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# Co-locating Agriculture and Solar Renewable Energy Production (agrivoltaics) to Improve Food, Energy, and Water Security

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School of Geography,  
Development & Environment



**TUCSON UNIFIED**  
SCHOOL DISTRICT



# **We want sustainable agriculture, but current practices are vulnerable to a changing climate**



## **LOW ON WATER, CALIFORNIA FARMERS TURN TO SOLAR FARMING**

August 6, 2019 / in All News, San Joaquin Valley / by News Article Report

# We want to move to renewables, but those may also be vulnerable

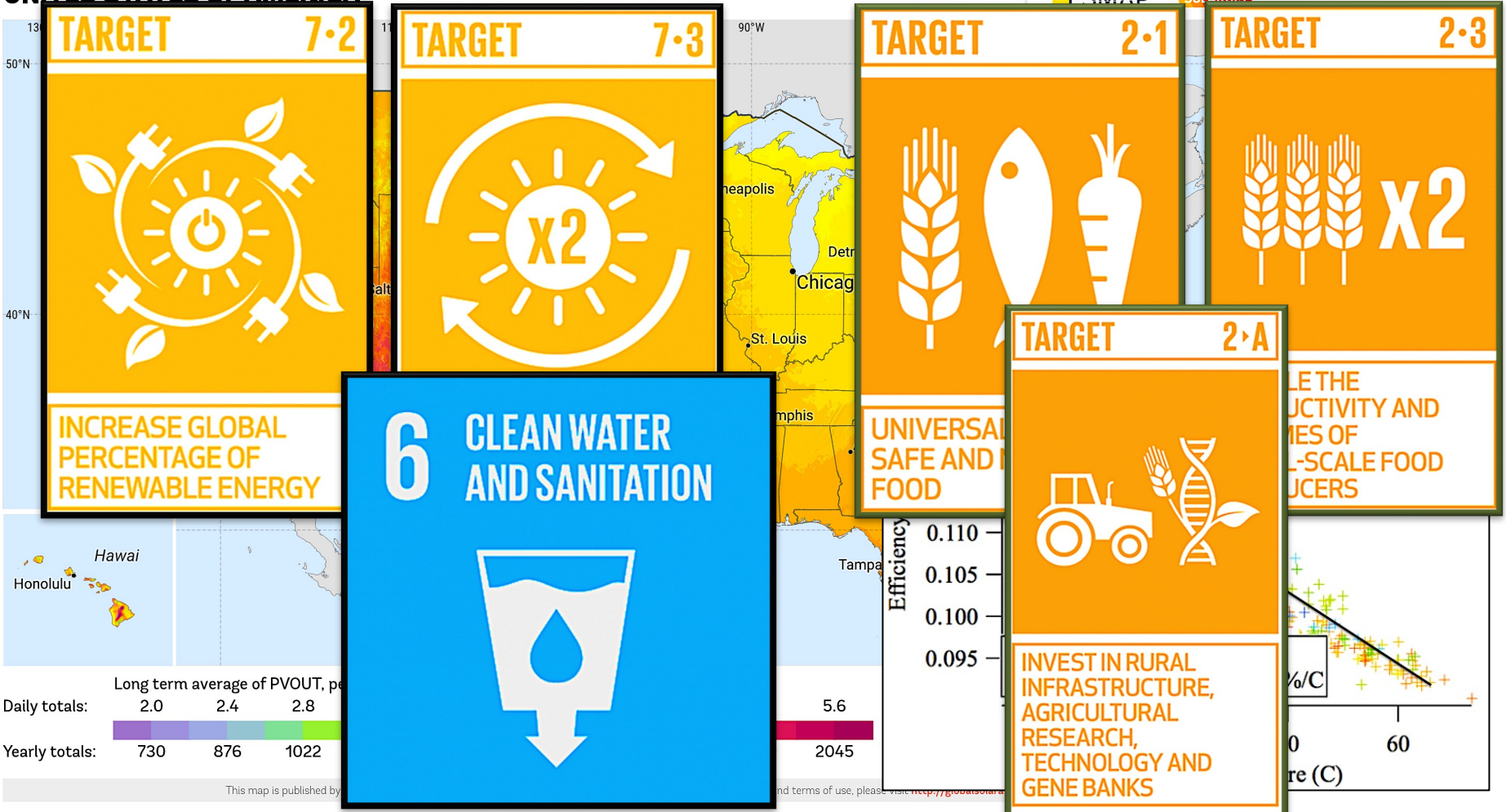
SOLAR RESOURCE MAP

**PHOTOVOLTAIC POWER POTENTIAL**

**UNITED STATES OF AMERICA**



ESMAP SOLARGIS



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# What is 'agrivoltaics'?

agrivoltaics = agriculture + photovoltaics  
(photovoltaics = renewable energy production from solar panels)



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## Farms That Harvest the Sun—Twice

By Eleanor Greene



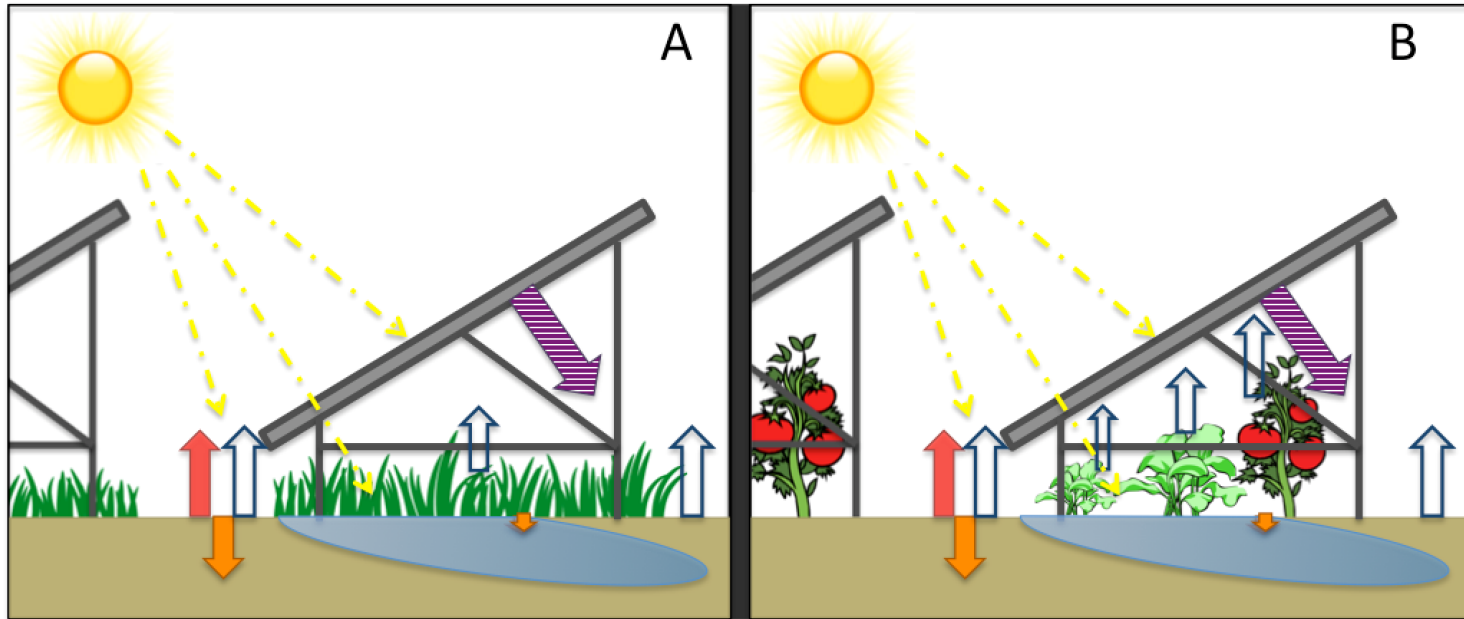
Photo by Moses Thompson

# What is 'agrivoltaics'?

agrivoltaics = agriculture + photovoltaics  
(photovoltaics = renewable energy production from solar panels)

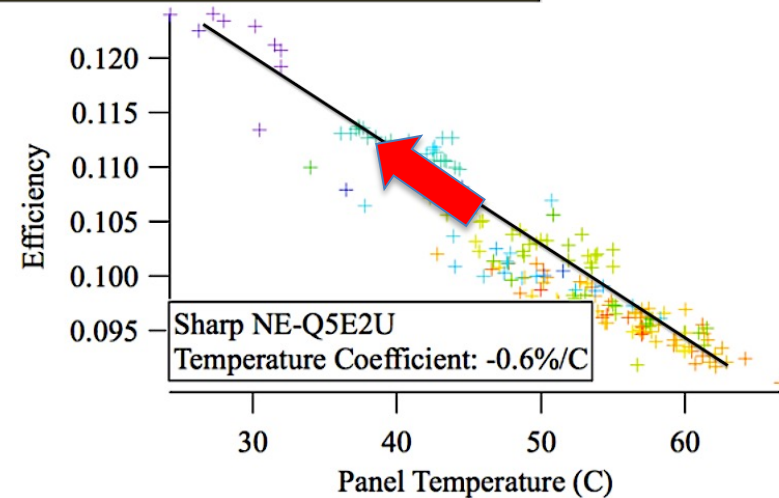


# Co-locating vegetation + renewable energy could = food, energy, and water benefits



Create novel ecosystems to:

1. Adapt food systems to survive drought and temperature stress
2. Improve renewable energy production
3. Ease our dependence on irrigation



# Co-locating vegetation + renewable energy could = food, energy, and water benefits

Energy  
Production

Revenue

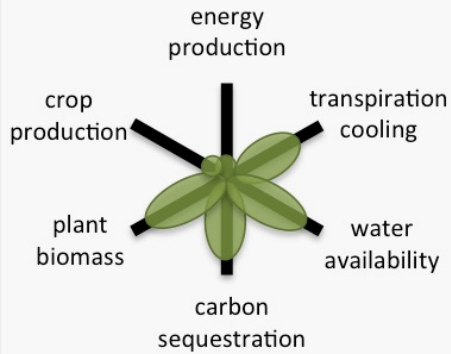
Water  
conservation

Food  
Production

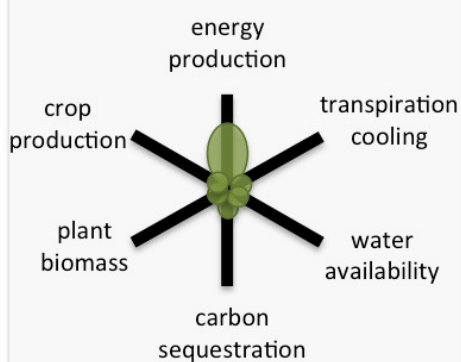




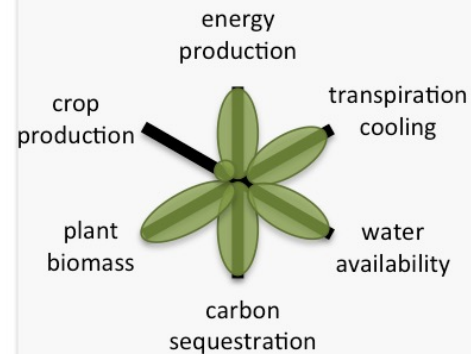
# Co-locating vegetation + renewable energy could = food, energy, and water benefits



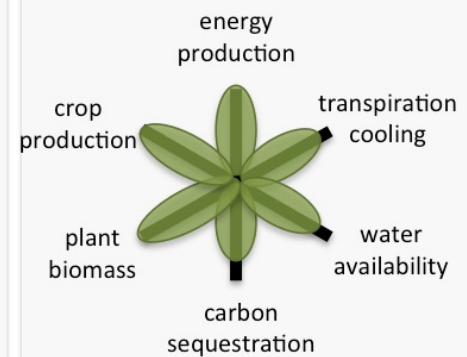
natural ecosystem



photovoltaic installation



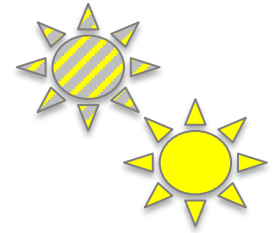
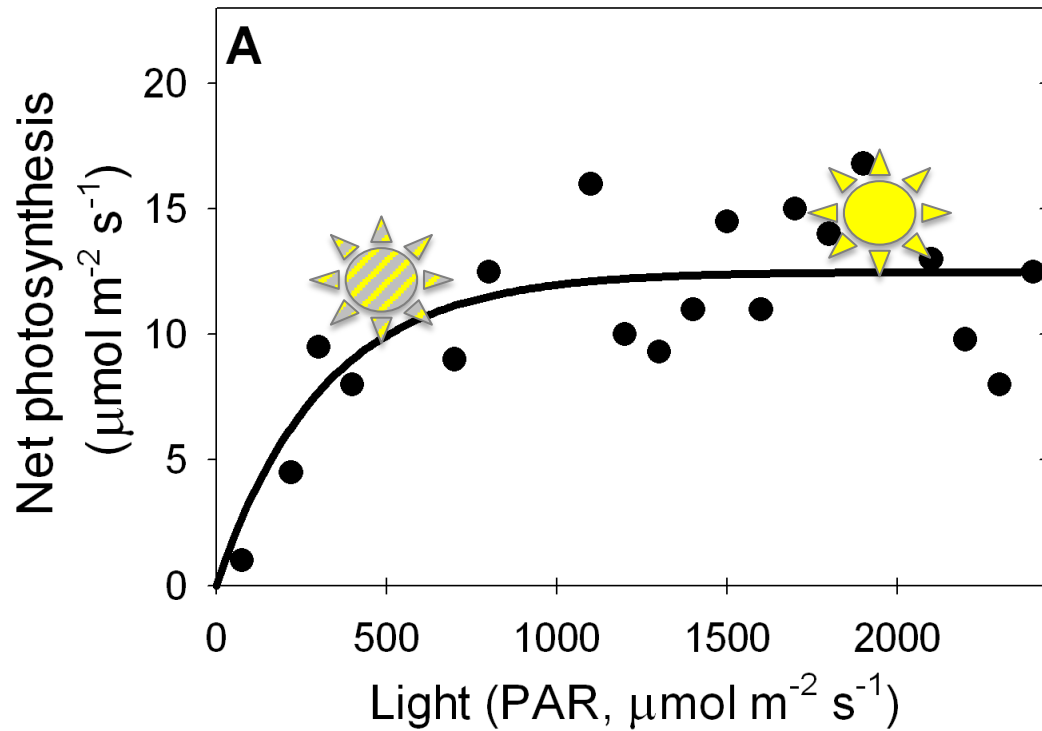
photovoltaic with restored ecosystem



photovoltaic with agroecosystem

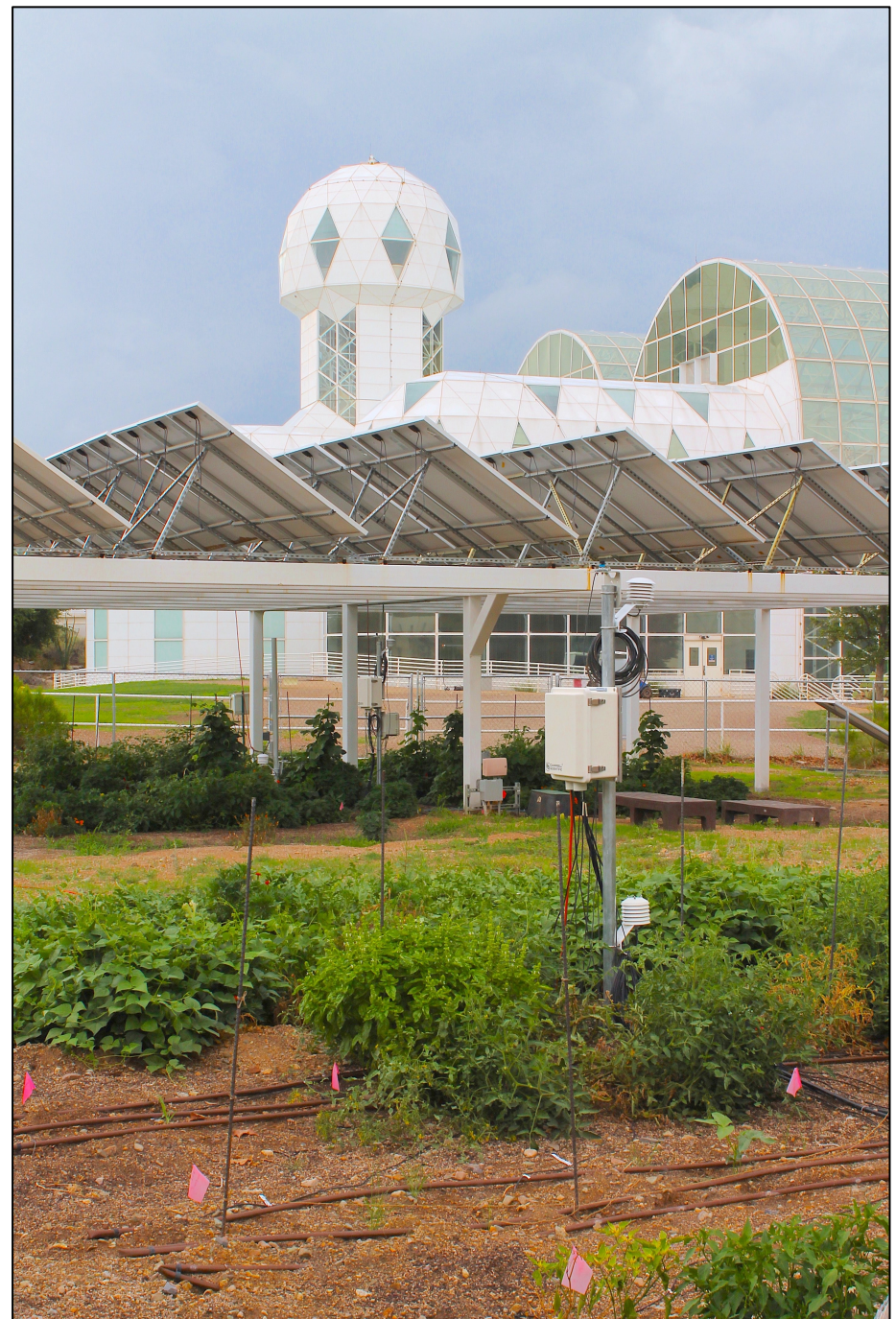
We need to move past an “either-or” in terms of our land allocation to generate many important ecosystem services

# Can plants handle being grown in the shade?

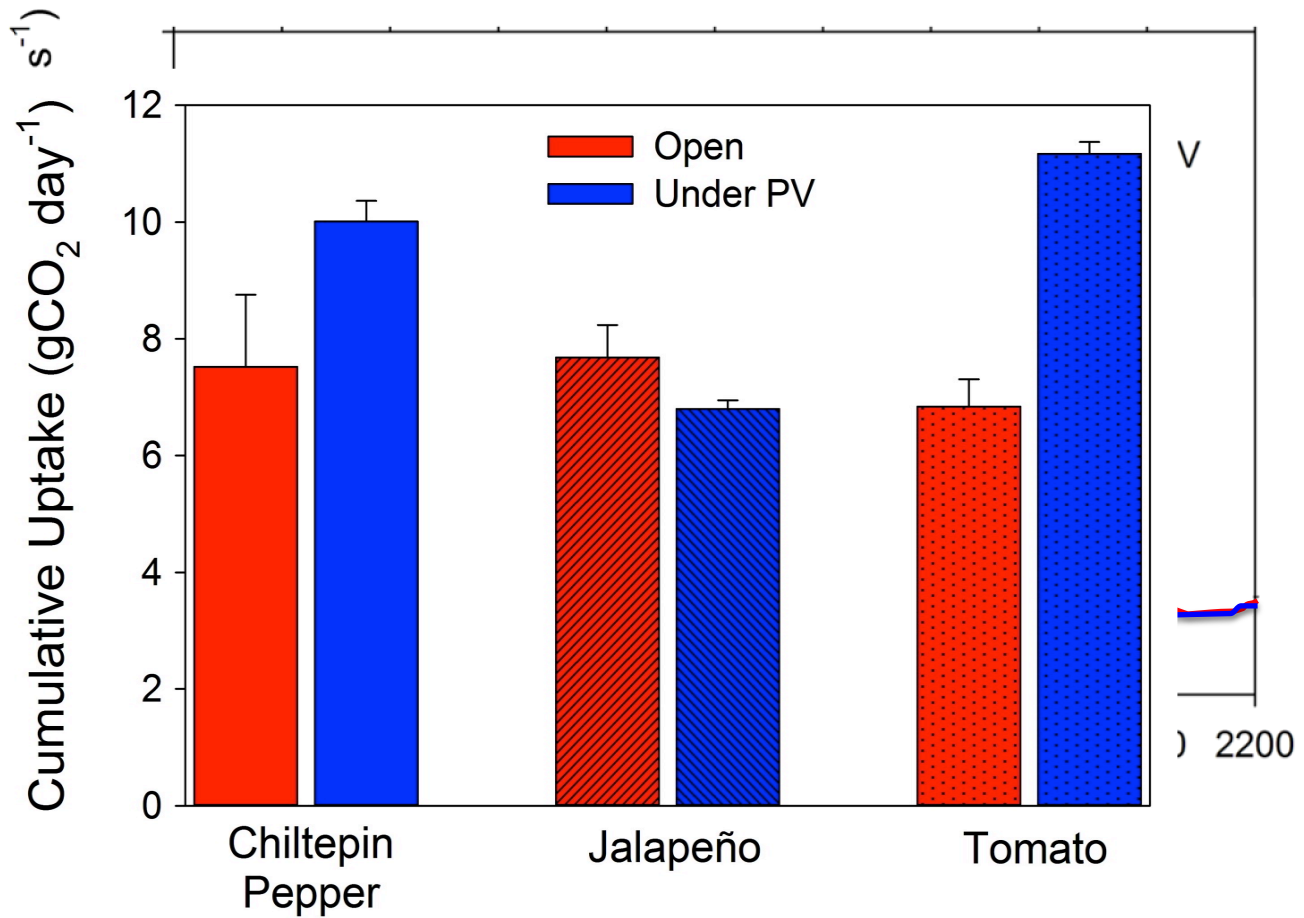


*A small reduction in photosynthetic capacity due to reduced light might be offset by better temperatures!*

# Biosphere 2 Agrivoltaics Learning Lab

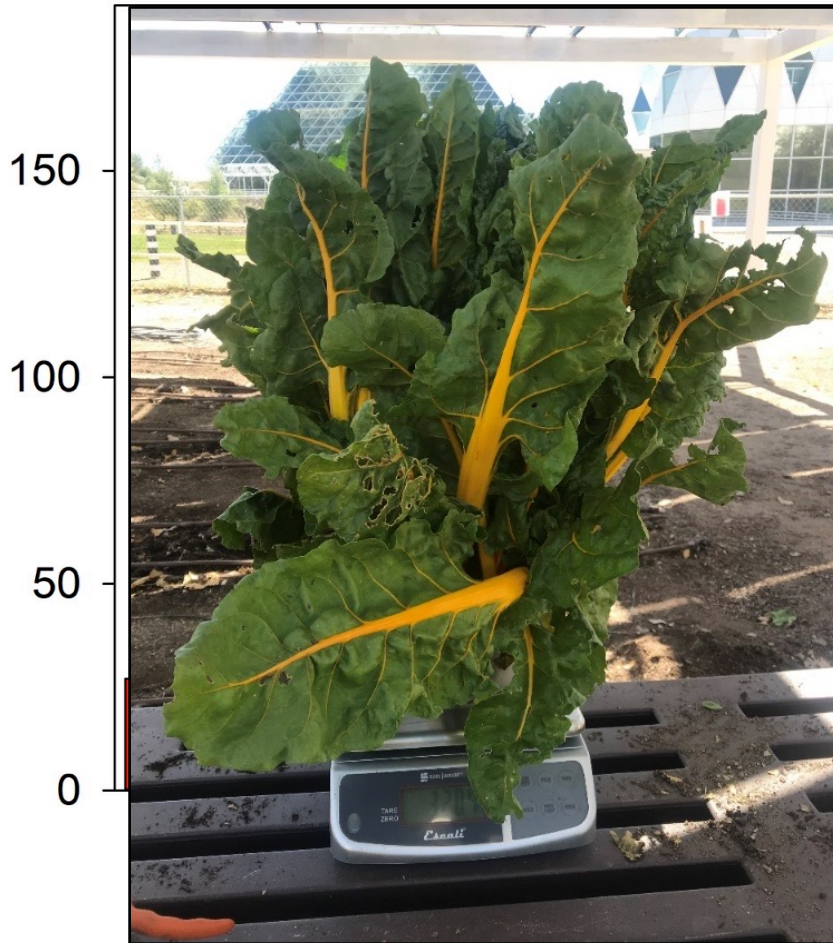


# Food - a win for plant function!



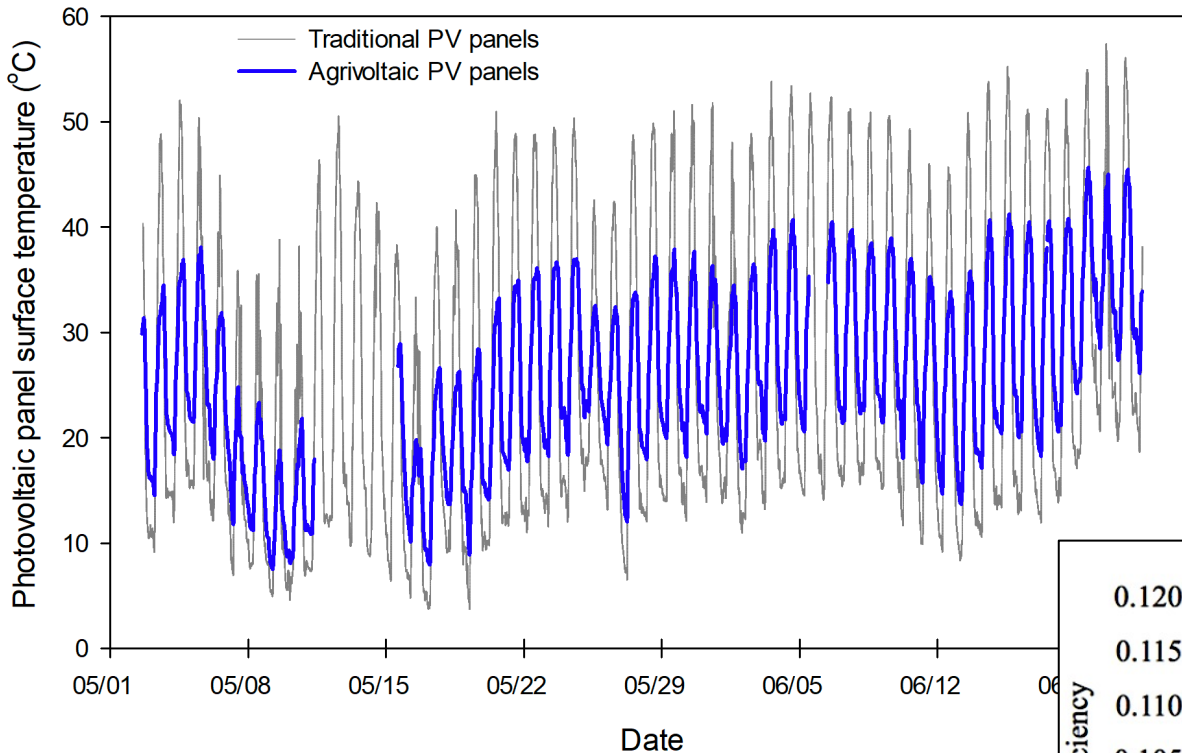
# Food - a win for food

Total Fruit Production  
(for 5 replicate individuals)



Crop Type	Impacts from agrivoltaics
Basil	++
Bell peppers / Jalapeño	0
Broccoli	+ / -
Cabbage	+
Carrots	++
Chard	+
Chiltepin peppers	+
Lemmon grass	+
Lettuce	++
Marigolds (cut flowers)	+
Melon	0
Sweet potatoes	+
Tomatoes	++

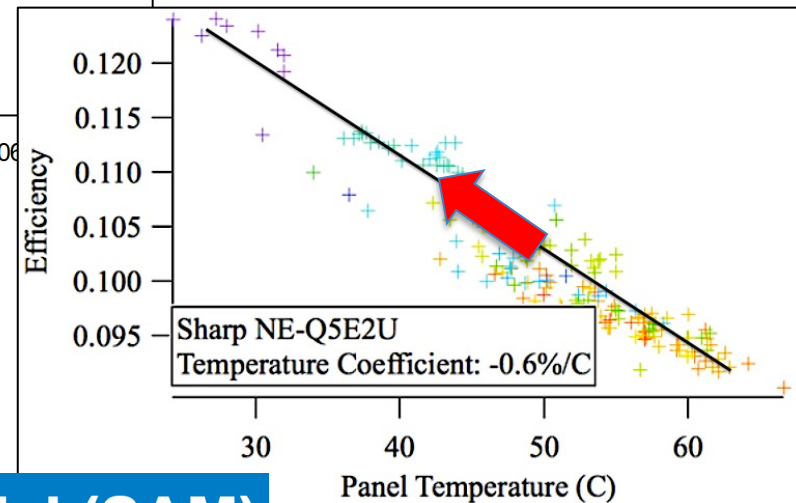
# Energy - a win for PV production!



Cooler temperatures =  
Increased PV efficiency  
and less wear-and-tear

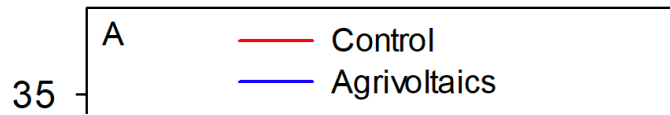
*Summer time average  
cooling ~9°C*

*... "3% increase in generation over  
those months, and a 1-2% increase  
in generation annually"*



 **NREL System Advisor Model (SAM)**  
NATIONAL RENEWABLE ENERGY LABORATORY

# Water - a win for irrigation savings!





nature  
sustainability

ARTICLES

<https://doi.org/10.1038/s41893-019-0364-5>

## Agrivoltaics provide mutual benefits across the food-energy-water nexus in drylands

Greg A. Barron-Gafford <sup>1,2\*</sup>, Mitchell A. Pavao-Zuckerman<sup>3</sup>, Rebecca L. Minor<sup>1,2</sup>, Leland F. Sutter<sup>1,2</sup>,  
Isaiah Barnett-Moreno<sup>1,2</sup>, Daniel T. Blackett<sup>1,2</sup>, Moses Thompson<sup>1,4</sup>, Kirk Dimond <sup>5</sup>,  
Andrea K. Gerlak<sup>1</sup>, Gary P. Nabhan<sup>6</sup> and Jordan E. Macknick<sup>7</sup>

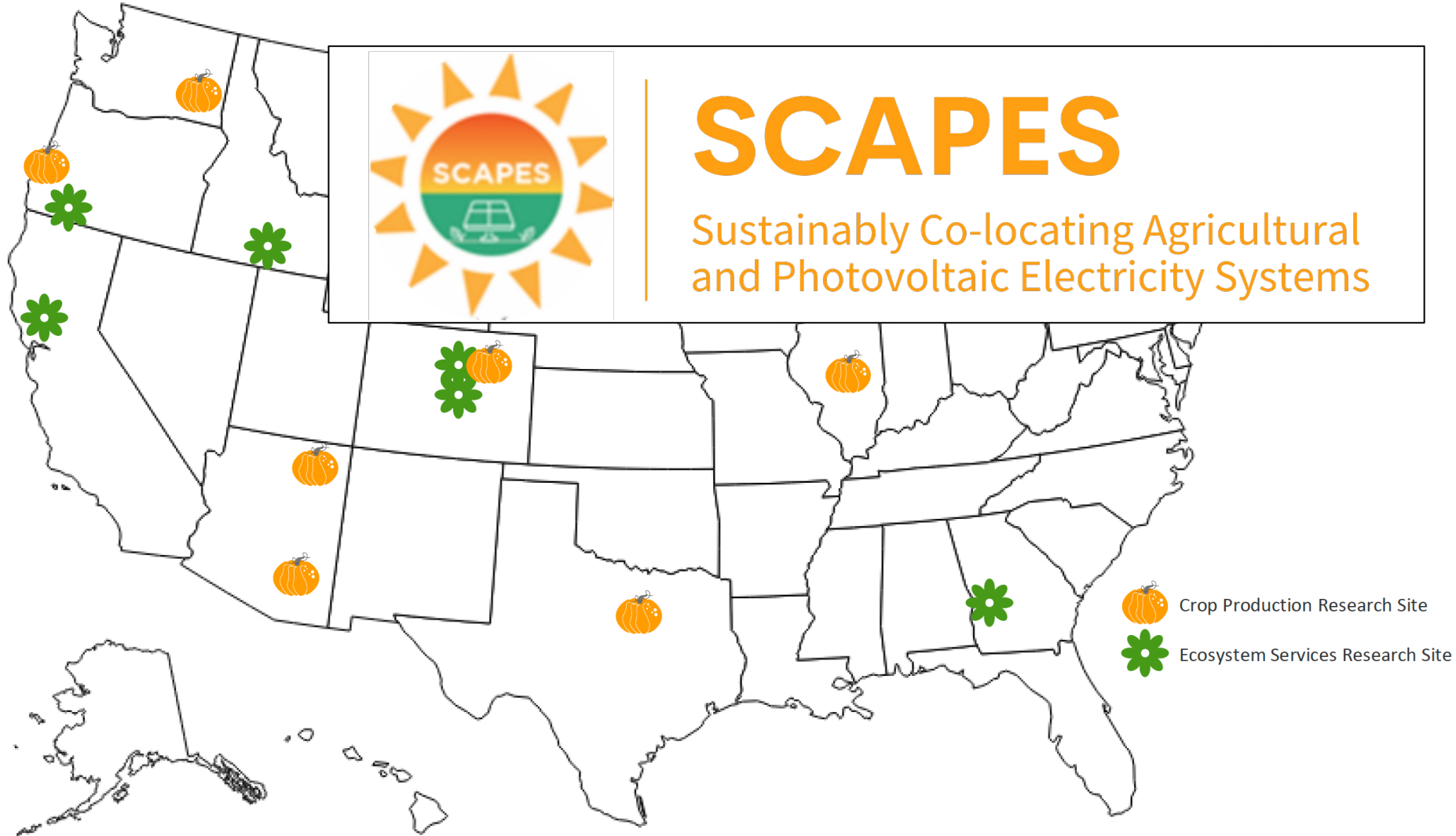
*Can we actually reduce our  
irrigation water use?*

# We are exploring agrivoltaics across the US to understand tradeoffs in different systems



## SCAPES

Sustainably Co-locating Agricultural  
and Photovoltaic Electricity Systems





# **Beyond the science about *food, energy, and water* benefits, agrivoltaics can help:**

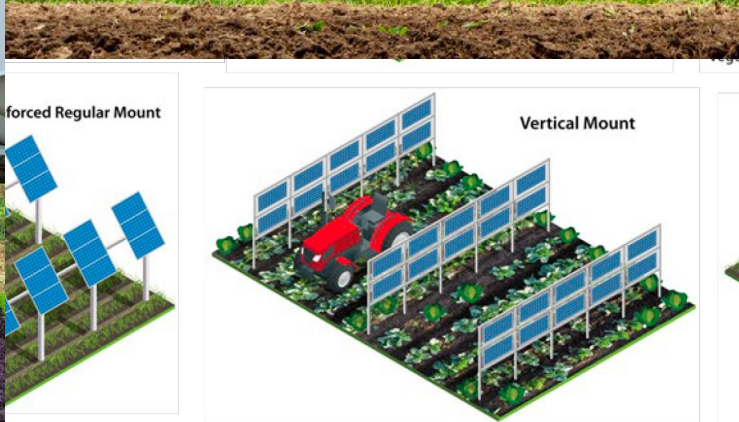
- \* Keep farms and ag in the community**
  - retain food production in rural and local markets, = dispersed resilient food systems across our country**
  - ‘canopy’ of solar can allow some places to become better at producing food or forage because we’ve reduced climate pressures**
  - reduce a slides towards more food deserts in rural areas and replace food deserts in urban environments**

# Beyond the science about *food, energy, and water* benefits, agrivoltaics can help:

\* Keep farms and ag *in the community*



LOW ON WATER, CALIFORNIA FARM



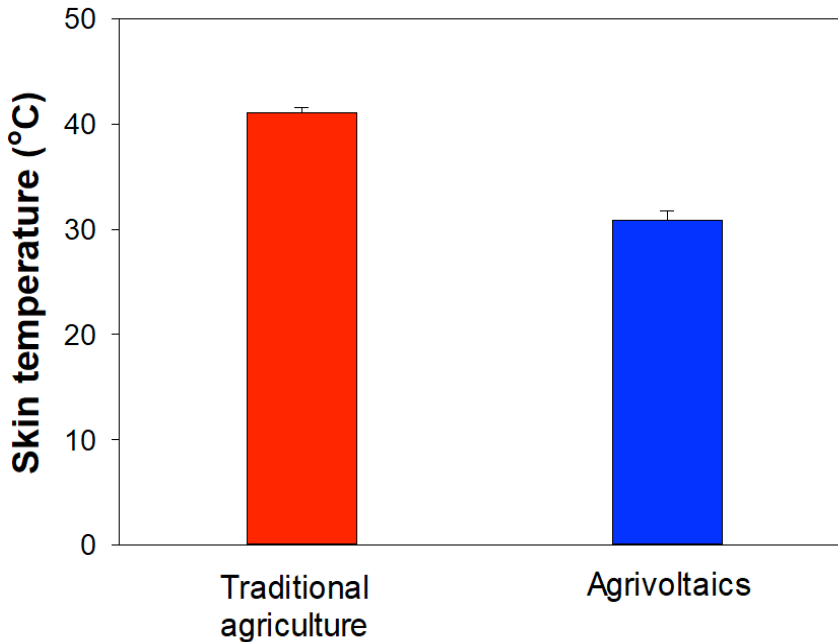
witz, Vignesh Ramasamy, Jordan Macknick and R  
*Multi-Land Use Photovoltaic Installations*. Golden, CO  
ratory. NREL/TP-6A20-77811

# Beyond the science about *food, energy, and water* benefits, agrivoltaics can help:

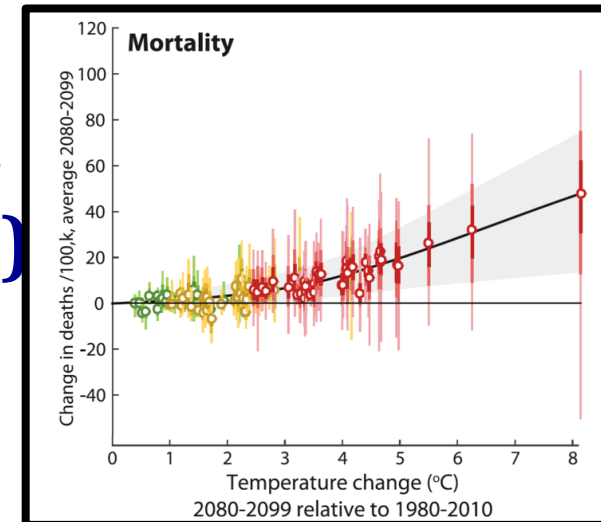
- \* Keep farms and ag *in the community*
- \* Income from solar can buffer against
  - (1) volatile market and trade disputes
  - (2) climate variability that is becoming even more unpredictable



# Beyond the science about *food, energy, and water* benefits, agrivoltaics can help:



**\* Access to better working conditions  
climate change (recent heat waves)**



# Experiential science learning and potential workforce development with K-12 kids

## Tucson elementary students help UA study how well plants grow under solar panels

By Marissa Heffernan Arizona Daily Star Nov 23, 2018



Kindergartners at Manzo Elementary School on Tucson's west side harvest chiltepin behind the school. The native plant is grown mostly in shade under solar panels and is part of a research project being done by Biosphere 2 scientists.

Photos by Rick Wiley / Arizona Daily Star

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Henry Brean Sep 12, 2020 Updated Sep 13, 2020

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### How Pan t

July 3, 2018



Greg Barron-Gafford, a biogeographer associate professor at the University of Arizona, and Alyssa Salazar, a research assistant and senior studying physical geography, weigh crops from a garden outside Biosphere 2, on Sept. 10, 2020. The gardens are part of an experiment on new crops and growing techniques for hotter, drier desert conditions expected as a result of climate change. This includes looking at the differences between full exposure gardening, utilizing shade of solar panels and various ranges of watering.

Josh Galemore / Arizona Daily Star

## ners 'ops

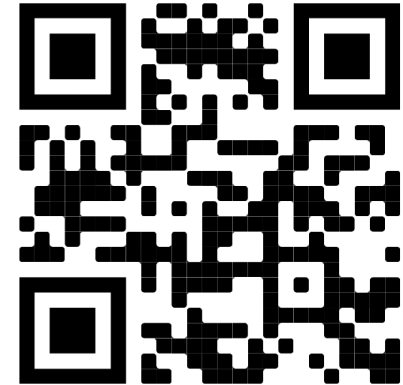
nd – and give



*To learn more, please visit:*  
*[www.TheSolarFarm.org](http://www.TheSolarFarm.org)*



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