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A Public-Private Partnership to Develop Agrivoltaics in the US Midwest

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Abstract. The expansion of solar energy at a utility scale in the Midwest of the USA will include land currently being used for farming. This development does not have to remove this land from agricultural use, if agrivoltaic practices are considered. However, there is a lack of data and recommendations for how solar facilities can be used for agricultural purposes. To address this gap, Iowa State University (ISU) and Alliant Energy have entered into a public-private partnership to explore the agronomic, economic and social aspects of agrivoltaic practices. This partnership models future interactions between landowner and utility companies interested in siting solar farms on land currently used for agricultural purposes. In this presentation, we describe how this partnership was developed and led to the construction of a solar farm that can measure both the value of crop production and the impact of understory vegetation on energy production. Through a series of meetings with Alliant Energy representatives and faculty at ISU, a site design was implemented, officially titled the Alliant Energy Solar Farm at Iowa State University. We summarize preliminary results from our initial field season, noting how a common vegetable crop, summer squash, was produced and responded to the conditions at this solar farm.

Keywords: Utility Scale, Horticulture, Beekeeping

1. Introduction

The expansion of solar energy production in the Midwestern region of United States of America will include land currently being used for farming. There is a lack of data and recommendations for how solar facilities can co-exist within agricultural landscapes. To address this gap, Iowa State University (ISU) and Alliant Energy have entered into a public-private partnership to explore the agronomic, economic and social aspects of agrivoltaic practices. We describe how this partnership was developed and led to the construction of a solar farm that allows for assessing the value of crop production, and the impact of understory vegetation on energy production, site operation and maintenance costs (O&M). Through a collaboration with Alliant Energy representatives and faculty at ISU, a site design was implemented, officially titled the Alliant Energy Solar Farm at Iowa State University, referred herein as the solar farm. The United States Department of Energy also is a key partner on this project through funding provided by their Foundational Agrivoltaics Research at Megawatt Scale (FARMS) program.

2. Methods

In 2021, ISU approached Alliant Energy regarding the possibility of developing a solar farm in an effort to reduce energy costs for the university. In response, Alliant asked if ISU would be interested in exploring agrivoltaic practices within and under the solar facility. A multi-disciplinary team of faculty was formed to work with Alliant in designing the facility to test multiple solar panel configurations and crop options.

This team considered which cropping systems would be of greatest interest and potentially viable to the farming community in Iowa and the surrounding Midwest. Several systems were considered, as well as key disciplines needed to address the agronomic and economic questions of future farmers. A series of meetings during 2022 developed a site design to address these questions through a rigorous research protocol. All parties discussed how the site could be designed to facilitate research, extension and teaching opportunites. Through discussion with Alliant, we determined what types of inputs and practices could be included within solar facilities that they supervise. This included the establishment of an apiary, a collection of honey bee colonies kept at the site to both pollinate our crops and be a source of revenue from honey production. We also determined which features of an industry standard configuration of PV panels could be modified and still be considered cost efficient by Alliant. Finally, we discussed if the site could be built such that the impact of vegetation under and around the panels could be measured on energy production.

We began a multi-year experiment in the fall of 2023 to determine which sub-set of vegetation types have the potential to be grown economically under an industry standard configuration of bifacial PV panels. Our overall hypothesis is that the economic and possible conservation value of vegetation options for solar farm management will vary, as will the energy produced by the panels directly above them. We predict that crops can be viable in partial shade environments, will have an impact on the microclimate under the PV panels and subsequently affect energy production. We also hypothesize that site O&M costs can be lower when agrivoltaic and pollinator conservation practices are implemented, compared to a conventional ground cover option (i.e. a grass and clover mix). Given the constraints of area under panels and the range of horticultural crop options, the team had to select a sub-set of vegetation options to be initially tested. Included in this test are vegetation cultivated for pollinator conservation as well as the conventional option considered an industry standard for solar developments throughout the midwest US. In this manuscript we highlight the production of summer squash, a crop widely grown by vegetable growers in Midwestern United States. We grew the crops with tools and techniques used by commercial growers in the region. Squash was seeded on May 7, 2024 and transplanted on May 31, 2024 in single row 24 inch spacing on raised beds with black plastic mulch. Weed fabric was used between the raised beds to manage weeds. HOBO sensors were used to measure soil temperature, air temperature, and light intensity. Spotted cucumber beetle (*Diabrotica undecimpunctata*) was managed by applying insecticides to foliage (zeta-cypermethrin, pyrethrin). Drip irrigation was used as needed throughout the growing season. Harvests were every 2 to 3 days, for a total of 31 harvests between July 1 and September 20.

3. Results

3.1 Site development:

After nearly a year of negotiations between Alliant and ISU, a 20-year lease was agreed to for a 10 acre (4.04 hectares) tract on the southern edge of campus. This land was part of a larger tract, all of which used for corn and soybean production.

The ISU team elected to focus on what the industry partner considered to be a standard design for a utility scale solar farm. This included using bifacial PV panels mounted on a single-axis tracking system at approximately 1.5 m above ground. A smaller area was set aside for the same PV panels mounted on a fixed-tilt configuration, with a standard hieght at the leading edge (0.76 m). The heights of both of these configurations (tracking, fixed-tilt) were increased to determine if increasing height would affect vegetation growth and energy production. This resulted in a solar farm consisting of four distinct areas/configurtions of bifacial solar panels that vary by height and tracking ability (Table 1). A critical design addition are inverters that allow for measuring energy production in subsets of each area (a string of 17 PV panels). Two additional areas were established, an untreated control without panels (Area 5) and a border comprised of native, perennial plants attractive to native pollinators (Area 6).

Table 1. *Solar panel configurations in the Allaint Energy Solar Farm at Iowa State University.*

Area (m^2)	Panel height	Tracking mechanism
1 (12,402 m^2)	1.52 m pivot height (industry standard)	Single-axis tracking
2 (2,464 m^2)	2.44 m	Single-axis tracking
3 (3,150 m^2)	0.762 m leading edge	Fixed Tilt
4 (6,300 m^2)	1.68 m leading edge	Fixed Tilt
5 (1,626 m^2)	No panels- control area	No panels

3.2 Vegetation options- initial assessment:

Although Iowa is a leading producer of corn and soybean, our initial assessment is that these crops are unlikely to be profitably given the unique limitations of a solar farm. We selected horticultural crops that have the potential to be profitable in an area consistent with the footprint of this and projected solar farms across the Midwest (Table 2). Two treatments (#2 and #3) applied to all areas of the solar farm include plants attractive to native pollinators and serve as nectar source and eventually honey for honey bees kept at the solar farm. These small patches of native, perennial flowering plants can address the needs of pollinator conservation and more sustainable beekeeping in the Midwest [1].

Table 2. *Summary of treatments in the Allaint Energy Solar Farm at Iowa State University.*

#	Treatment	Species/Cultivar descriptions
1	Grass-Control	Grass and clover mix planted during construction, representing an industry standard practice and serving as a control to compare to the seven treatments.
2	Pollinator mix-Regime 1	A mix of perennial flowering plants established with an industry standard management protocol (e.g., mowed once per year).
3	Pollinator mix-Regime 2	Same mix used for Regime 1 but established and maintained with more intense and frequent management (e.g., weeding and mowing).
4	Vegetable crop 1	Broccoli
5	Vegetable crop 2	Summer squash
6	Vegetable crop 3	Bell pepper
7	Fruit crop 1	Thornless raspberry
8	Fruit crop 2	Day-neutral strawberry

We tested these multiple vegetation options under a PV panel configuration that was considered by Alliant as the industry standard for solar development within the Midwest (Area 1). The eight types of vegetation were randomly assigned to Area 1 within a randomized complete block design (Fig. 1). Each treatment was replicated within an experimental unit (EU) comprising 19.5 m by 8 m of ground on either side of a string of 17 panels. Upon completion of construction and planting, three blocks were established, each including eight EUs, for a total of 24 EUs. To avoid edge effects, EUs do not include the last row of panels on the outer edges of the area to the north and south.

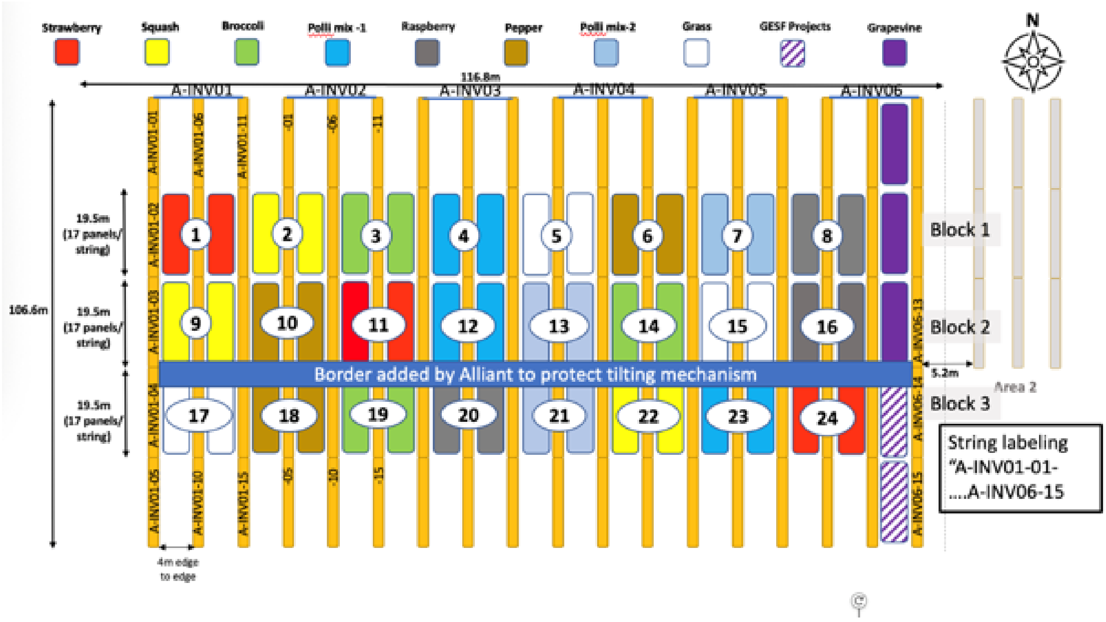

Figure 1. *Diagram of Area 1 describing the experimental units and Experimental design within the "industry stand-ard" includes eight treatments replicated three times across three blocks. All treatments are replicated in an open field control (i.e. Area 5).*

3.3 Site construction and initiation:

After completing negotiations, a lease agreement was approved in 2022 and construction initiated in the spring of 2023. By November of 2023, the above ground infrastructre was established and the grass-control (treatment #1) was seeded throughout the site. By March of 2024, the pollinator mix was planted in areas 1-5. By May of 2024, all fruit and vegetable treatments were planted in Area 1 and 5 (Fig. 2).

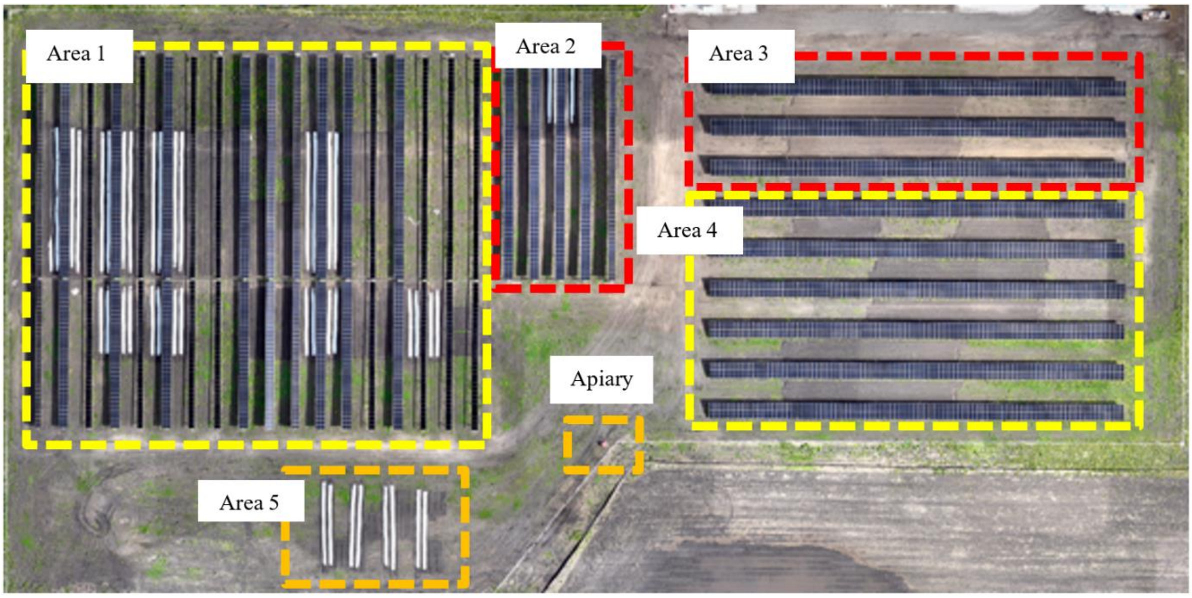

Figure 2. *This photo was taken on June 6, 2024 and shows the five areas described in Table 1. The higher panel configurations are outlined in red, the lower in yellow dotted lines. Area 5 serves as a control for treatments grown without PV panels above*

3.4 Summer squash production

Summer squash production took place between the solar panels (Area 1) and also under open-field production (Area 5; Fig. 1). The plants established and grew well between the panels (Fig. 3). With respect to insect pests, cucumber beetle was the primary pest. Squash bugs were also present but their population was too low to require management. Spraying of insecticide was necessary to guarantee harvests and marketable produce. There was no difference in pest populations between solar panels and open-field growing conditions (data not shown). With respect to marketable produce, the crop between the solar panels yielded 28% more marketable produce than the open-field treatment (Fig. 4). Based on the temperature sensor data, higher temperatures were recorded in the open-field conditions.

Figure 3. *Squash production between the solar panels*

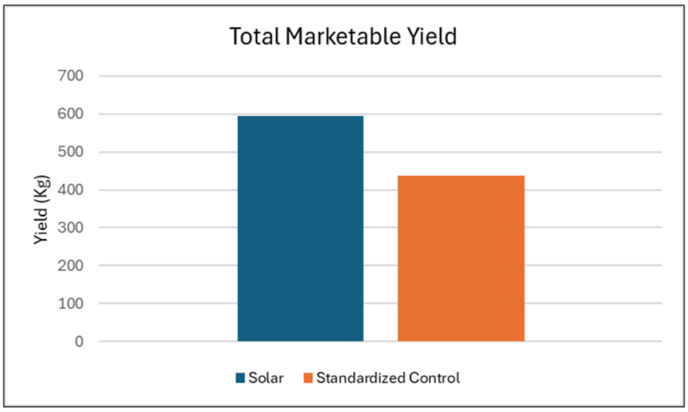

Figure 4. *Total marketable yield between solar treatment and standardized open-field treatment*

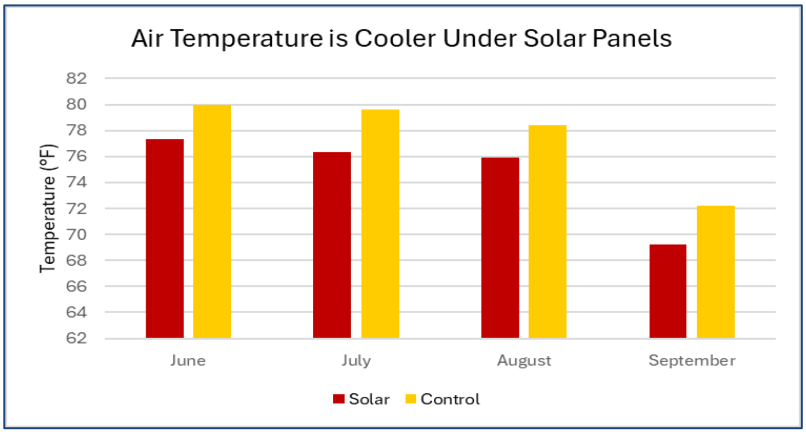

Figure 5. *Comparing air temperature between solar treatment and open-field conditions*

4. Discussion

Although we have yet to fully summarize data generated from our solar farm, we have modelled the practice of developing a solar farm that is suitable for agrivoltaic practices for a considerable region of the US Midwest. In this case, ISU is playing the role of a landowner whose holdings, before the solar farm, were used for the production of the two most common crops (i.e., corn and soybean) in the US Midwest, a 12-state region that includes Iowa. The landowner negotiated a lease agreement and contributed to a farm design that allows for agriculture to be practiced after the utility-scale PV configurations were built. After major construction activities were completed, farming activities started, but only after a Site-Access Data Sharing Agreement was approved by all parties. In this scenario, the researchers and ISU support staff are the farmers who conducting agrivoltaic practices at the solar farm. It is unclear if the different forms of vegetation management (e.g., cultivation of pollinator habitat or horticultural crops) will have very different financial outcomes when considering inputs, harvested produce and management costs. Regardless of how profitable the various vegetation treatments will be, having a lease and site-access agreement allow for these questions to be asked. Going forward, we suggest that completing these initial steps will be necessary for others to replicate such a site, whether it be for research, education or production agriculture.

Within the site-access agreement, consideration should be given for the degree of access (e.g., unfettered, all-year) and any associated costs incurred by either party. This agreement should answer questions like, will there be a rental fee assessed to the farmer practicing agrivoltaics, will specific personal protective equipment be required, and what type of agricultural practices will be allowed (e.g., tilling, pesticide applications, drip irrigation, crop rotations). Discussions need to happen about the use of small- and medium-scale farm machinery such as small tractors, tilling equipment, plastic mulch layer, etc. Farmer participation is likely to be limited without a clear, explicit agreement. If rental costs are eliminated, we hypothesize that the constraints of farming within a solar facility may be overlooked by farmers, especially new, younger farmers seeking to enter into the agricultural sector. Beginning farmers, especially the ones interested in specialty crops like fruit and vegetables, face a serious challenge of land access in the Midwest and agrivoltaics could be a promising option for them. To attract such farmers, questions about liability need to be answered, especially with regard to the inevitable risk of damage to PV installations by any farming practice. By addressing these issues, innovation, whether by scientists like the authors, or farmers at future sites, can be explored.

Data availability statement

Data generated from this project will be summarized and shared via our project web site: https://agrivoltaics.research.iastate.edu/

Author contributions

MO wrote the original draft, NP, LD, HF, AK, RK, AN, SS, JT, and HV reviewed and provided edits. All authors contributed to the conceptualization. MO, LD, HF, AK, AN, SS, JT and HV contributed to funding acquisition. NP provided supervision and project administration through the contributions with Alliant Energy, RK was the equivalent with Iowa State University.

Competing interests

The authors declare that they have no competing interests.

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