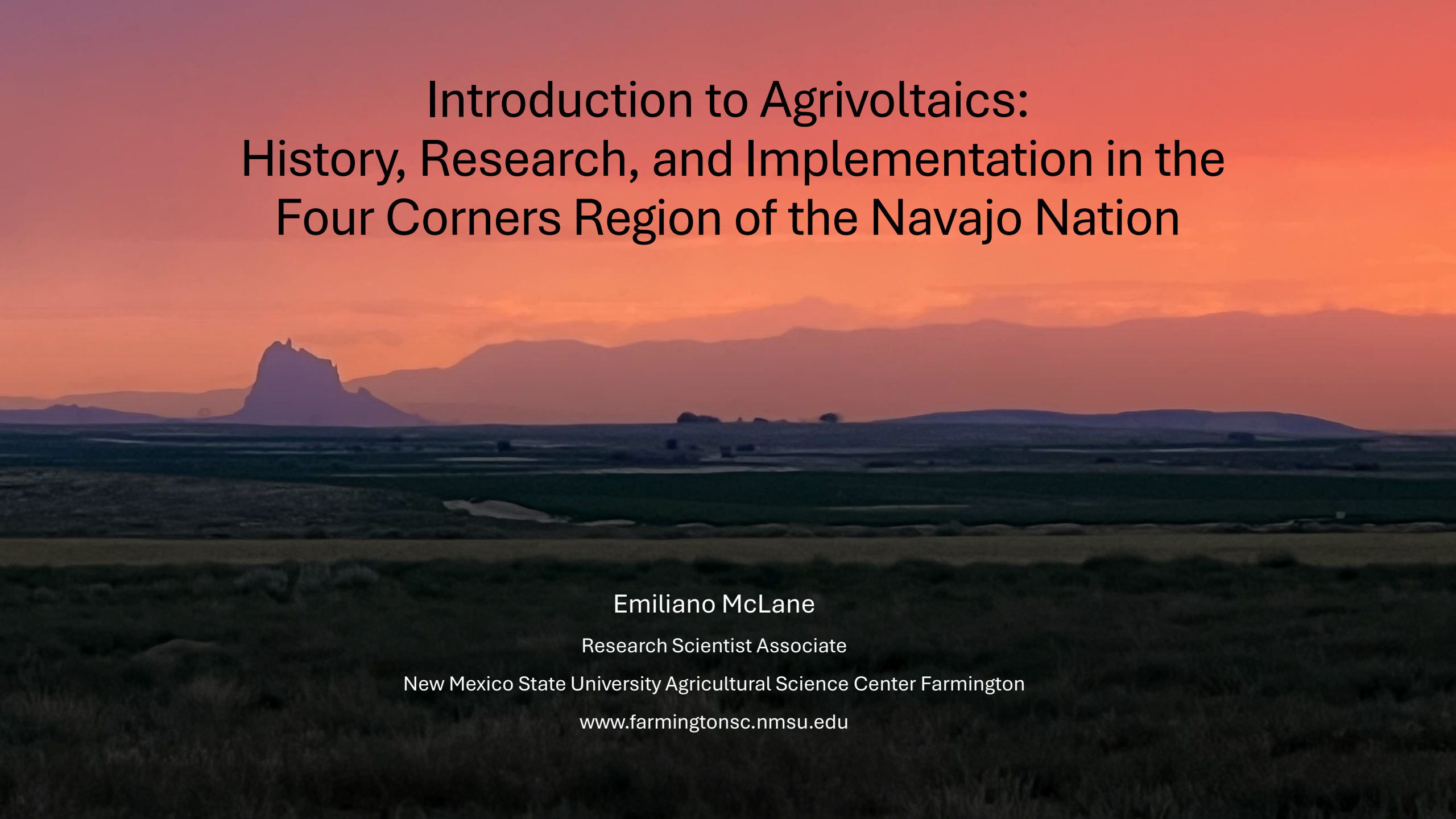
Introduction to Agrivoltaics: History, Research, and Implementation in the Four Corners Region of the Navajo Nation



Emiliano McLane

Research Scientist Associate

New Mexico State University Agricultural Science Center Farmington

www.farmingtonsc.nmsu.edu

About me

Enrolled member of the Te-Moak Tribe of Western Shoshone

Descendant of the Tāp Pīlam Coahuiltecan Nation
Wailaki and Nomlaki tribes of the Round Valley Indian Reservation

University of Idaho - **Bachelor of Science**
Agricultural Science, Communication, and Leadership

Minor: Agricultural Business, Leadership, and Education

New Mexico State University - **Master of Arts**
Agricultural & Extension Education

Master's Thesis Project Title:

Integrating Agrivoltaics in the Navajo Nation: A Synthesis of Research, Community Perceptions, and Demonstration of Agrivoltaics in the Four Corners Region

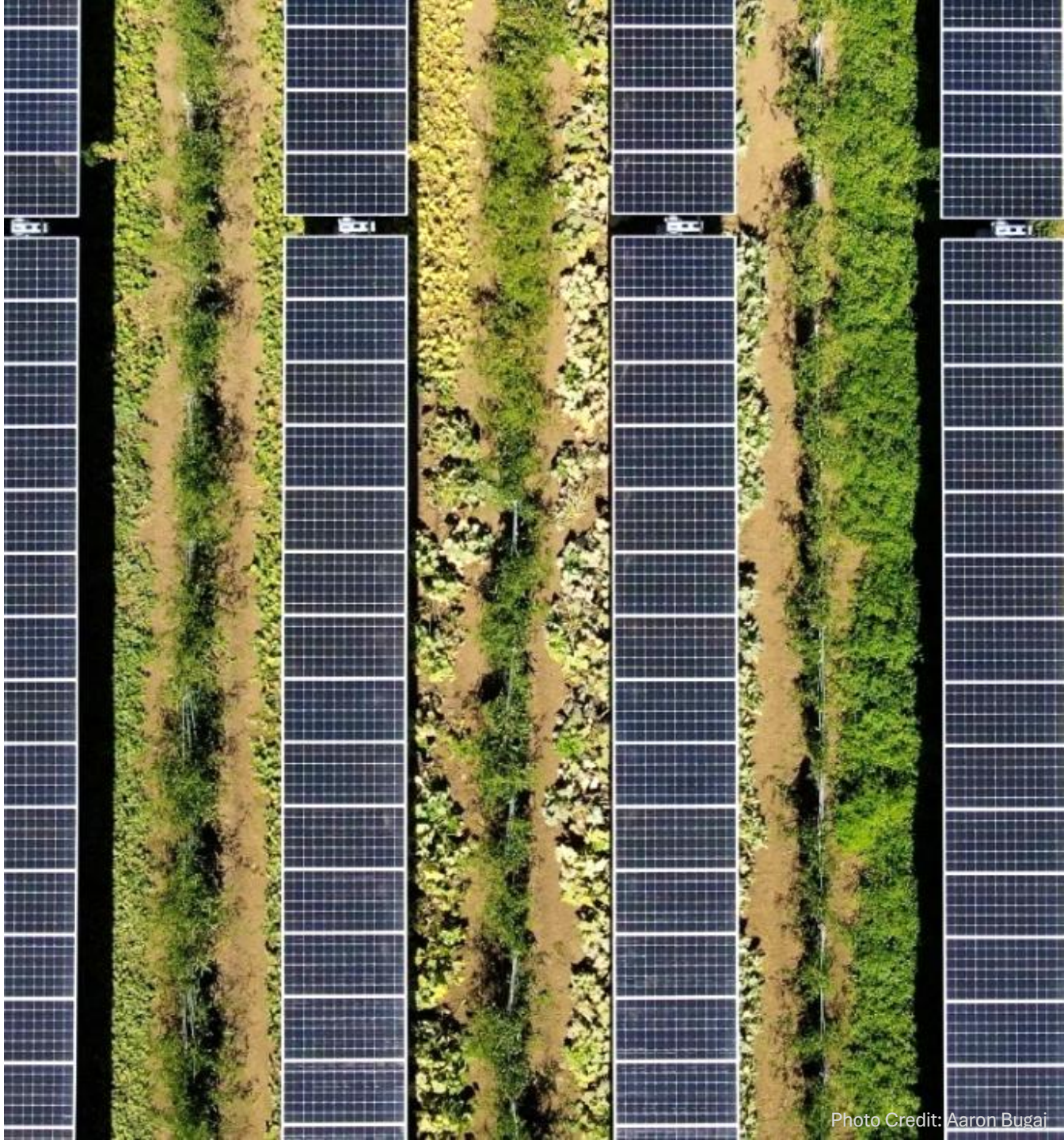
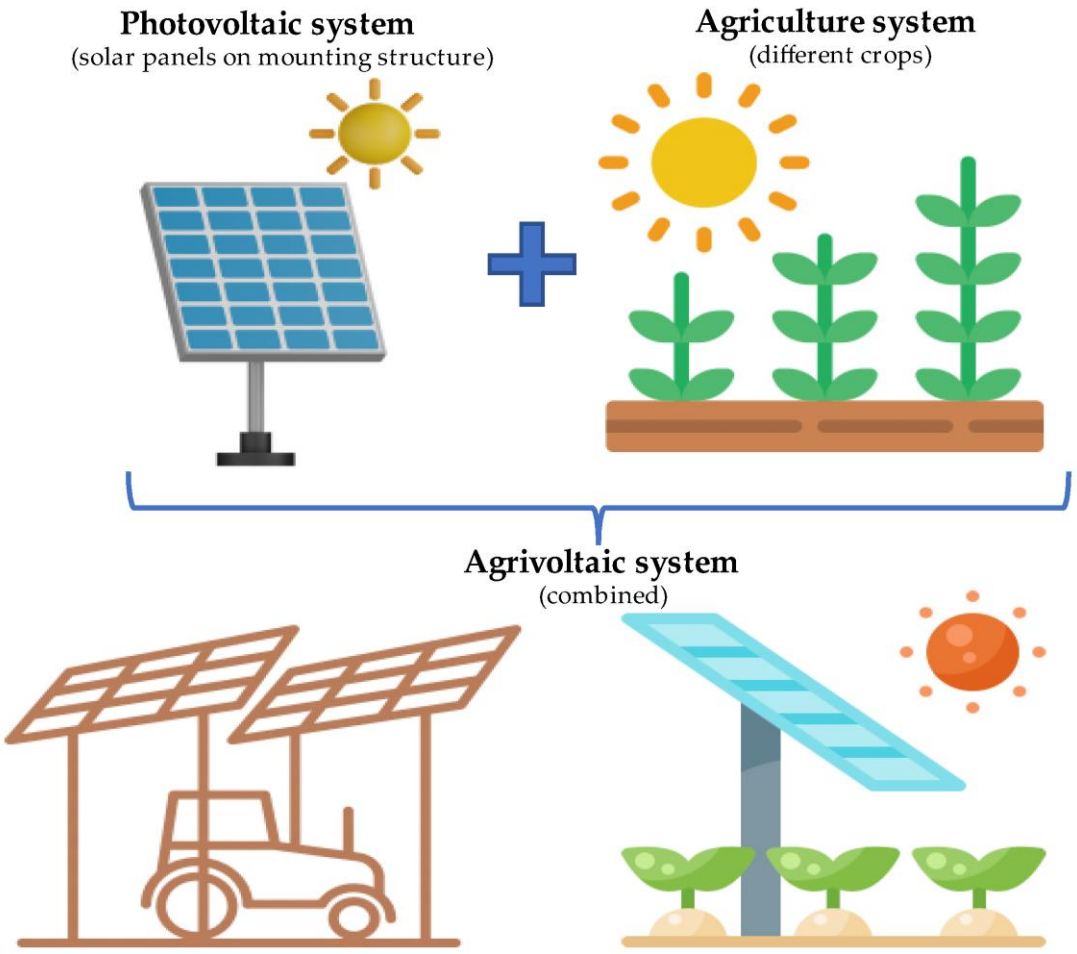
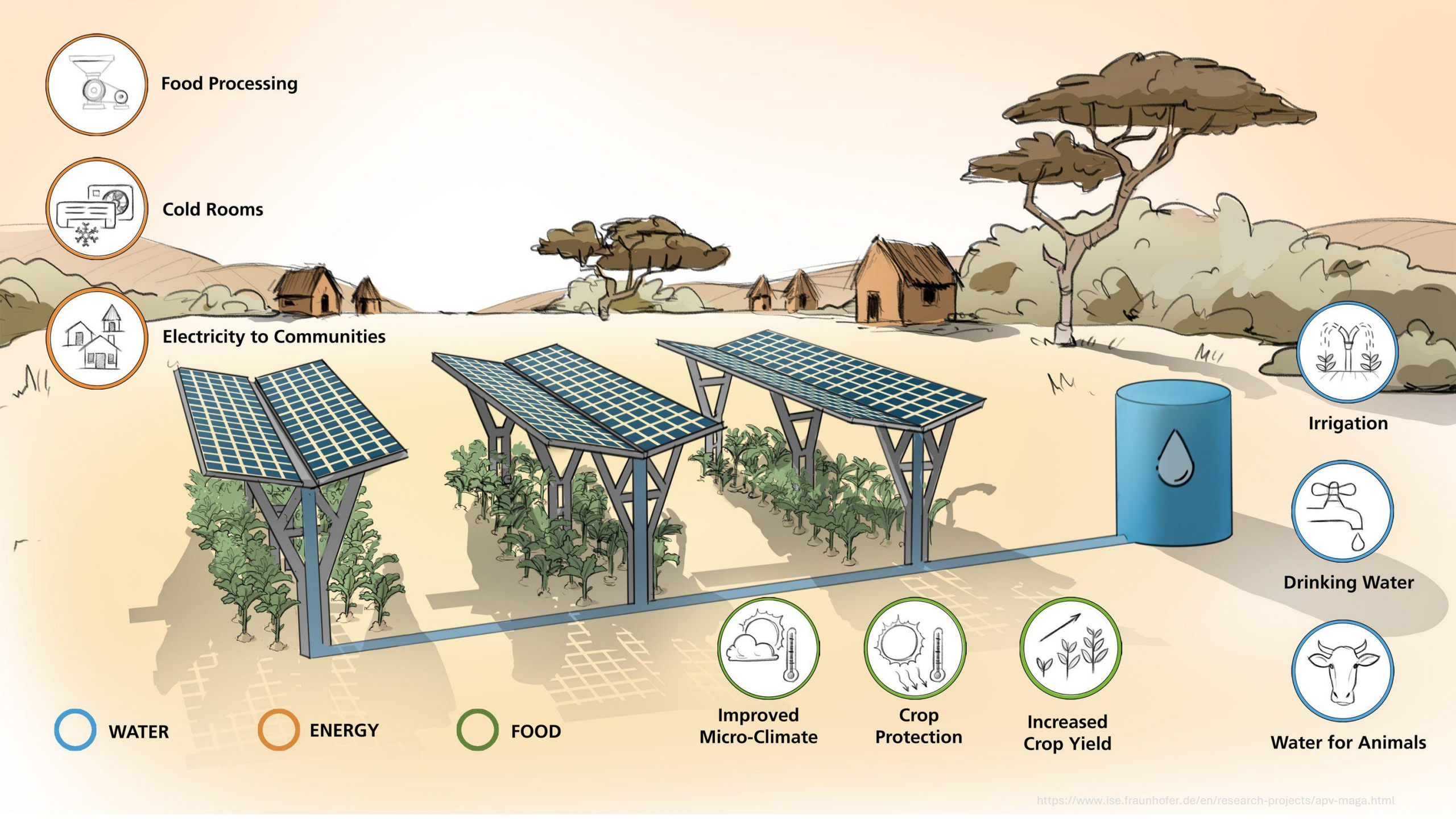


Photo Credit: Aaron Bugai

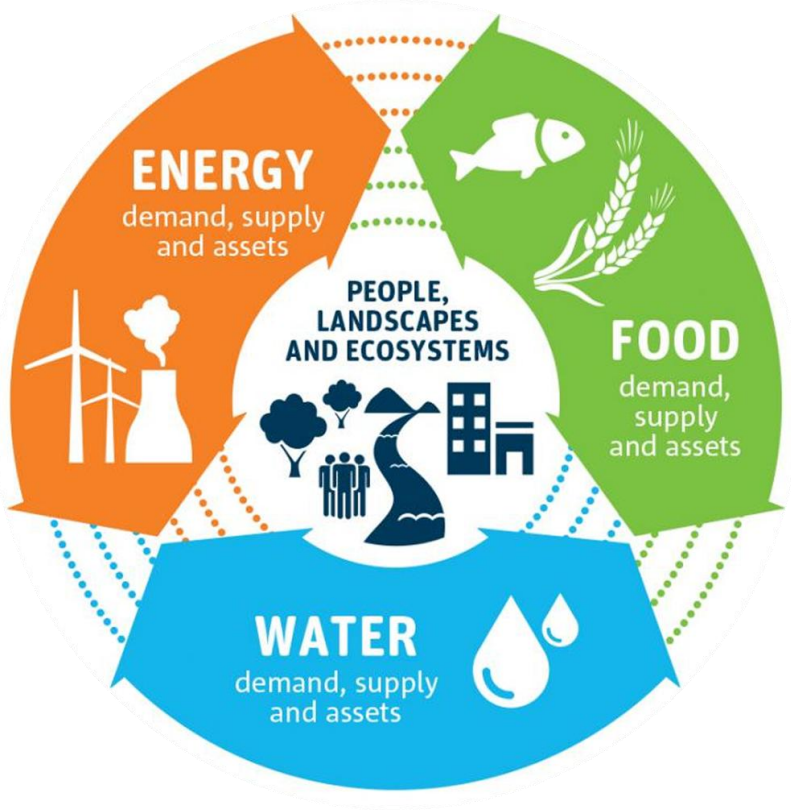
What is Agrivoltaics?



https://www.mdpi.com/1996-1073/16/2/611



https://www.ise.fraunhofer.de/en/research-projects/apv-maga.html

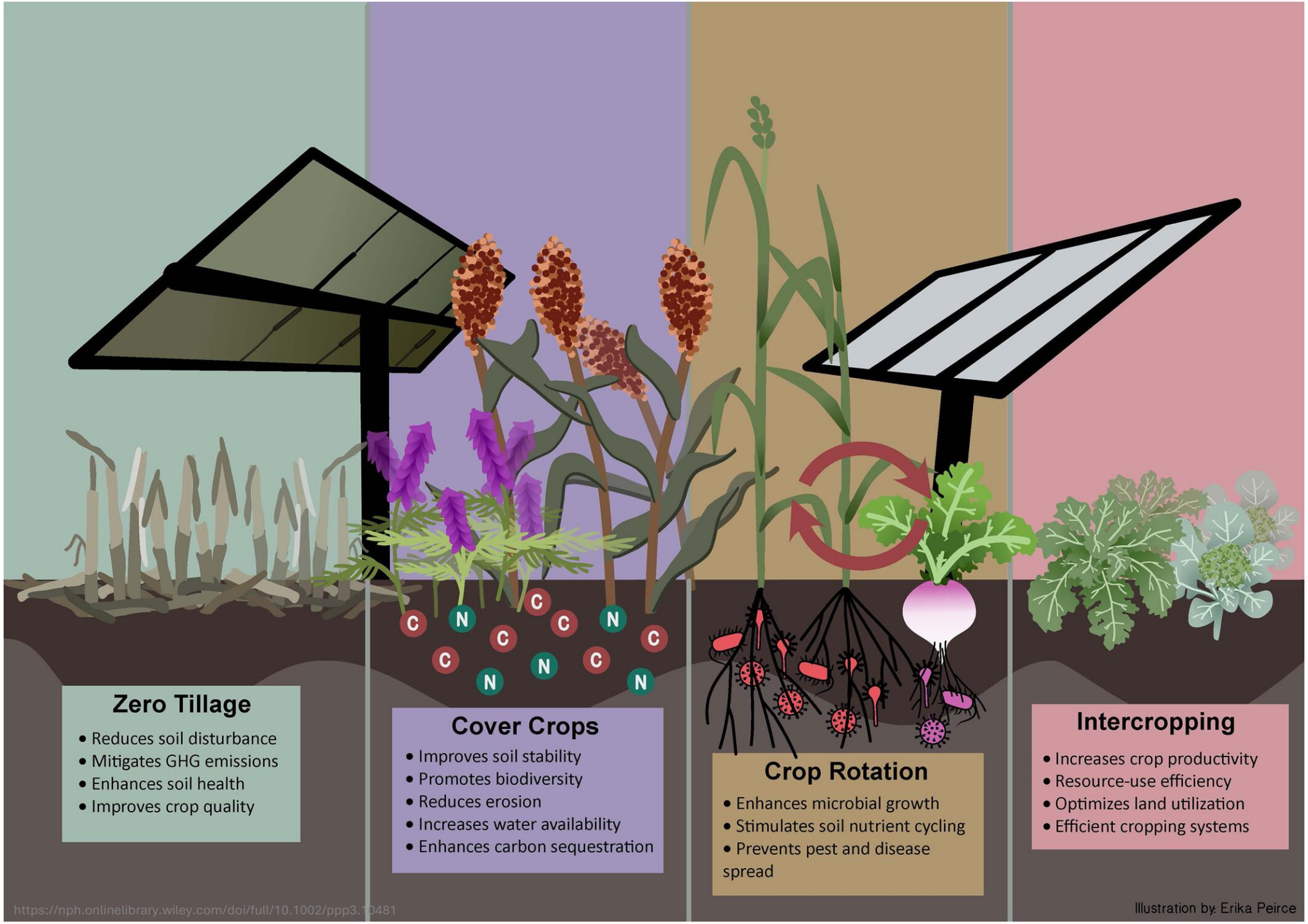


https://sandboxsolar.com/agrivoltaics/

https://standardsolar.com/blog/how-solar-grazing-supports-agrivoltaics-projects/

Benefits of Agrivoltaics

- Expansion of Solar Farms
- Unused Space Under Solar Panels
- Global Warming
- Economic Development
- Off-Grid Sustainability
- Workforce Development


Zero Tillage
• Reduces soil disturbance
• Mitigates GHG emissions
• Enhances soil health
• Improves crop quality
C
N
Cover Crops
• Improves soil stability
• Promotes biodiversity
• Reduces erosion
• Increases water availability
• Enhances carbon sequestration
Crop Rotation
• Enhances microbial growth
• Stimulates soil nutrient cycling
• Prevents pest and disease spread
Intercropping
• Increases crop productivity
• Resource-use efficiency
• Optimizes land utilization
• Efficient cropping systems
https://nph.onlinelibrary.wiley.com/doi/full/10.1002/ppp3.10481
Illustration by: Erika Peirce

Relative Advantage

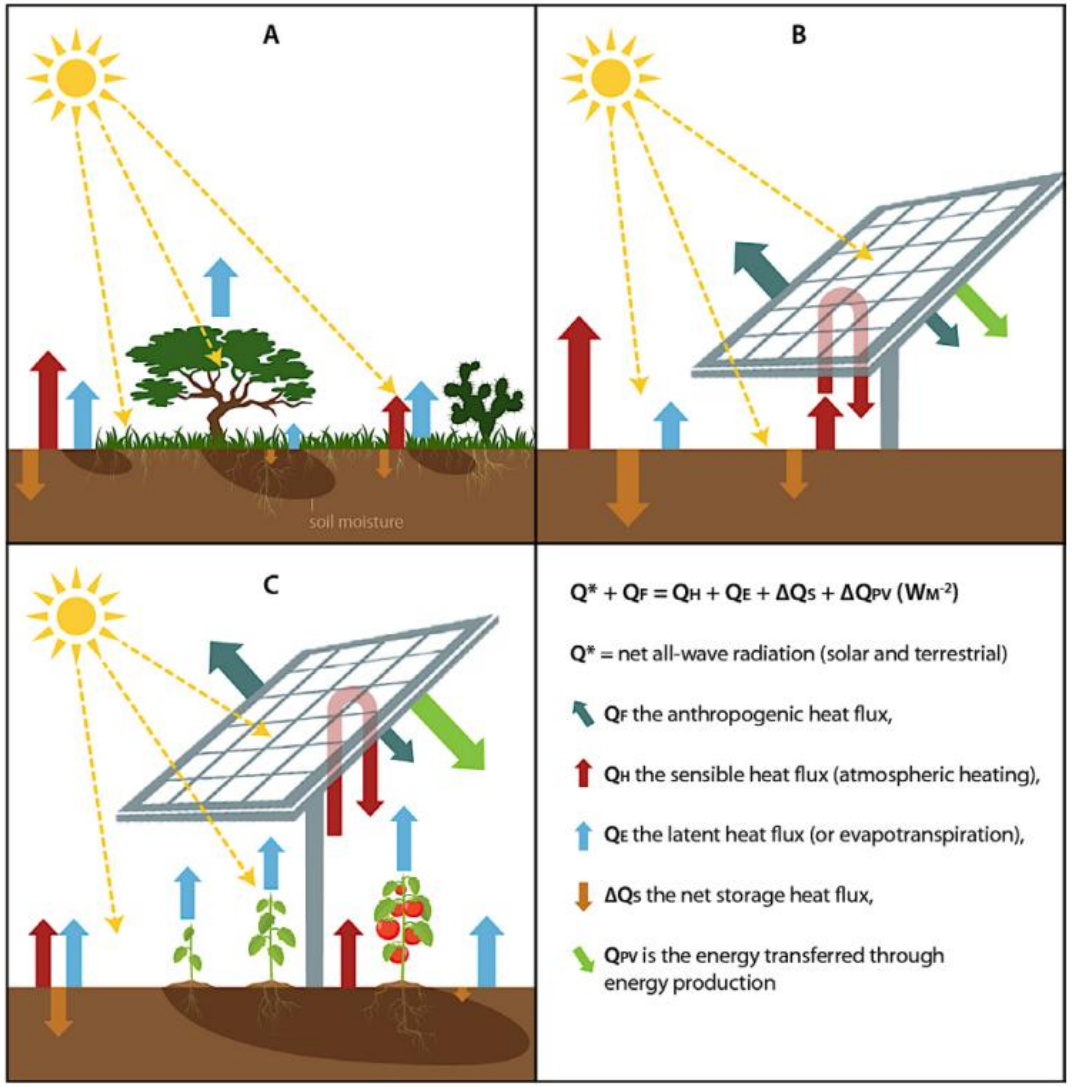
Protects soils, plants, animals, and beneficial insects

Enhances climate resilience

Allows for sustainable energy and food production on a single lot of land

Beneficial to shade-tolerant plants

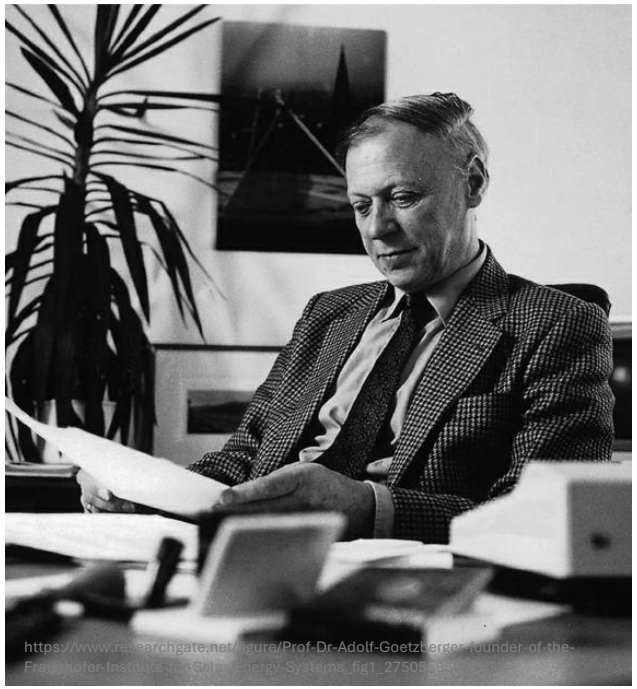
Crops grown under the panels contribute to lowering soil temperatures and increasing solar production performance

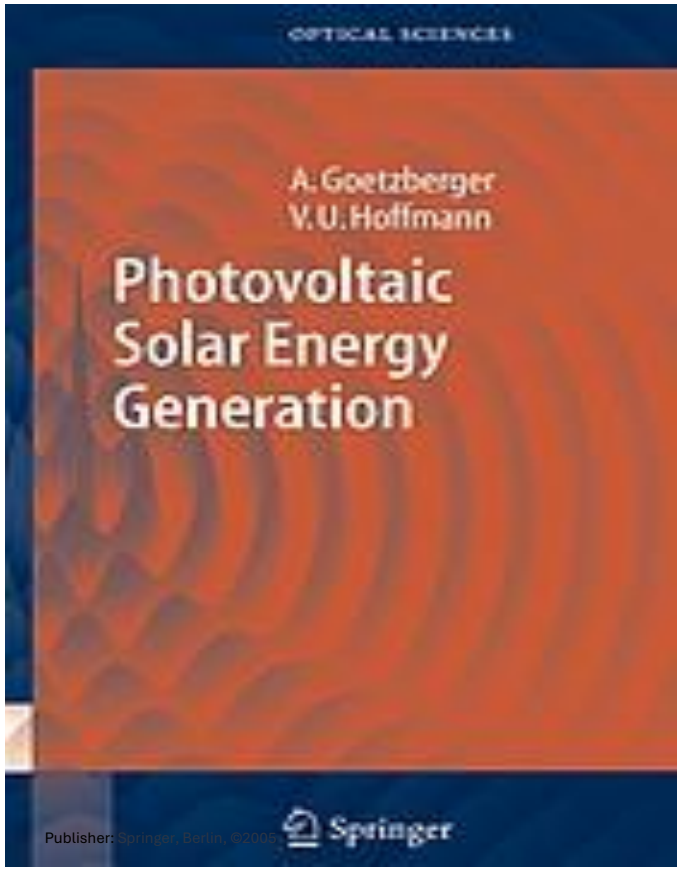


https://www.osti.gov/servlets/purl/1567040

Origin/Inventor

Prof. Dr. Adolf Goetzberger





Founder of Fraunhofer Institute for Solar Energy Systems in Freiburg Im Breisgau

Studied physics in Munich, Germany at the University of Freiburg

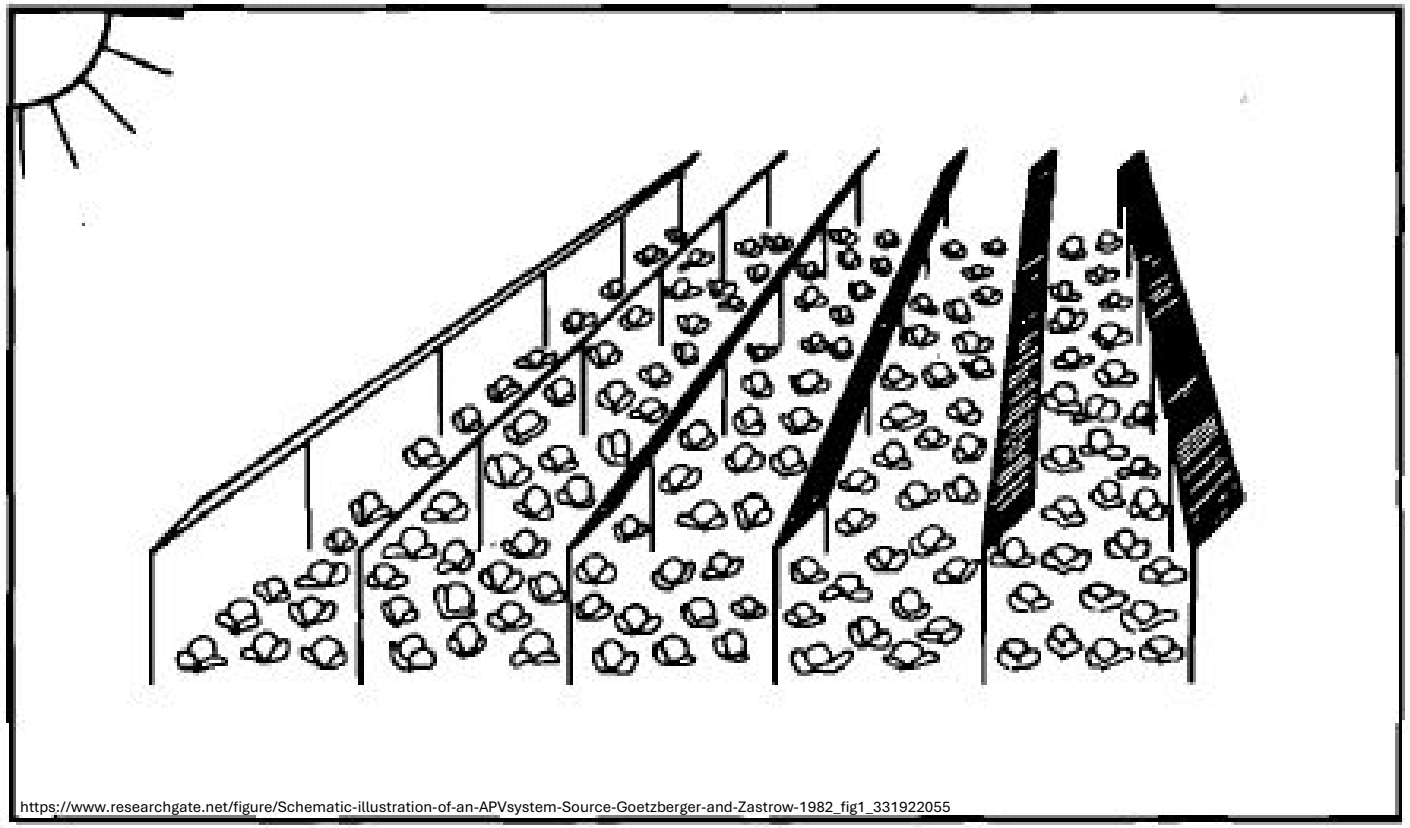
Former president of the International Solar Energy Society and the German Solar Energy Society

Performed his work on agrivoltaics at Bell Labs in Palo Alto, CA

Origin/Inventor

Dr. Armin Zastrow

On the Coexistence of Solar-Energy Conversion and Plant Cultivation
International Journal of Solar Energy
January 1982, Volume 1, Issue 1, Pages 55-69



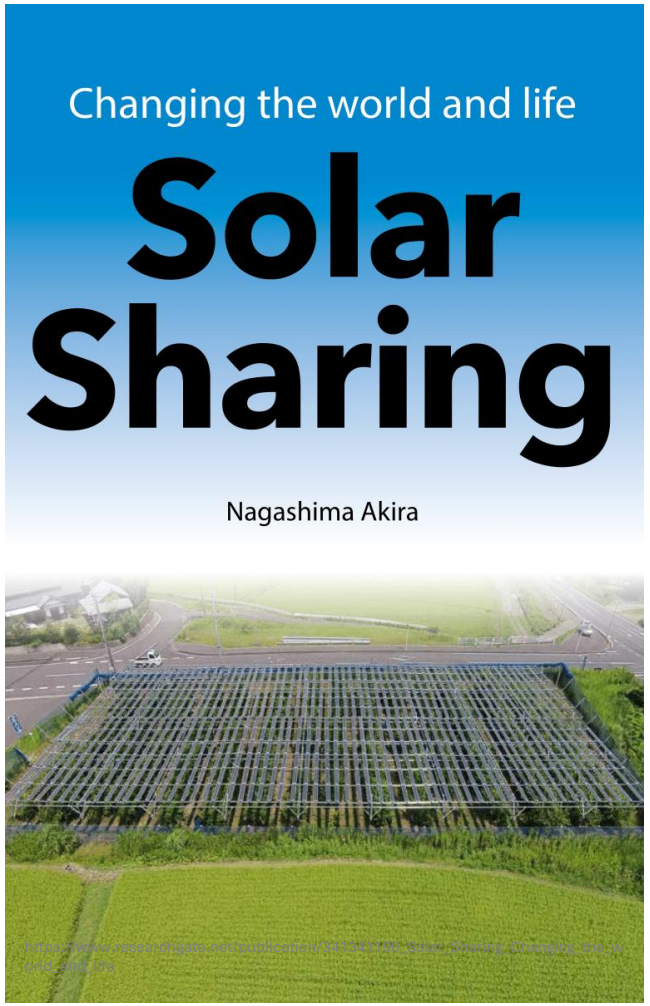
https://www.researchgate.net/figure/Schematic-illustration-of-an-APVsystem-Source-Goetzberger-and-Zastrow-1982_fig1_331922055

Implementation

Akira Nagashima

https://www.renewableenergyworld.com/solar/japan-next-generation-farmers-cultivate-agriculture-and-solar-energy/#gref


https://www.renewableenergyworld.com/solar/japan-next-generation-farmers-cultivate-agriculture-and-solar-energy/



Developed the prototypes in Japan in 2004

3,474 agrivoltaic farms (872.7 ha) 2020

Estimated 500,000 to 600,000 MWh or 0.8% of the total power generated by photovoltaics is from agrivoltaics (2019)

Feed-in tariff policy supports the development of renewable energy sources by guaranteeing high market prices for producers (2012)

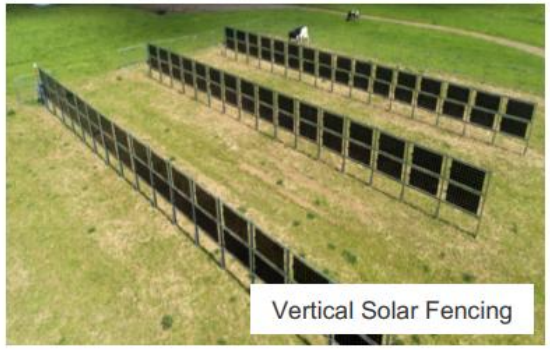
In April 2022, an amendment was enforced to preference the development of agrivoltaics.

The Ministry of Agriculture, Forestry, and Fisheries (MAFF) established and promoted the development of agrivoltaics (March 2013 and May 2018)

Fixed-Tilt

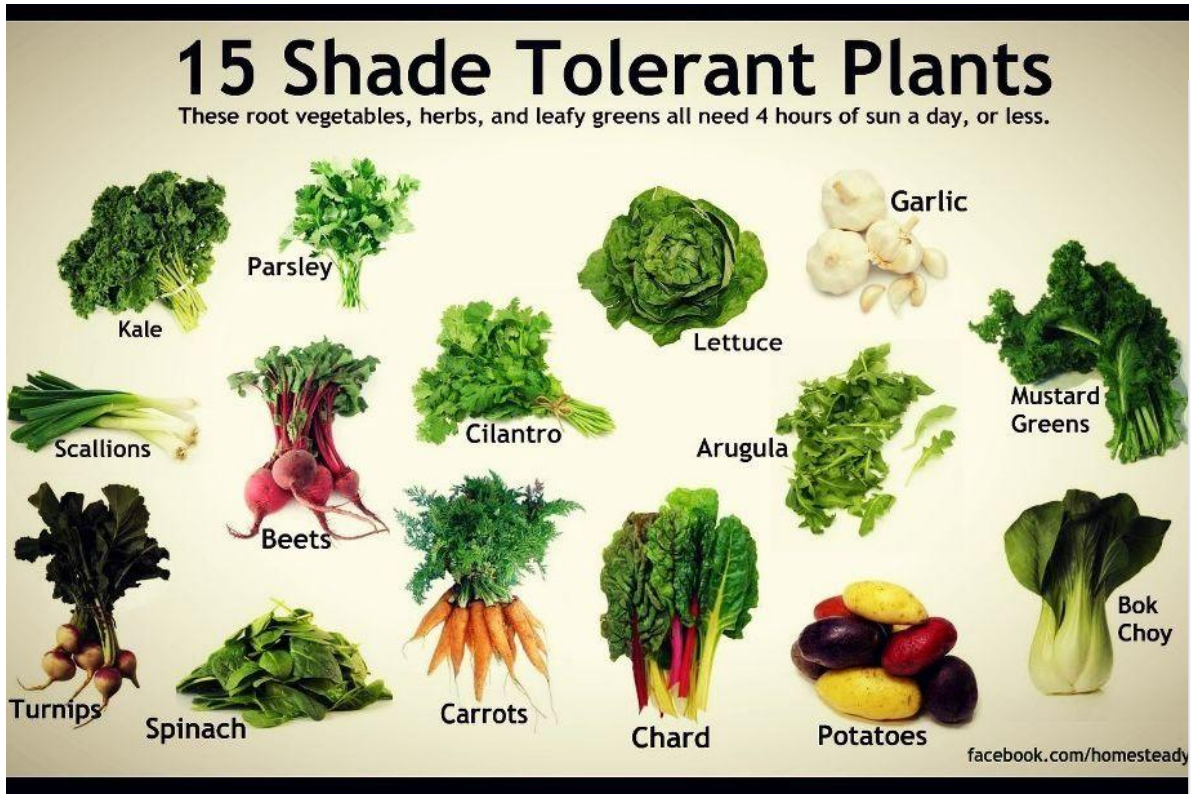
Trackers

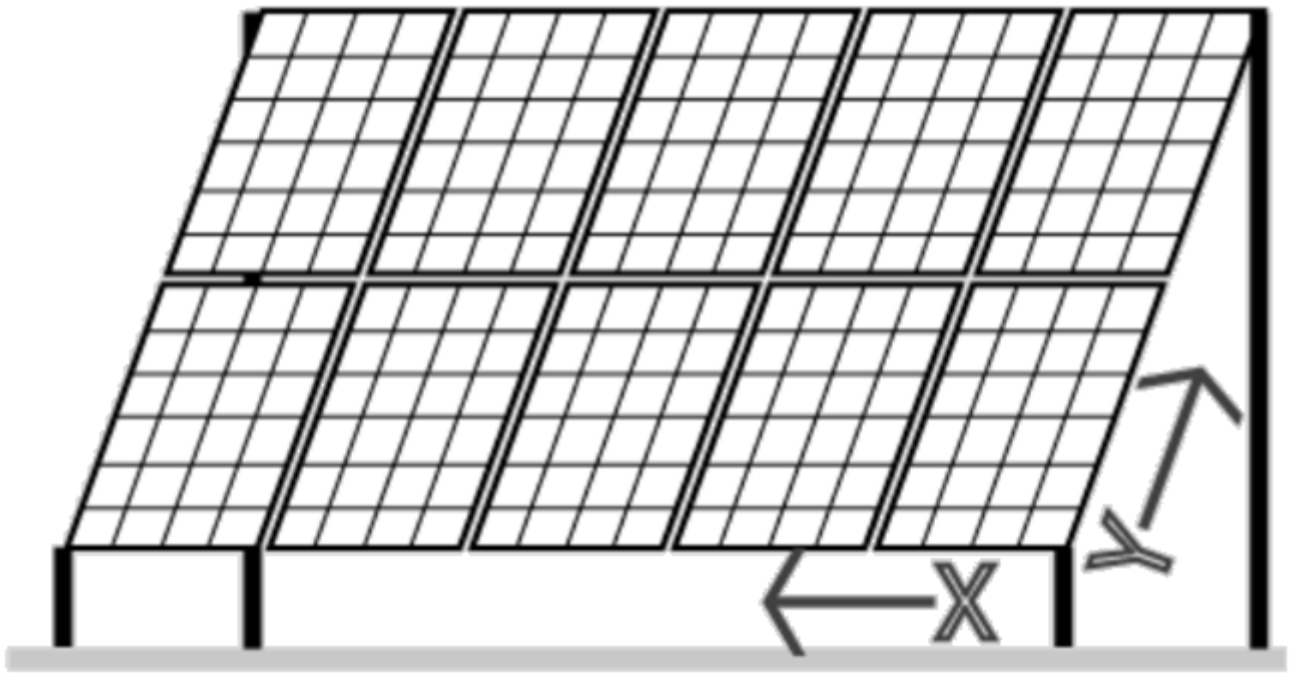
Novel



https://cleantechnica.com/2022/08/22/agrivoltaics-growing-plants-power-partnerships/

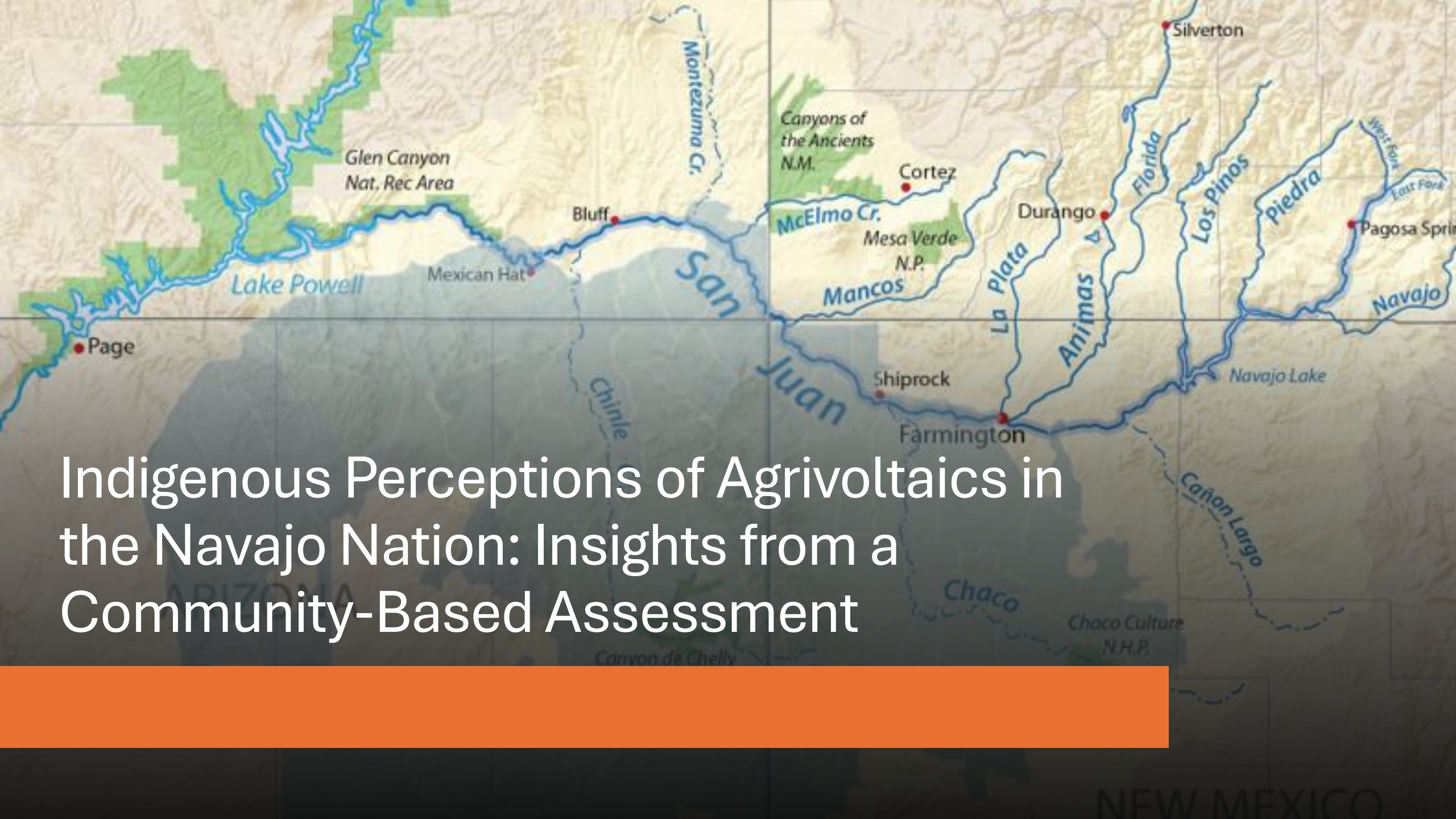
Research


15 Shade Tolerant Plants
These root vegetables, herbs, and leafy greens all need 4 hours of sun a day, or less.
Kale
Parsley
Lettuce
Garlic
Mustard Greens
Scallions
Cilantro
Arugula
Beets
Turnips
Spinach
Carrots
Chard
Potatoes
Bok Choy
facebook.com/homesteady



NMSU Agricultural Science Center at Farmington

The mission of the NMSU-ASC Farmington is to *conduct research, demonstration, and educational programs that will best fill the needs of the Agricultural community of San Juan County and the Navajo Nation in particular, and the State of New Mexico, Four Corners Region, and Nation in general*



Indigenous Perceptions of Agrivoltaics in the Navajo Nation: Insights from a Community-Based Assessment

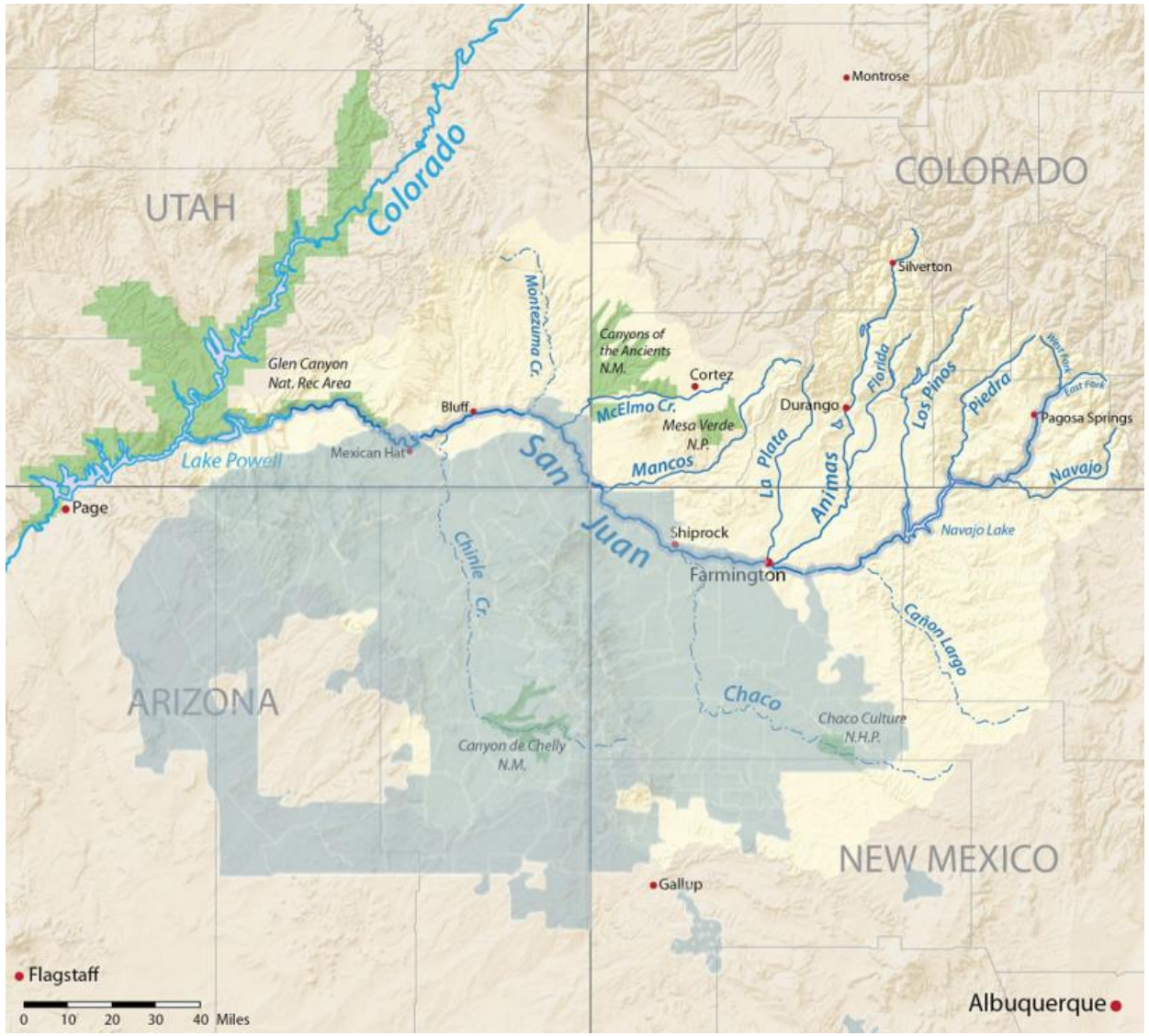
Section 14 – Agrivoltaics (pages 46-52)

Four Corners Indigenous Farm Assessment: Soil, Land-use, Controlled Environment Agriculture and COVID-19 Impacts on Navajo farmers in the San Juan River Valley

Publication by Brandon Francis (2024)

Objective

To assess the interest, experience, and capacity for implementing AgV of Indigenous farmers in the San Juan River Valley on the NN.



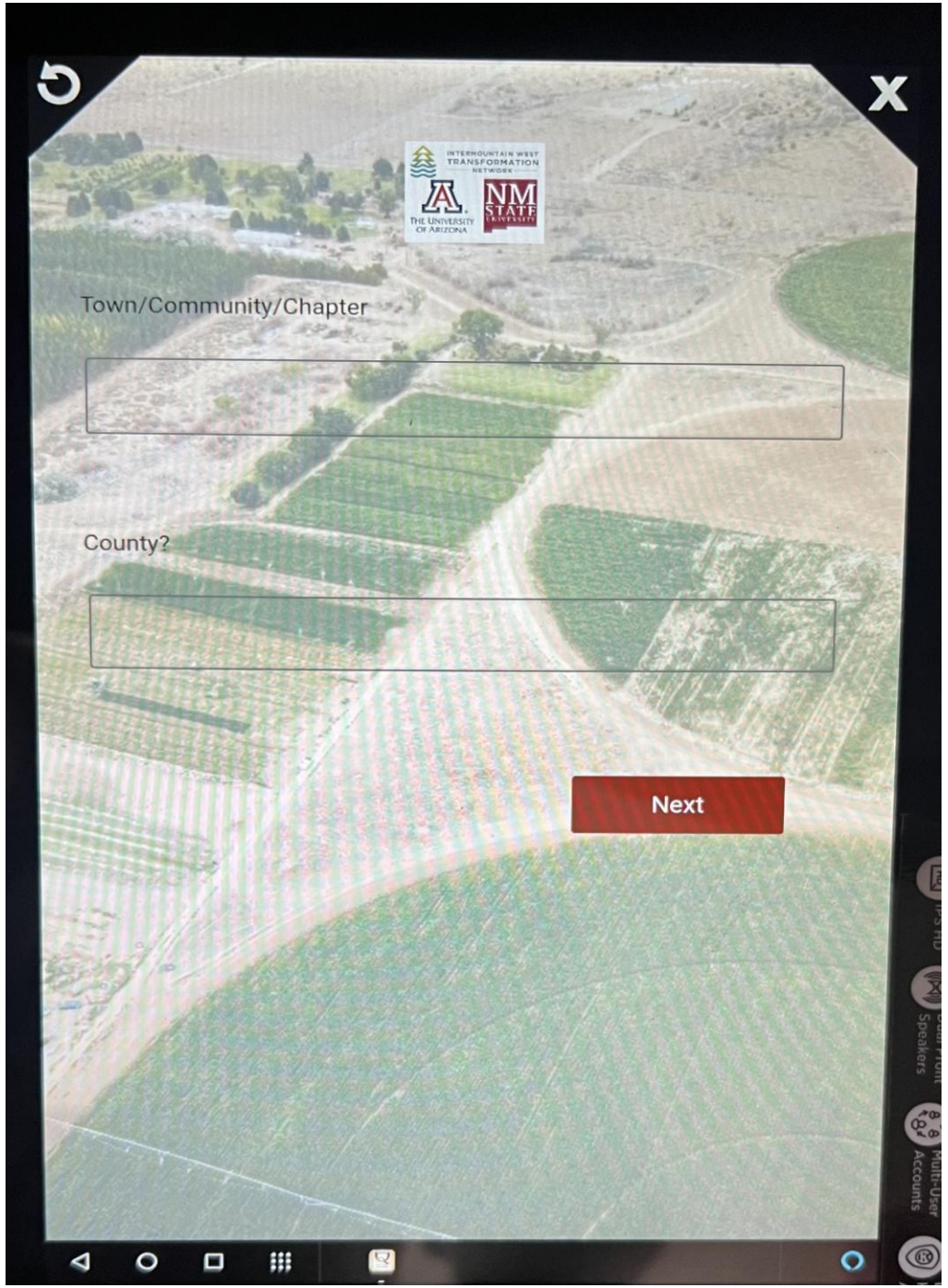
4CIFNA Survey

IRB approval was obtained, NMSU Protocol #:2305060241

Navajo Nation Human Research Review Board under modification of protocol #NNR-21.398: “Assessing Navajo COVID-19 Risk and Increasing Indigenous Resilience”

Qualtrics

An online platform that allows users to create and distribute surveys, collect responses, and analyze the resulting data



126 farmers from various Navajo Chapters

- 35 - Shiprock
- 21 - Nenahnezad
- 17 - Upper Fruitland
- 13 - Gadii'ahi
- 13 - Hogback
- 6 - San Juan

Northern Agency chapters outside SJRV had 7 farmers

6 - Eastern Agency

3 - Fort Defiance Agency

1 - Western Agency

The responses were optional, and the participants could choose to end the survey at any time or leave some responses blank. This led to some responses being left unanswered.

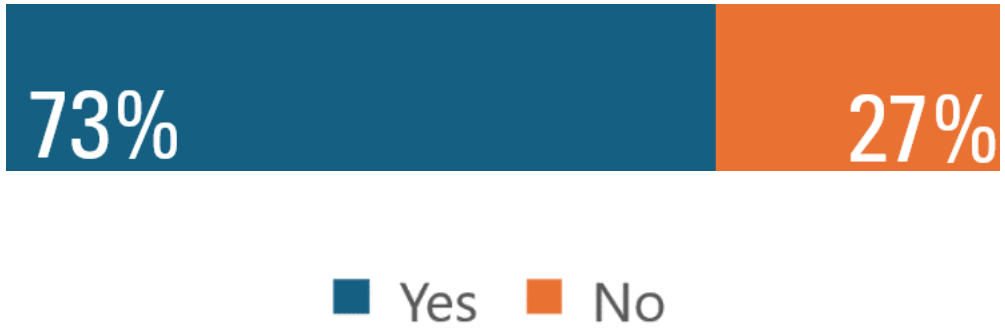
Survey Questions

1. Do you have any interest in placing renewable energy infrastructure on your property (e.g. solar panels)?
2. Are you interested in learning about how to support the energy needs of your farm with photovoltaic (solar) panels?
3. Do you have experience working with solar panels?
4. Would you be able to manage a solar energy system on your own?
5. If not, would you be open to receiving training on managing a solar energy system?
6. Have you heard of agrivoltaics?
7. Agrivoltaics creates an environment under the solar panels that uses less water, less nutrients and reduces the heat stress on crops. Would you be interested in learning more about it?
8. If you were able to grow the same crops you are currently growing in an agrivoltaic system, would you do so?

Themes

Q.1 Do you have any interest in placing renewable energy infrastructure on your property (e.g., solar panels)?
Yes=91, No=33 (n=124)

Q.2 Are you interested in learning about how to support the energy needs of your farm with photovoltaic (solar) panels?
Yes=91, No=33 (n=124)



Strong Interest in Renewable Energy

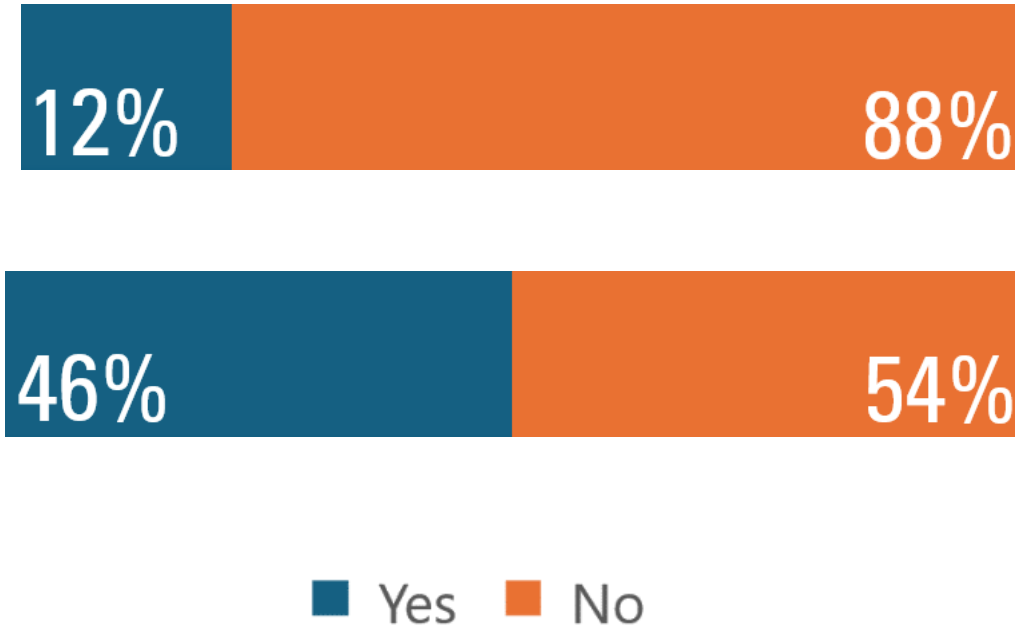
High willingness (73%) to explore on-farm solar energy solutions.

Demand for education on how PV systems can support agricultural needs.

Themes

Q.3 Do you have experience working with solar panels?
Yes=15, No=109 (n=124)

Q.4 Would you be able to manage a solar energy system on your own?
Yes=56, No=67 (n=123)



Limited Prior Experience with Solar Technology

88% had no experience working with solar panels.

54% felt unable to independently manage a solar system.

Themes

Q.4 Would you be able to manage a solar energy system on your own?
Yes=56, No=67 (n=123)

Q.5 If not, would you be open to receiving training on managing a solar energy system?
Yes=50, No=17 (n=67)

Need for Training and Technical Support

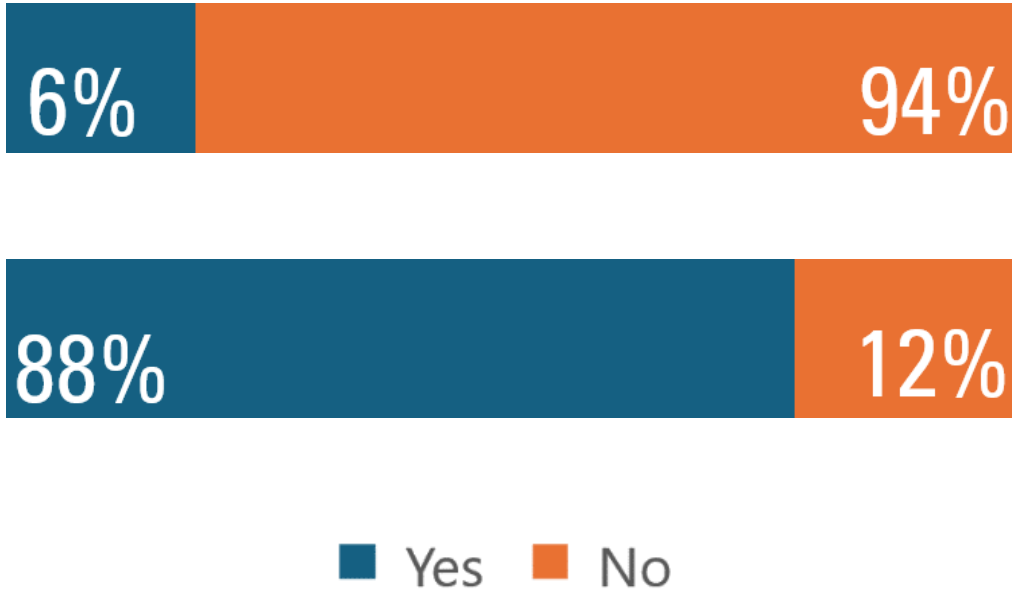
46% felt confident managing a solar system but could still benefit from further education.

75% of respondents lacking experience expressed willingness to receive training.

Themes

Q.6 Have you heard of agrivoltaics?
Yes=8, No=115 (n=123)

Q.7 Agrivoltaics creates an environment under the solar panels that uses less water, less nutrients and reduces the heat stress on crops. Would you be interested in learning more about it?
Yes=109, No=15 (n=124)



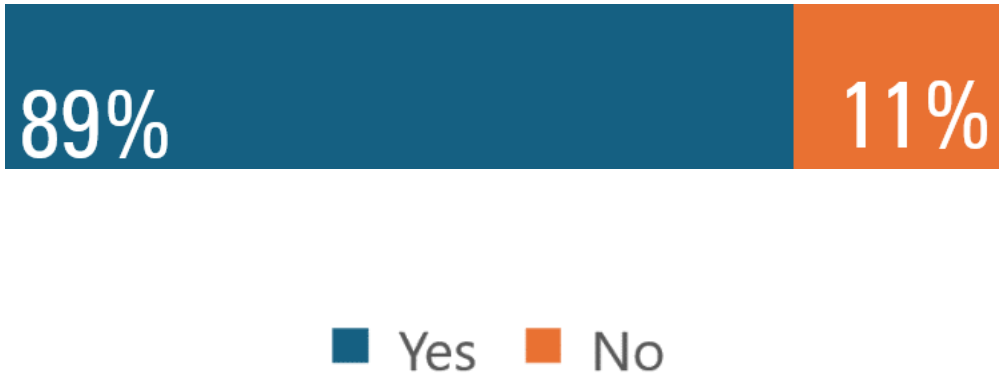
Low Awareness but High Interest in Agrivoltaics

94% had no prior knowledge of AgV.

88% wanted to know more, after learning about AgV.

Themes

Q.8 If you were able to grow the same crops you are currently growing in an agrivoltaic system, would you do so?
Yes=109, No=14 (n=123).



Potential for AgV Adoption

89% were willing to cultivate their current crops under an agrivoltaic system.

Indicates strong adoption potential if adequate resources and support are provided.

Overall theme

Outreach and Education

Need for targeted educational programs and capacity-building initiatives.

Bridging knowledge gaps can facilitate the successful integration of agrivoltaics in Navajo farming communities.

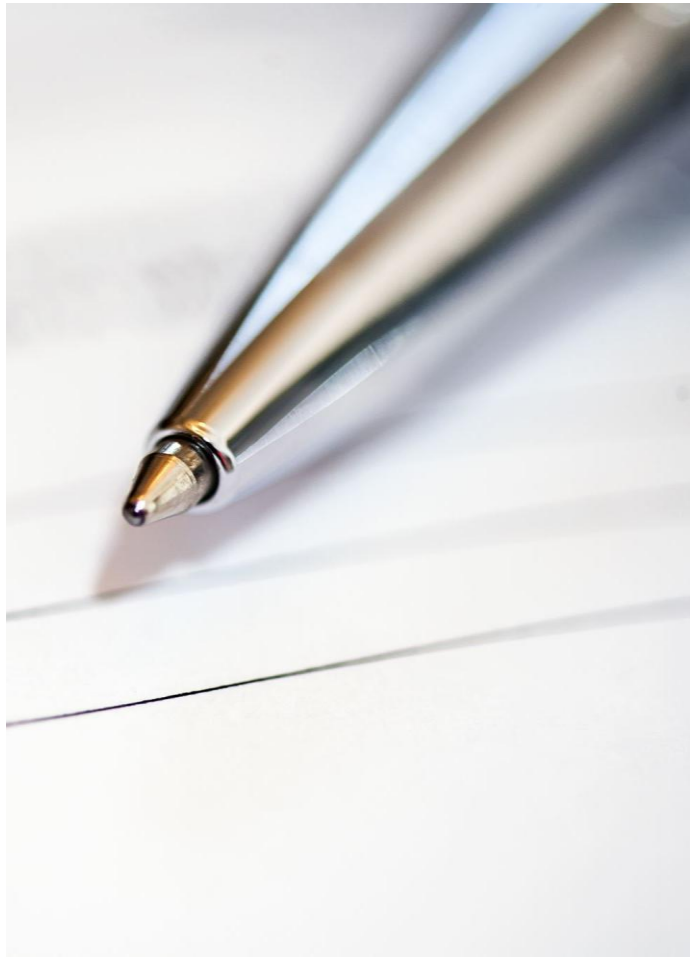
Bridging Knowledge Gaps: Understanding Navajo farmers' perceptions of agrivoltaics is crucial for overcoming adoption barriers and integrating the technology into their farming systems.

Role of Education and Policy: Supportive policies, training programs, and collaborative research efforts are key to facilitating agrivoltaic adoption while respecting traditional land stewardship practices.

Value of Feasibility Studies: Research initiatives provide critical insights into agrivoltaic system acceptance and inform future training, institutional partnerships, and policy development.

Demonstration Projects: Field trials with preferred crops can generate empirical data on crop performance, water use, and long-term viability under agrivoltaic conditions.

Future Work



Economic Feasibility Analysis: Assessing financial impacts, revenue potential, and ownership models for PV infrastructure is essential for small-scale and Indigenous farmers.

Training & Capacity Building: Developing tailored education programs on system maintenance, energy management, and financial planning can empower farmers to manage AgV systems.

Path to Sustainable Integration: Future research should focus on practical, scalable solutions that enhance the economic, environmental, and social benefits of AgV for Navajo communities.

ESTABLISHMENT OF A SMALL-SCALE AGRIVOLTAIC RESEARCH AND DEMONSTRATION PLOT ON THE NAVAJO NATION

Small-scale and demonstration plot

Designed to assess plant growth under PV panels while serving as a demonstration site for visitors at the science center.

Experimental Site Design

Comparison of PV Panel Types

Radish as a Model Crop

Drip Irrigation System

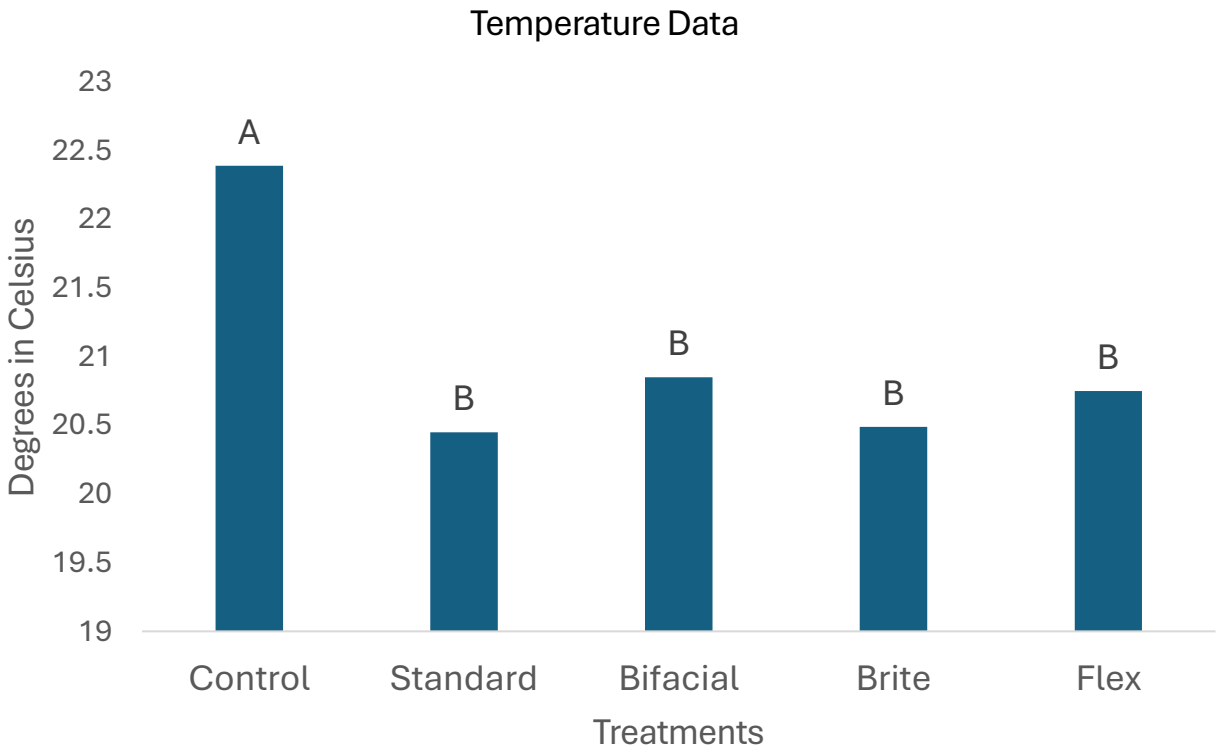
Environmental Monitoring

Data from this pilot study informs the potential benefits of AgV for small-scale agricultural operations.

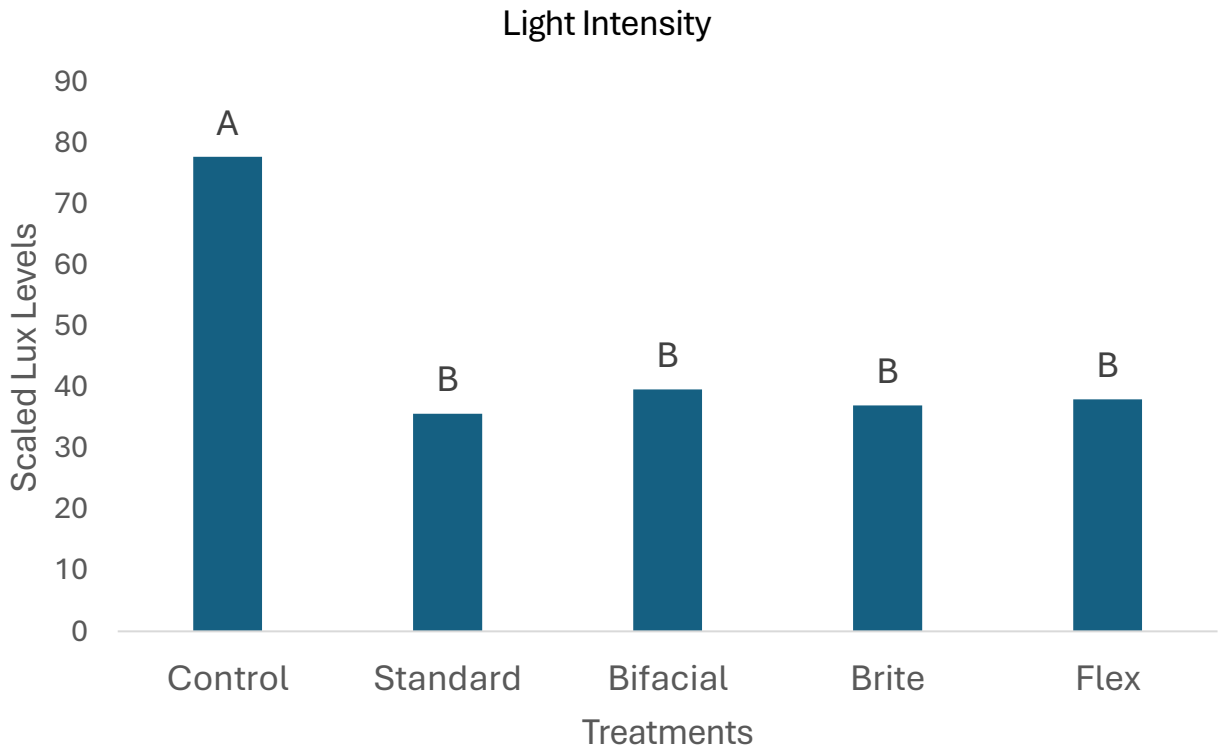
Microclimate Parameters

Light Intensity & Temperature: Key factors influencing plant growth under PV panels.

Temperature Reduction: All agrivoltaic treatments significantly lowered temperatures compared to the Control, though no single treatment stood out.



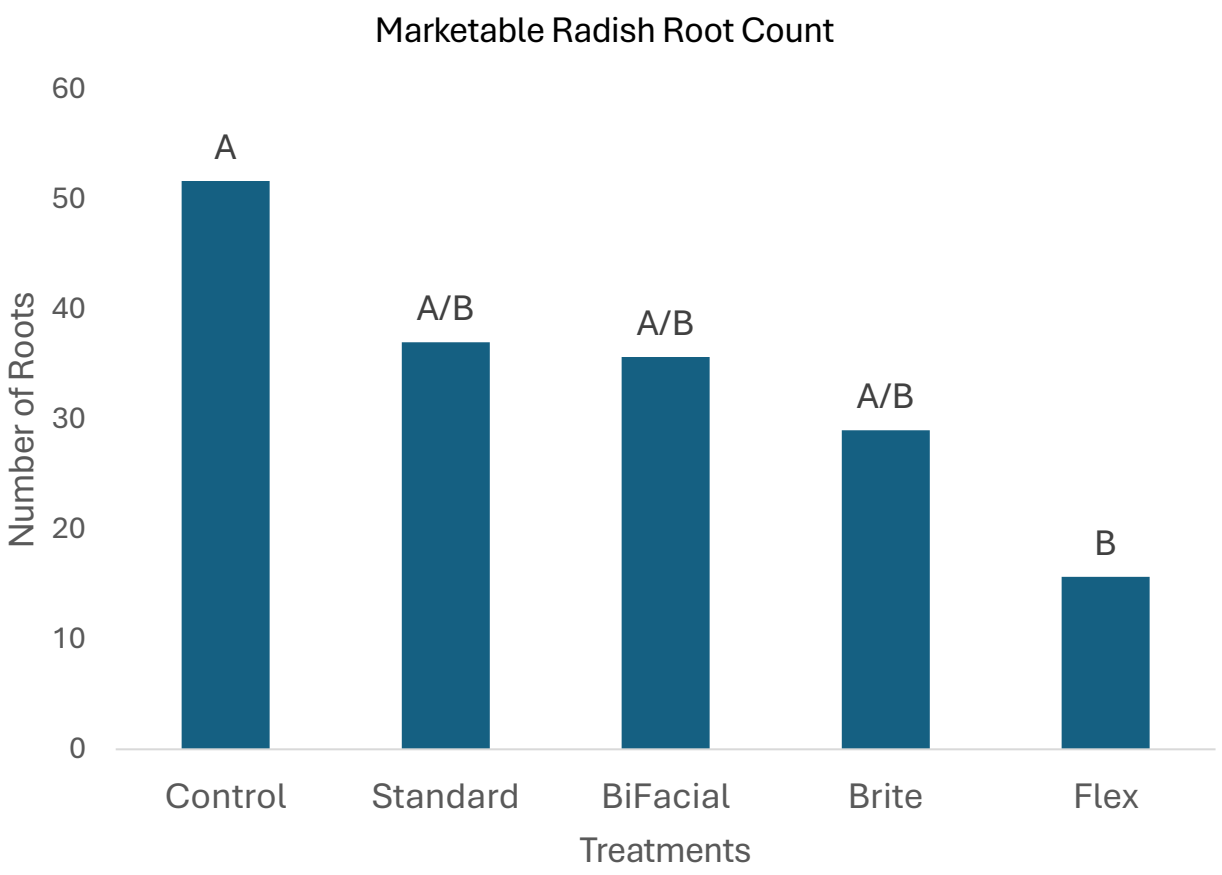
Light Intensity Reduction: PV panel treatments resulted in significantly lower light intensity than the Control, with no differences among them.

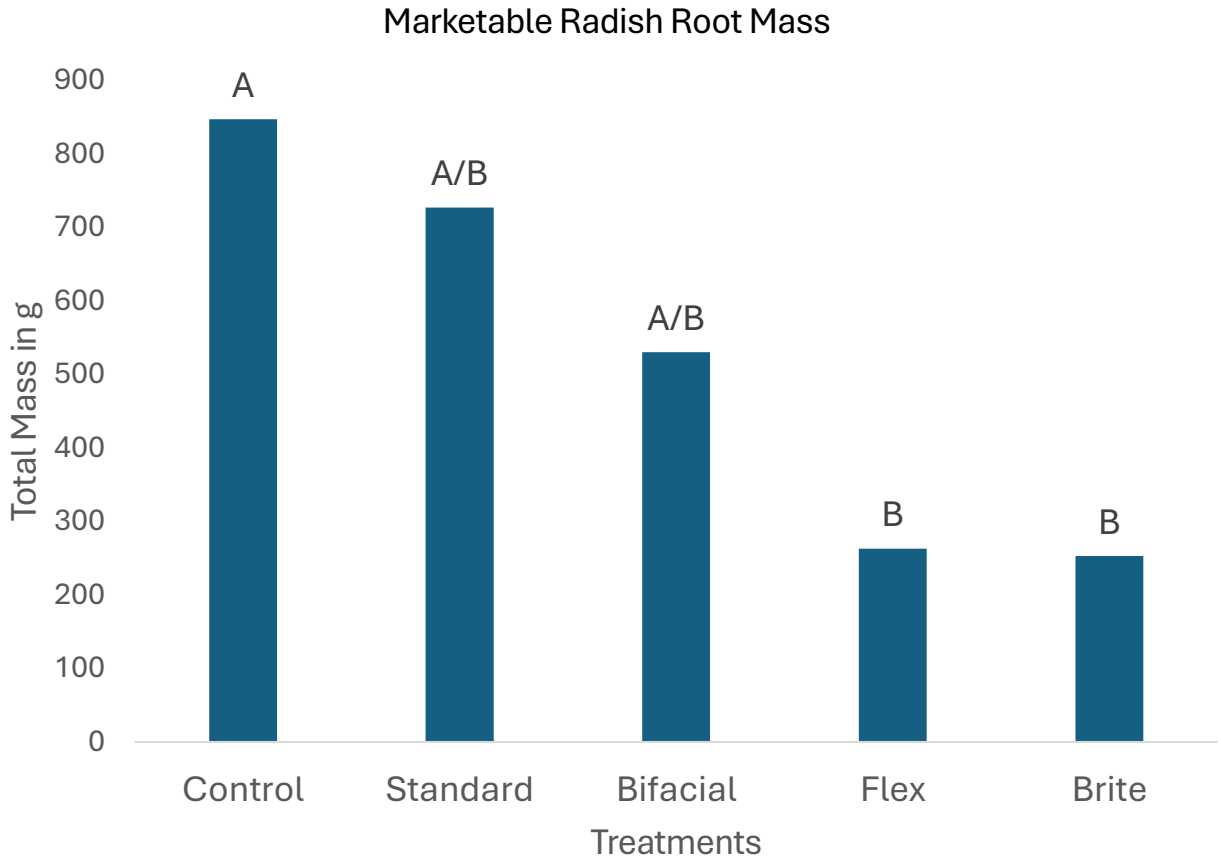


Radish Yield Performance

Root Count (≥16 mm): The Control produced the highest number of marketable radishes; Standard, Bifacial, and Brite had intermediate yields, while Flex performed the worst.

Marketable Root Mass (≥16 mm): Control had the highest estimated mean, followed by Standard and Bifacial, while Flex and Brite showed the lowest values.





Conclusion

Educational & Outreach Impact

Grow boxes serve as a valuable tool for technology transfer, facilitating hands-on learning through workshops and demonstrations.

Future Research

Long-term trials are needed across multiple growing seasons. Testing a wider range of crops.

Current Research


76.3 ft


https://earth.org/agrivoltaics/


Tracker Mounted PV Array
50 x Silfab 530 Watt Modules
Tracker Motor
Inverters
AC Combiner
Production Monitoring

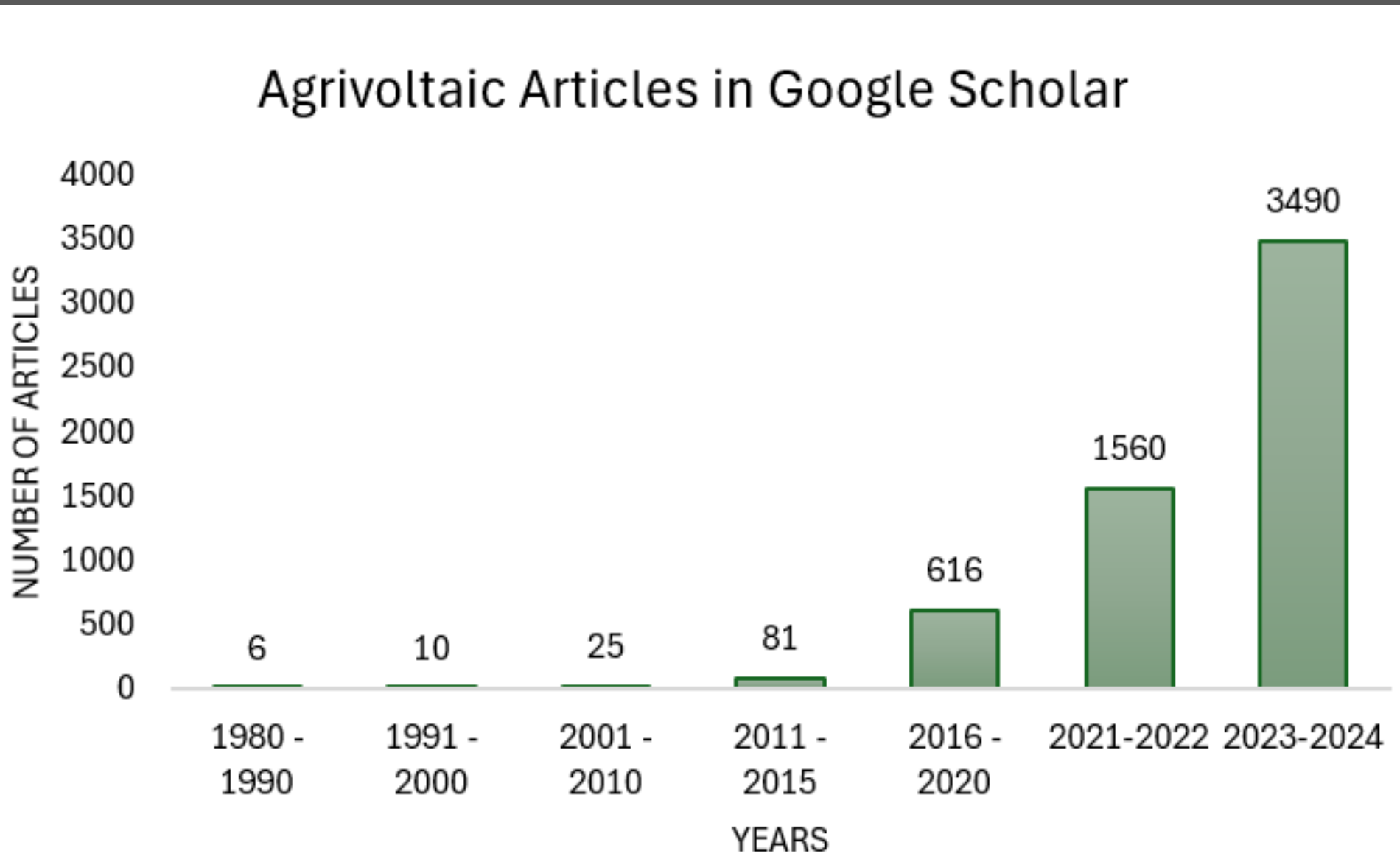
Workshops

Community Engagement: Interactive learning experience, introducing community members to agrivoltaic concepts through hands-on participation.

Multi-Format Outreach: Informational booth, Oral presentation, Hands-on grow box assembly.

Increased Awareness: Workshops addressed low awareness of agrivoltaics (as identified in survey data) while generating interest in small-scale AgV systems.

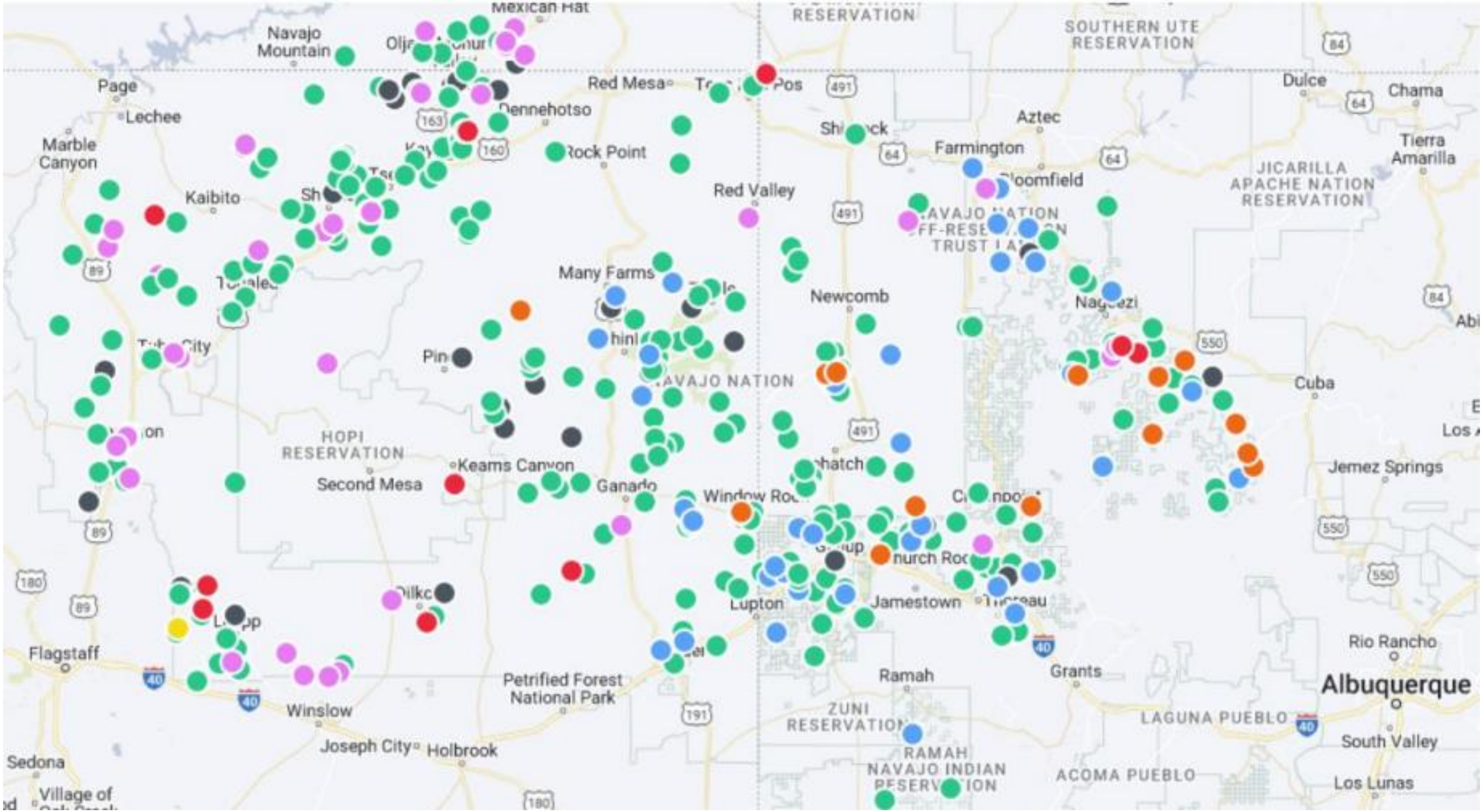
Foundation for Future Projects: These sessions pave the way for continued engagement, encouraging local experimentation with agrivoltaic systems and future collaborations in tribal agricultural sustainability.


Agrivoltaic Articles in Google Scholar
NUMBER OF ARTICLES
4000
3500
3000
2500
2000
1500
1000
500
0
6
10
25
81
616
1560
3490
1980 - 1990
1991 - 2000
2001 - 2010
2011 - 2015
2016 - 2020
2021-2022
2023-2024
YEARS

Energy Independence & Resilience

Solar power reduces reliance on grid electricity and fossil fuels, making farms less vulnerable to fluctuating energy prices and power outages.

Battery storage can further enhance energy security.


Mexican Hat
RESERVATION
SOUTHERN UTE RESERVATION
Navajo Mountain
Page
Lechee
Marble Canyon
Kaibito
Red Mesa
Dennehotso
Red Valley
Farmington
Aztec
Dulce
Chama
Tierra Amarilla
JICARILLA APACHE NATION RESERVATION
Many Farms
Newcomb
Cuba
HOPI RESERVATION
Keams Canyon
Second Mesa
Ganado
Jemez Springs
Lupton
Jamestown
Flagstaff
Winslow
Petrified Forest National Park
Joseph City
Holbrook
Sedona
Village of
Ramah
Grants
Rio Rancho
Albuquerque
LAGUNA PUEBLO
South Valley
ACOMA PUEBLO
Los Lunas

Off-Grid System Examples

https://na.panasonic.com/us/green-living/new-vision-farming-chickens-sheep-and-solar-panels

https://www.agrisolarclearinghouse.org/sweet-deal-beekeeping-at-solar-sites-offers-economic-and-environmental-benefits/

https://www.watereducation.org/western-water/solar-paneled-canopies-over-canals-catching-southwest

https://www.novergysolar.com/powering-the-future-of-agriculture-with-novergy-solar-water-pumps/

https://www.premier1supplies.com/p/electronet-pro-9-35-12-braided-electric-fence

© Fraunhofer ISE

Illustration of the planned aqua-PV research facility in Vietnam.

https://www.bmbf-client.de/en/projects/shrimps

Acknowledgements

New Beginnings for Navajo Students
(USDA Grant #2022-70411-38313)

INTERMOUNTAIN WEST TRANSFORMATION NETWORK National Science Foundation's Sustainable Regional Systems Program
(NSF Grant #2115169)

New Mexico Attorney General's Office (GR0007668)
Northwest New Mexico Agriculture Restoration Project

Questions?

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