Agrivoltaics

MISSOURI Local Science Engagement Network AAAS

Executive Summary

Solar energy is regarded as a promising renewable energy source to help meet the global demand for carbon-free energy.[1] Because of the diffuse nature of solar energy, large land areas must be converted to solar fields in order to sustain ample energy production and meet demand.[2] Large-scale land conversion for solar fields pits energy production against agriculture for access to flat and open tracts of land.[3] However, under some scenarios, solar panels can be integrated into cropping or livestock systems, providing an overall boost to productivity. These dual-use systems, known as "agrivoltaics", may aid efforts to mitigate and adapt to climate change,[4] provide farmers with alternative revenue sources,[2] and help to meet the growing energy and food demands worldwide.[5] Nevertheless, agrivoltaics is still in its infancy and has not been widely implemented; much of the research touts potential drawn from simulations or performance of small-scale systems.

Science Highlights

- Overall, agrivoltaics could make land more productive; its effectiveness depends on many factors such as geography, climate, number, density, and orientation of solar panels, shade tolerance of crops, and ease of tying into the electric grid.
- Incorporating solar fields into cropping and grazing systems could help reduce reliance on non-renewable energy.
- Because agrivoltaics provide shade, they could help alleviate heat stress on livestock. The shade also helps regulate soil moisture, potentially lessening drought impacts on crops.
- Adoption of agrivoltaics could increase and diversify revenue streams for farmers.
- Barriers for farmer adoption include uncertainty about future land productivity, reduced flexibility, management, adequate compensation, and market potential for solar energy.

Limitations

- The practice and research associated with agrivoltaics is less than 20 years old and therefore full lifecycle assessments are largely unknown.
- There are no large-scale agrivoltaics operations in the US, and only few in the world; much of the research is based on modeling and proof-of-concept projects less than 25 acres in scale.
- Only a subset of total possible combinations of solar and crops or livestock have been investigated.

This community science note was prepared by the Missouri Local Science Engagement Network (LSEN), a partnership between MOST Policy Initiative and the American Association for the Advancement of Science (AAAS) aimed to elevate science in policy conversations in Missouri. **For more information, contact Zack Miller – zachary@mostpolicyinitiative.org or MOST- info@mostpolicyinitiative.org. This was prepared on 2/6/2022.**

Research background

Definitions

The term "agrivoltaics" is a portmanteau, with *agri-* stemming from agriculture and *-voltaics* from photovoltaic solar panels. Agrivoltaics is the co-location of solar panels and food or biofuel systems.[6] By putting solar panels on elevated ground mounts above crops or grazing systems, or affixing these systems to greenhouses, land can serve the dual purposes of agriculture and energy production.

Performance of Agrivoltaics

The performance of agrivoltaics depends on a number of factors including geography, climate, architectural design of solar system, and compatibility of cropping or livestock systems. Solar energy production performs best in areas with high solar irradiation.[7] The Midwest has moderate solar capacity compared to the desert Southwest (highest capacity) and the Northeast and Northwest (lowest capacity).[8] Even so, the Midwest had the highest rate of utility-scale solar project implementation in the US in 2018,[9] suggesting high suitability for solar energy production in the Corn Belt.

Although solar fields can inhibit plant growth by reducing the sunlight available for photosynthesis, under some scenarios the overall productivity of land can be increased.[6,10] One approach to measuring the performance of agrivoltaics is by using the Land Equivalent Ratio (LER), which is a common metric for assessing intercropping and agroforestry systems.[11] The LER is the relative land area required under a single use (e.g., monocropping or solar fields) to produce the same yields as in dual- or multi-use systems. One study found that integrated solar and plant systems had high LER and suggested that agrivoltaics may increase land productivity by 35-73% depending on plant requirements and solar panel density.[6] Other studies have used the Price-Performance Ratio, which measures total output against total costs, and found that, while many shade-tolerant plants like lettuce have beneficial ratios, shade-intolerant plants like wheat are likely economically infeasible to grow in agrivoltaics systems.[10]

Agrivoltaics Systems and Compatibility with Agriculture

There are three main agrivoltaics approaches: agriculture-centric, energy-centric, and agriculture-energy-centric.[12] In *agriculture-centric* operations, the aim of the farmer is to maximize the productivity of the agricultural output. Solar panels may be intentionally placed throughout the farm if they positively contribute to biomass or product quality and do not substantially change management strategies. In *energy-centric* operations, farmers seek to maximize solar energy output by positioning solar panel arrays as densely and expansively as possible. More sophisticated designs include solar tracking systems, where solar panels rotate to maintain optimal orientation to the sun. Grazing animals like goats and sheep can be used to control weed growth under and near the panels. In *agriculture-energy-centric* operations, the goal is to maximize both solar and agricultural output as an overall production. Even if the output from each is reduced compared to monocropping or solar fields, the overall production of the land is increased.[12] These systems require substantial design and details of irrigation along with panel height, orientation, spacing, and density must align with the physiological needs of crops or forage.

Several types of agricultural systems, including biofuel production, animal grazing, and food crops, may be compatible with solar panels. In one study, simulations combining corn for ethanol with solar panels produced up to twice as much energy per unit area than either in monoculture.[13] In animal grazing systems, solar panels could help to deter predators, lessen wind intensity, and reduce animal stress by providing shade and shelter. Positive impacts of agrivoltaics systems on animal welfare have been documented for cattle[14] and sheep,[15] and environmental and economic analyses of rabbit production under solar panels suggest increased colony growth rates and farmer revenue.[16] A negative impact of solar arrays on grazing systems is that it leads to uneven pasture growth.[5]

In cropping systems, appropriately locating plants under solar panels is important because the microenvironment—e.g., water and sunlight availability—varies drastically over short spatial scales.[5] Agrivoltaics have demonstrated favorable impacts on shade-tolerant plants including lettuce and potatoes.[2,10] Due to lower maintenance needs, perennial shade-tolerant crops like berries, bananas, and grapes are expected to have high compatibility with solar panels but have not been empirically tested.[12] Agrivoltaics help to maintain the soil-moisture content of soil, which can reduce reliance on irrigation systems and benefit farmers in drought-prone regions.[5,17] However, increased humidity from shading could also increase the prevalence of fungal pathogens and pest outbreaks.[12] Permanent solar arrays are not currently recommended for large-scale rotational crop systems like corn, soybeans, and wheat.[10,12] Only a subset of the total plant-animal-solar panel combinations have been investigated.

Industry Perspectives on Agrivoltaics

In 2020-2021, industry professionals from solar and agricultural sectors across the U.S. were interviewed about their perspectives on agrivoltaics.[18,19] Nine of the ten surveyed agriculture professionals expressed openness to adopting new innovations related to agrivoltaics, and all saw the potential benefits associated with locating solar panels on farmlands.[19] Barriers for adoption included high startup costs, reduced flexibility with land use, long-term productivity of the land, long-term viability of solar panels, and adequate compensation.[19] Solar industry professionals saw the benefits of agrivoltaics on both sectors, by increasing profitability for farmers and by giving solar energy more social and market acceptance.[18] The main challenges identified by solar professionals were market potential, community acceptance, complexity, risk, and liability.[18]

Agrivoltaics in Missouri

There is currently no legislation or published research about agrivoltaics in Missouri, and there are no known agrivoltaics operations in the state. Several other countries—e.g., Japan, Italy, and

Germany—have policy measures in place to incentivize agrivoltaics systems.[10] In the US, Massachusetts is the only state to support agrivoltaics by providing additional payments ($0.06/kWh) on top of the base compensation rate for electricity generated by dual-use farmers.[10] SB 824 and HB 1536, filed in the current legislative session in Missouri, propose to implement and incorporate community solar gardens to existing electric grids, but these do not apply to rural and agricultural areas. Additionally, HB 2167 and HB 1997 would remove property tax exemptions for solar panels, which could be relevant in the profitability calculations of agrivoltaics in Missouri (see recent Science Note on Solar Panel Lifetimes and Property Taxes). Given that Missouri is a high-producing agricultural state and has moderate levels of solar irradiance,[8] agrivoltaics could be feasibly adopted by farmers. The shade provided by solar panels could help mitigate impacts of projected summer droughts on crops and livestock,[14,17] and solar energy could offer farmers an additional revenue stream.[2,16] Limitations likely include high startup costs, concerns over long-term flexibility and productivity of land, community acceptance, market potential, and ability to connect solar energy with local utility providers.

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