Crop and energy profit tradeoffs in agrivoltaic system

**Introduction**

Solar energy has become one of the most promising technologies to meet clean energy demand replacing fossil fuel and thus, vital to combat climate change. Agricultural land has greatest solar potential due to its flat terrain, long sun exposure duration, close to human settlement, well developed transportation network, and close to energy transmission grids compared to marginalized land making it the most suitable land for solar energy generation. As a result, solar energy production in agricultural land is expected to expand in the future, imposing competition for land between solar energy production and food production. Collocating solar panels with agricultural crops—agrivoltaics system—is an innovative approach to minimize the conflict between energy and food production.

The agrivoltaics system creates a unique condition where the tradeoff between land use for crops and solar panels is unavoidable. Producers face a land allocation problem as the land allocated for crop production decreases with the increase in land allocated for solar panels for given unit of land. This changes crop production and its profitability.

**Method**

Summarize parameters and assumptions in 1-2 paragraphs.

We used crops enterprise budget and simulated crop profit by varying crop yield and price.

We further simulated profit from solar energy production.

**Results**

**How crop profit changes (at different prices) with land allocation for solar panels (in four regions of AL) for two sun tracking systems and at different heights?**

Results shows the tradeoff between land allocation for crop and solar at which crop still become profitable.

Summarize results from three crops in one to two paragraphs.

Three charts (one for each crop).

**Joint profit from crops (at different prices) and energy from agrivoltaic systems (in four regions of AL) for two sun tracking systems at different heights.**

Results shows total profit from agrivoltaic systems.

Summarize results from three crops in one to two paragraphs.

Three charts (one for each crop).

**Limitation of our study:**

The land requirement may be higher than 1 acre to comply with the local, state, and federal government policies. The land requirement and profitability of operation may vary based on the scale of operation. So, our analysis should be taken as reference benefit cost analysis estimation from one acre of land for given agrivoltaic system operation. Also, this estimation can be taken as a reference estimation for a larger agrivoltaic farm which has multiple one-acre plots solely allocated for agrivoltaics operation and additional land available to meet regulatory obligations and moving spaces between plots. It should not be taken as a benefit cost analysis from one acre plot from which land is allocated to fulfill regulatory obligations and other logistic arrangements needed to build AV onsite farm because several regulatory obligations in local, state, and federal level and the local context for agrivoltaic system development at the given location were not completely and accurately accounted in this research. Also, logistic requirements such as walking space, space for machinery storage and additional land buffers needed are not incorporated in this simulation.

**Conclusion**

Conclude paper with major findings.

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* IGNORE TEXT BEYOND THIS LINE \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

**AV Scenario Simulation**

**Assumptions:**

Total area of plot = 1 Acre = 43560 sq. ft.

Shape = Square (Length and width of plot are equal) = 208.71 ft. \* 208.71 ft.

No buffer at the edge of plot because we want to estimate net return from 1 acre so our estimation will do benefit cost analysis of return per acres in the State of Alabama.

Solar panel size = 7.75 ft by 3.5 ft.

Non-transparent solar panels which blocks sunlight and generates shadow on the ground.

Panel ground clearance = 4.6 ft and 6.4ft; The capital expenditure cost (CAPEX) varies with the height of solar panels.

Four regions of Alabama (north, central, black belt, south) (Electricity price, solar potential, electricity generated)

We assumed two types of tracking solar panels: 1) single axis sun-tracking solar panel (rotates up to 60o angle on both sides of horizontal beam) and 2) single axis non-tracking solar panels (solar panel surface always remain parallel to the ground surface) both mounted on horizontal beam supported by two poles on the either side of the row.

We assumed agricultural activities use manual labor and small equipment such that buffer spacing to move agricultural equipment is not necessary. The spacing between solar panels allocated for agricultural crops is enough to move and use small agricultural equipment. There is no walking or passing space within the one-acre plot.

Solar energy is not produced in crop only scenario and crop is not grown in solar only scenario. Agricultural crops are planted parallel to solar panels in open spaces and under the solar panels in agrivoltaics scenarios. The crop density is affected by row-to-row spacing and plant-to-plant spacing of given crop and not by solar panel orientation, rotation, or spacing. The yield of crops are assumed to vary based on solar radiation that plants received which was not blocked by solar panels. Solar panels creates shadow which could have positive and negative effects on crop yield. So, we simulated crop yield variation from -50% to 200% assuming the range of yield variation due to the fluctuation in solar radiation received by the plant.

**Limitation of our study:** The land requirement may be higher than 1 acre to comply with the local, state, and federal government policies. The land requirement and profitability of operation may vary based on the scale of operation. So, our analysis should be taken as reference benefit cost analysis estimation from one acre of land for given agrivoltaic system operation. Also, this estimation can be taken as a reference estimation for a larger agrivoltaic farm which has multiple one-acre plots solely allocated for agrivoltaics operation and additional land available to meet regulatory obligations and moving spaces between plots. It should not be taken as a benefit cost analysis from one acre plot from which land is allocated to fulfill regulatory obligations and other logistic arrangements needed to build AV onsite farm because several regulatory obligations in local, state, and federal level and the local context for agrivoltaic system development at the given location were not completely and accurately accounted in this research. Also, logistic requirements such as walking space, space for machinery storage and additional land buffers needed are not incorporated in this simulation.

**Spacing for Strawberry:**

Plant-to-plant spacing is 2 ft.

Row-to-row spacing is 3 ft.

Strawberries grow from 0.5 ft to 1 ft. tall.

**Spacing for Tomato:**

Plant-to-plant spacing is 3 ft.

Row-to-row spacing 3 ft.

Tomato grow 3 (Determinate) to 6 ft tall (Indeterminate).

A chart of a solar panel

Description automatically generated with medium confidence

A map of a stadium

Description automatically generated

Only for internal use and set perspective: One acre inside Auburn University Football Stadium (1 Acre = 43,560 sq. ft.) and ~835 ft. perimeter for a square. The square inside stadium is quite close to the plot designed.

The layout below needs to be updated.

A diagram of a tractor

Description automatically generated

Source: The cost of PV + Crops (reinforced regular mount) holds panels at 8.2 ft above the ground while maintaining structural integrity under wind and snow loads.

Inter-row spacing is 44 degrees except for vertical mount (90-degree). Panel height taken from Table 1, Page 7, https://www.nrel.gov/docs/fy21osti/77811.pdf

Site preparation cost is included under install labor and equipment and contribute to difference in cost across the scenario.

Suggested Citation

Horowitz, Kelsey, Vignesh Ramasamy, Jordan Macknick and Robert Margolis. 2020. Capital Costs for Dual-Use Photovoltaic Installations: 2020 Benchmark for Ground Mounted PV Systems with Pollinator-Friendly Vegetation, Grazing, and Crops. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77811. <https://www.nrel.gov/docs/fy21osti/77811.pdf>.