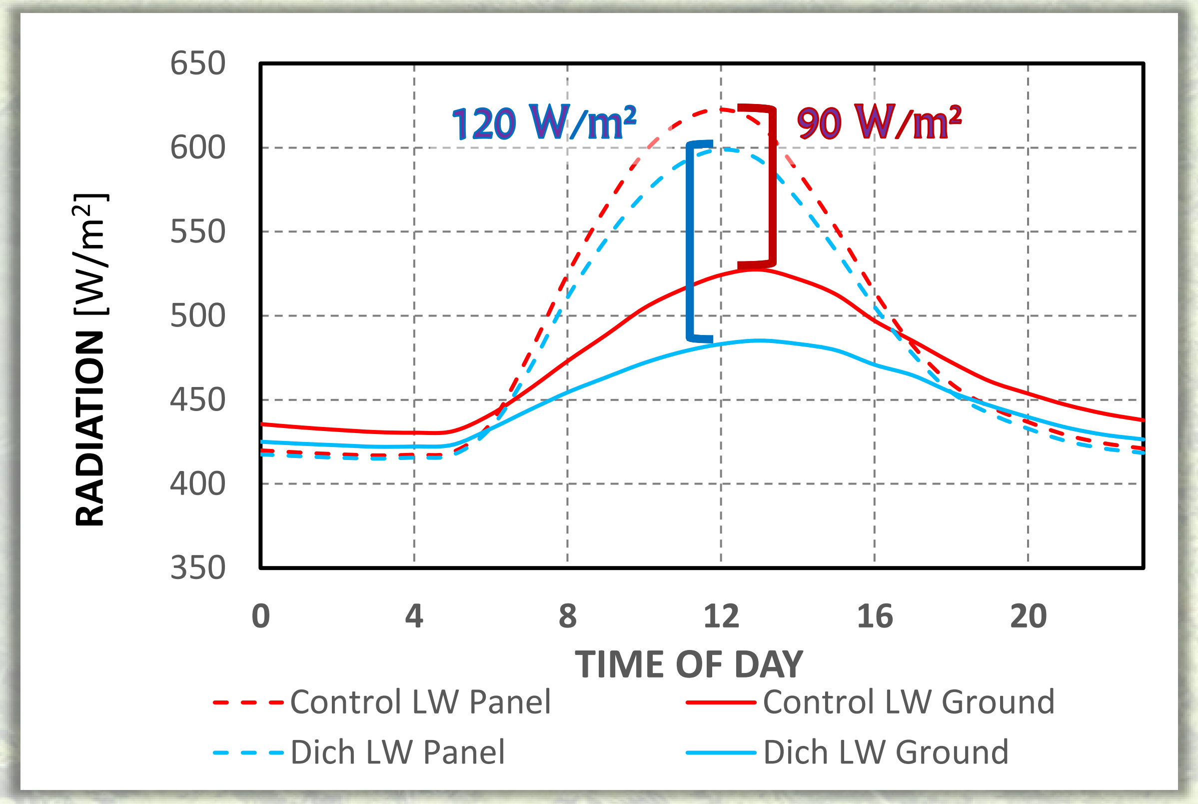
Temperature difference between control plot and test plot.
Ensemble for July-August 2020

Net radiation below panels

Net Radiation

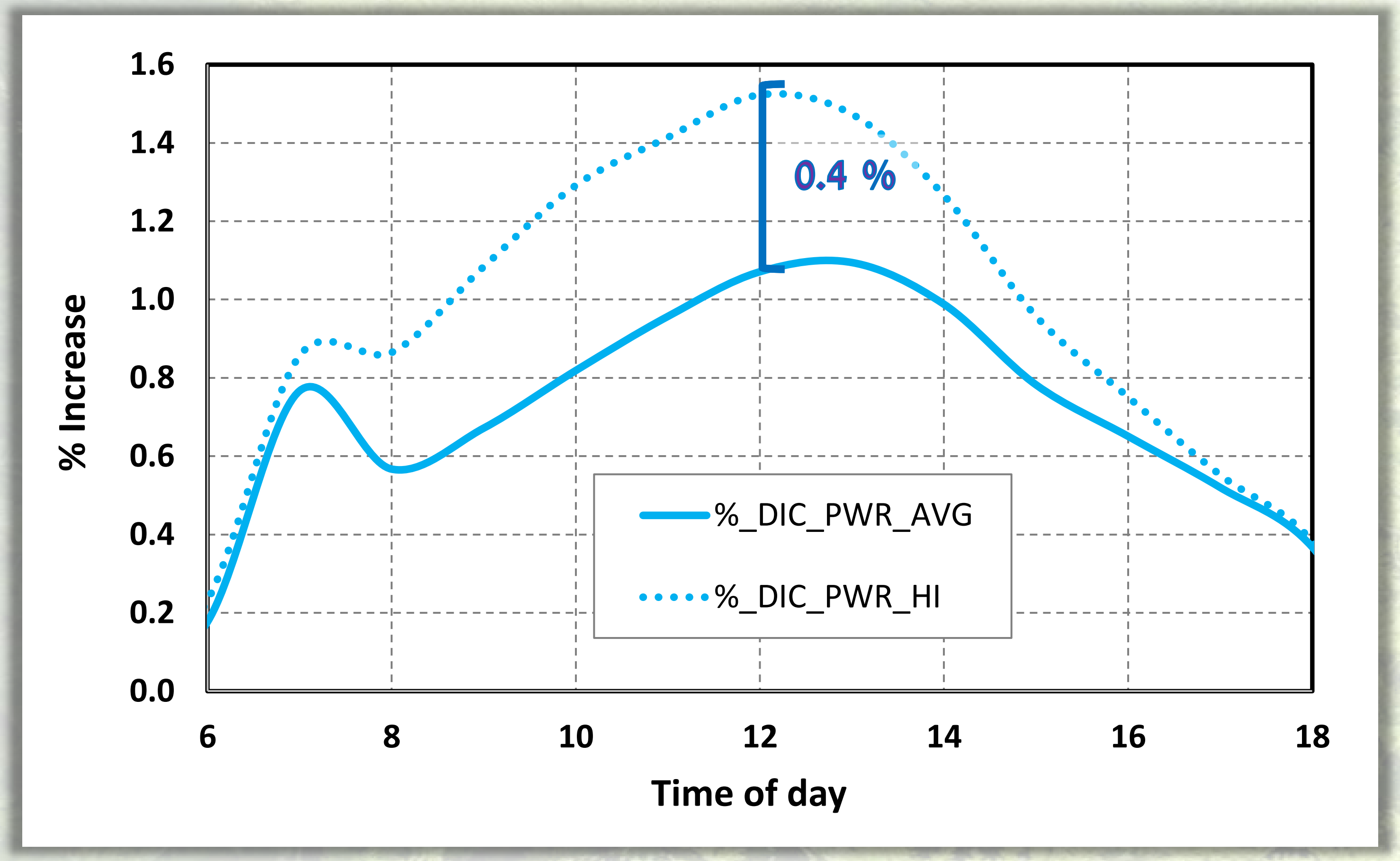


Longwave from Panel vs. Ground



Electricity Output

Calculated Increase in Output (%) - Dichondra



An empirical model of panel temperature

Faiman equation:

$$T_m = T_a + \frac{E}{U_0 + U_1 \times W}$$

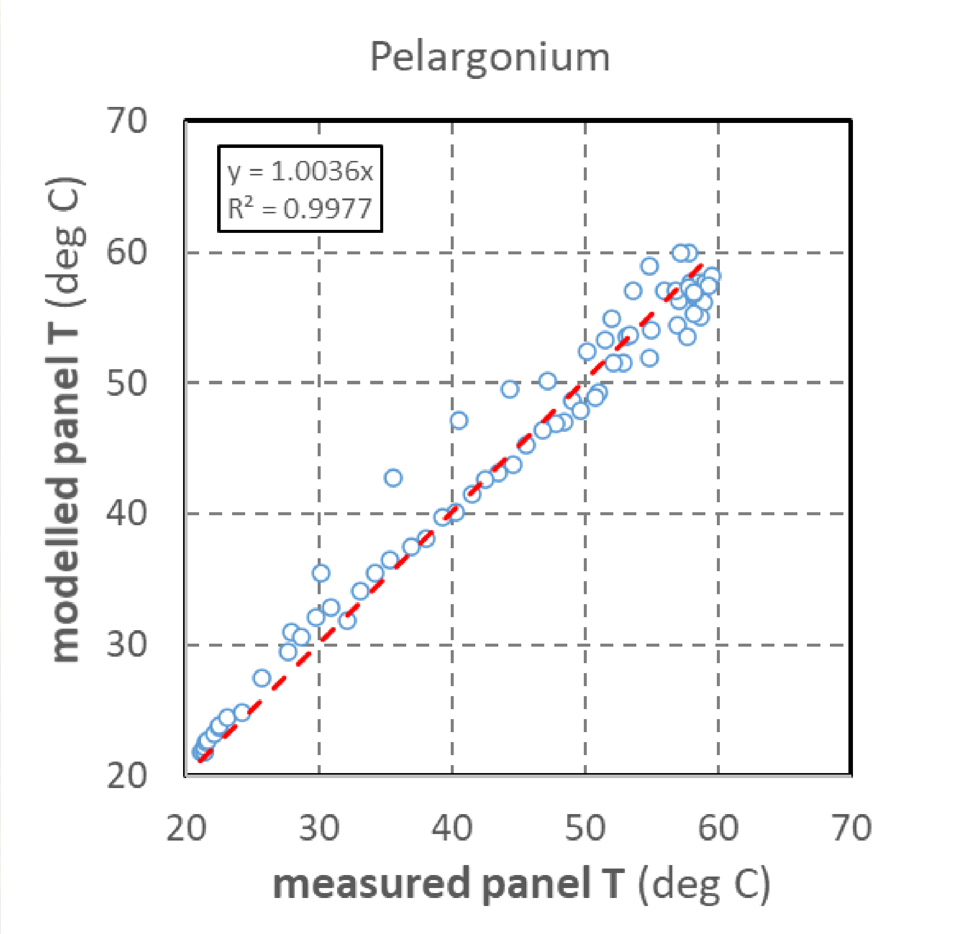
Ta - air DBT (deg C)

E - solar radiation (W/m^2)

W - wind speed (m/s)

U_0 - 25 W/m^2

U_1 - 6.84 W/m^2



Modified Faiman equation:

$$T_m = T_a + \frac{\alpha E}{U_0 + U_1 \times W}$$

Ta - air DBT (deg C)

E - solar radiation (W/m^2)

α - absorptivity

W - wind speed (m/s)

U_0 - 18 W/m^2

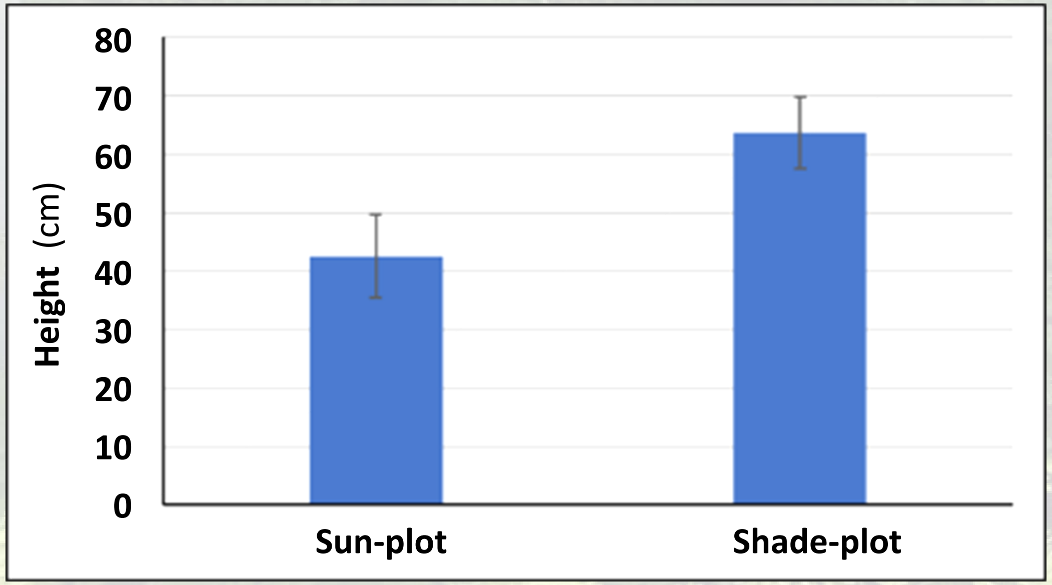
U_1 - 6.84 W/m^2

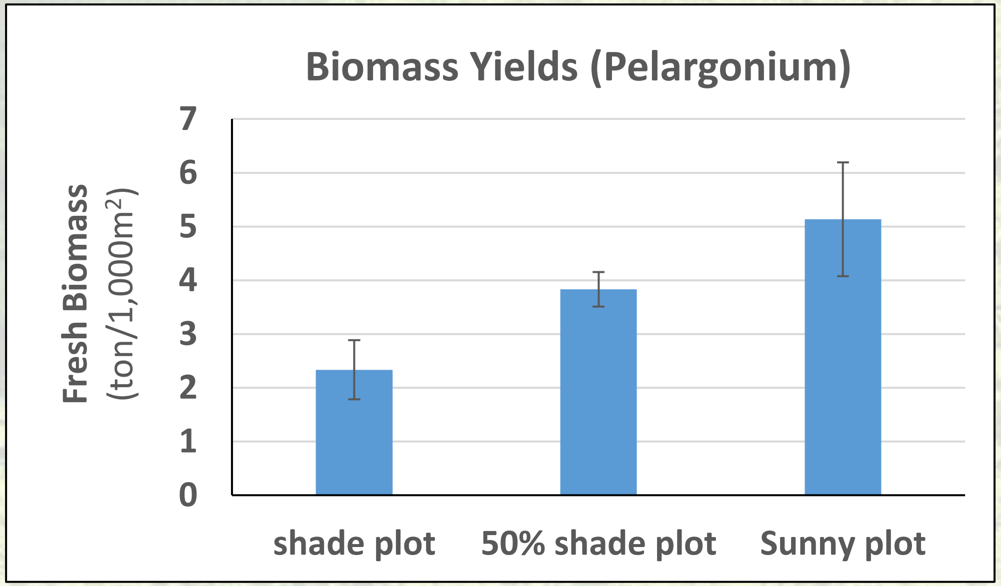
α = 0.95 over bare soil,
0.91 over plants

Crop Growth

Taller plants and larger leaves in the shade

...but more biomass in the sun





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Land Equivalent Ratio

167%

104%

100%

100%

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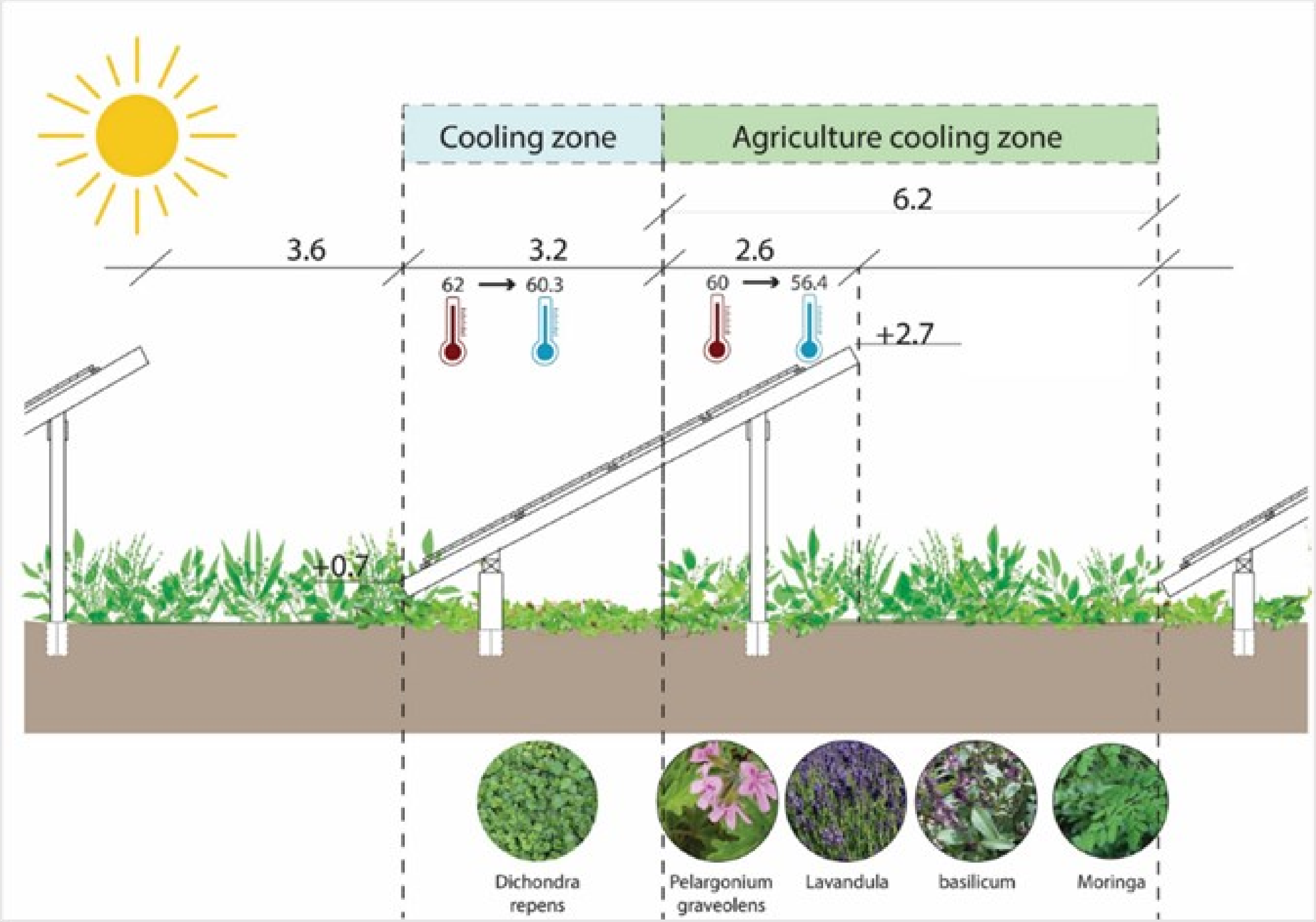
Schematic proposal for retrofitting existing solar farms



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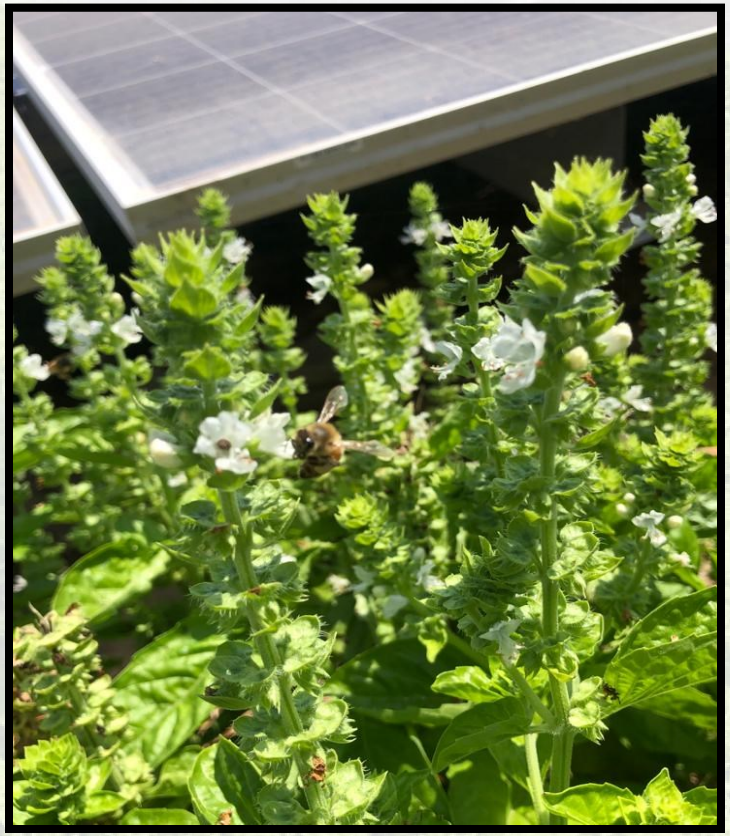
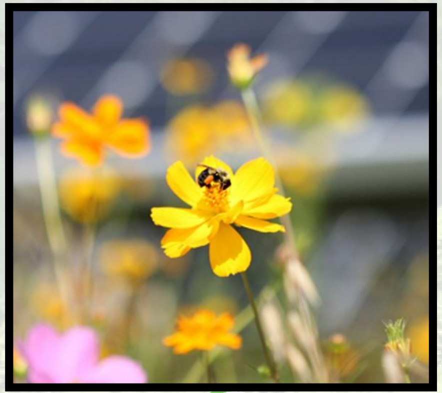
Summary

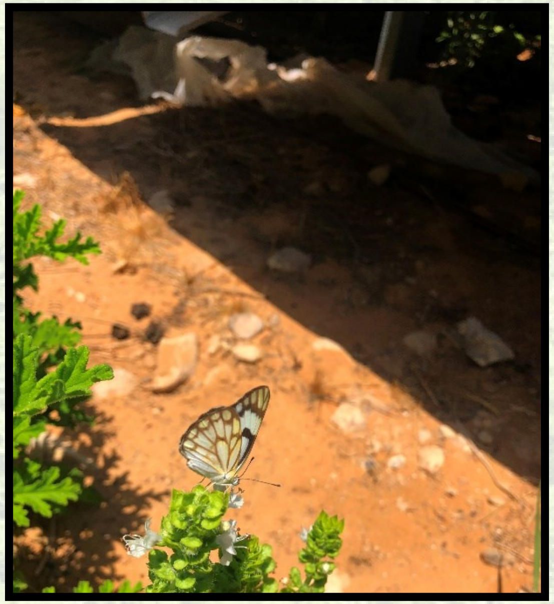
Further research

1. Agriculture
   - Plants with different evapotranspiration regimes
   - Taller crops

2. Solar panels
   - Increasing panel height above the ground
   - Tracking (single axis)
   - Orientation of strings (N-S vs. E-W)







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