A TECHNO-ECONOMIC ANALYSIS OF AGRIVOLTAIC SYSTEMS WITH TOMATO AND STRAWBERRY IN ALABAMA

BY

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Abstract

This study presents a techno-economic analysis of agrivoltaic systems (AV) with tomato and strawberry in Alabama, exploring their profitability from the perspectives of farmers. We consider a hypothetical four acres of square land in Auburn, Alabama and compare the profitability of various land uses including photovoltaic (PV) only, specialty crop only (strawberry or tomato), and AV with different solar panel density. Specifically, we study for a given crop price, a given crop yield, a given solar density, the profitability of AV systems. The study suggests that AV systems present a viable solution for sustainable agricultural and energy production, capable of boosting profits while reducing the risks associated with conventional farming. Under certain conditions, the profits from AV can be higher than those from PV only.

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A Techno-economic Analysis of Agrivoltaic systems with Tomato and Strawberry in Alabama

Abstracts

This study presents a techno-economic analysis of agrivoltaic systems (AV) with tomato and strawberry in Alabama, exploring their profitability from the perspectives of farmers. We consider a hypothetical four acres of square land in Auburn, Alabama and compare the profitability of various land uses including photovoltaic (PV) only, specialty crop only (strawberry or tomato), and AV with different solar panel density. Specifically, we study for a given crop price, a given crop yield, a given solar density, the profitability of AV systems. The study suggests that AV systems present a viable solution for sustainable agricultural and energy production, capable of boosting profits while reducing the risks associated with conventional farming. Under certain conditions, the profits from AV can be higher than those from PV only.

1. Introduction

Commitments in mitigating climate change are leading to increase in renewable energy production, and together with declining cost of solar, are trailblazing to a rapid increase in solar energy implementation in the United States (US) (AL-agele et al., 2021). Since 2017, solar energy generation in the US has increased by threefold (Ravilla et al., 2024), expected to grow by 7 to 8 folds by 2030 from 2022, contributing to 100% carbon-free electricity by 2035 (Bowie et al., n.d.). Agricultural land has the greatest solar potential as it is accessible and flat , making it suitable for solar energy generation (Adeh et al., 2019). As a result, solar energy production in agricultural land is expected to expand in the future, imposing a competition for land between solar energy production and food production (Kim et al., 2021).

Because agrivoltaics systems (AV) support solar energy while keeping the land under farming, community support for agrivoltaics systems is growing. A study by Pascaris et al. (2022) found that about 82% respondents would be likely to support the AV system. Agrivoltaics systems have lately attracted much attention from researchers, policy makers, and legislators in the United States and the world (Mamun et al., 2022). For example, the introduction of bill in the first session of 118th congress of the United States (US) requires the Secretary of Agriculture to carry out research and demonstration on agrivoltaics systems (Luepke, 2023). Several articles agreed on multiple benefits of agrivoltaics systems and their positive role in mitigating negative effects of climate change (Dinesh & Pearce, 2016). The shading effects of agrivoltaics systems into drylands have the potential to reduce plants drought, heat stress and water use efficiency and also enhance the efficiency of the food, water and energy nexus (Barron-Gafford et al., 2019). The purpose of this research is to investigate the techno-economic prospect of agrivoltaics systems involving tomato and strawberry in Alabama.

Study of agrivoltaics systems is in its early phase and study of specialty-crop-based agrivoltaics systems such as tomato and strawberry are rare despite their high economic and nutrient importance. To the best of our knowledge, the only published peer–reviewed paper from tomato-based agrivoltaics systems is based on experiments in Arizona (AL-agele et al., 2021), where the authors observed a rise in the yield of tomato grown under the photovoltaics systems due to an improvement of photosynthesis probably caused by a reduction in temperature and shade protection provided by solar panels from the intense solar radiation in Arizona. To the best of our knowledge, there are no studies examining the potential profitability of agrivoltaics systems involving specialty crops in Alabama. we aim to fill the gap by focusing on agrivoltaics systems with two specialty crops: tomato and strawberry.

Tomato (*Solanum lycopersicum L.*) is one of the most widely cultivated specialty crops in the US with total economics contribution of $4.8 billion, 33,000 jobs, $400 million in federal tax, and $350 million in state and local taxes in 2016 (Esquer, 2018). Nevertheless, tomato is mostly grown in the southwest (i.e., California and Arizona) and some southeast (i.e., Florida, Georgia and South Carolina). In Alabama, tomatoes are one of the most grown vegetables both in terms of the number of farms that cultivate them and the volume of production. Tomatoes contribute to the state's economy, with a total of $161.5 million, value added production of $103.6 million, job creation of 1,121 jobs and indirect business taxes of $2million with commercial farming (Esquer, 2018). For specialty crop production such as tomato experiment involving solar panel have been performed mostly in greenhouse that are partially shaded by solar panels (Touil et al., 2021).

The United States produces almost 20% of the world strawberry. The farm gate economic value of strawberries has been between $2.3 and $ 2.8 billion (Samtani et al., 2019). Strawberries are an integral part of Alabama's agricultural landscape, cherished for their flavor, nutritional benefits, and the economic opportunities they provide. This is because Alabama climate allows for a relatively long strawberry growing season (Khoshnevisan et al., 2013). Strawberries also hold cultural significance in Alabama, encompassing prominently in community events and festivals. The Cullman Strawberry Festival, for example, is a famous event that celebrates the local strawberry harvest with parades, vendors, and strawberry picking contests. Events like these depict the role of strawberries in fostering community ties and supporting local economies.

How do the agrivoltaics systems impact the profitability of and the economic viability of tomatoes and strawberries as compared to conventional farming in Alabama? Agrivoltaics systems, by combining solar energy production and agriculture, allow farmers to generate additional profit from the same plot of land. The two sources of income farmers can buffer against bad seasons or fluctuations in market prices (Dupraz et al., 2011). In this paper we study whether it is economically viable to participate in the agrivoltaics systems rather than maintaining the conventional way of farming in Alabama. We do so by examining for a given crop price, a given crop yield, a given solar density, what the profitability of agrivoltaics is for tomatoes and strawberries in Alabama.

2. Literature review

The agrivoltaics systems can be a solution for maintaining agricultural production while providing energy benefit (Barron-Gafford et al., 2019). According to (Barron-Gafford et al., 2019), given appropriate design configuration, AV systems can improve economics efficiency and viability for farmers and solar developers, provide valuable ecological services, and expand opportunities for solar deployment.

AV was introduced by Goetzerger & Zastrow (1982) four decades ago. Not too long, several studies and facilities had been established around the world (Dupraz et al., 2011). As shown by several studies, AV can enhance land productivity (Barron-Gafford et al., 2019). Also, its offers great potential as resource efficiency, water use efficiency has been shown to increase underneath the panels on PV installations (Agostini et al., 2021). These findings are becoming even more significant, as water demand for irrigation is expected to enhance in the future climatic conditions (Weselek et al., 2019)

A few studies have distinctively and carefully examined the profitability of AV systems compared to crops or solar-only options. Dinesh & Pearce, (2016) posited that solar energy production coupled with agricultural production from shade-tolerant crops such as lettuce could increase farm profit by 30% when compared to conventional farming only in the US. Consequently, Mamun et al. (2022) found that over 30% increase in profits for farmer deploying AV systems for lettuce production in Kansas City compared to crop only. Additionally, study by Chae et al. (2022) estimated profit of integrated power and agricultural production by AV to increase profitability by 300%-5,000% relative to a farm-only scenarios. Thompson et al. (2020) estimated that about 2.5% and 35% economic return for AV systems with basil and spinach compared to crops alone, respectively, in

Italy. Sojib Ahmed et al. (2022) identified that profits from AV can be 22-115 times higher than those of conventional rice cultivation across six countries. (While these studies find economic benefits for AV System compared to crops, it is unclear how the profitability compares to PV only).

Weselek et al. (2019) opined that AV system can increase land productivity by up 70% , they also asserted that given the impacts of climate change and conditions in arid climates, potential benefits most likely for crop production through additional shading and observed improvements of water availability, they also demonstrated that AV can be significantly in technical approach for more sustainable agriculture, helping to meet current and future needs of energy and food production and at the same time sparing land resources. Brothers et al. (2022) observed the factor affecting solar system profitability for southeastern broiler growers, they observed how the system size, photovoltaic power generation and utility compensation affect solar system profitability. Their results showed that due to the poultry usage profile, when electricity buyback rates are low, system size and utility compensation are more important than solar availability in determining profitability.

On the contrary, Feuerbacher et al. (2022) estimated the profit from land cultivated below AV system to decline by 40.3% for cereal and 73.9% for vegetables farming in Germany. These reductions were mainly due to shading effects on the crop yield, higher machinery and labor and the abandoned agricultural profits from area lost due to the mounting structure of the PV system. They opined that these reductions in agricultural profits might generate negative incentives for farmer to abandon agricultural production underneath AV system, indicating to similar development on solar farms on agricultural land in the United Kingdom. Building on the previous study, Feuerbacher et al., 2022 demonstrated that solar radiation and investment costs are the critical determinants of the adoption of AV system, whereas agronomic costs from crop shading and land losses have more impacts. They also demonstrated that crop yield under AV decreased by about 40%, often leading to negative agricultural profit. The study ended that substantial policy support was needed to make AV competitive with ground motivated PV. Hence, it is with this knowledge and understanding that it is imperative that, this study is of importance to farmers, policy makers, researchers, and technologists to clearly cut out the profitability measure to ensure benefits and gains from the collocation of agricultural land and solar panels.

While Barron-Gafford et al. (2019) opined that AV system is mutual benefits that exist between food, energy and water nexus in dryland, this study is focused on the southeastern region, Alabama. To the best of our knowledge, no studies have been conducted to quantify the cost and benefits of AV system in specialty crops in Alabama. Hence, more knowledge is needed to understand variation in the profitability of AV system as the determinant of AV profitability.

3. Methods

We consider a hypothetical 4 acres of square land in Auburn, Alabama and compare the profitability of various land uses including PV only, specialty crop only (strawberry or, separately, tomato), and AV with different solar panel density. For PV only, we assume that the system will be using 3.5 feet by 7.75 feet solar panels and that the space between two solar panel rows is 6 feet. We did not consider capital cost in the analysis.

We calculate the number of panels per row of solar panel by dividing the side length by panel width. The number of panel row is calculated by using side length of the four-acre square field divided by the sum of spacing between two rows and the panel length. Total number of panels was gotten by multiplying number of panels per row of solar panel with number of panel rows. PV capacity was obtained by multiplying total number of panels multiplied by output per panel. Electricity generated was gotten by multiplying PV capacity by annual electricity generated by 1kw capacity in Auburn, AL. Revenue was generated by multiplying electricity generated by price of electricity, total cost of PV was the sum of installation cost and operating and maintenance costs. PV profit equals revenue minus total costs. Specifically, we have the following formulas:

$$NPPR_{FT} = \frac{SL}{PW}$$

$$NPR_{FT} = \frac{SL}{PL+S}$$

$$TNP_{FT} = NPPR_{FT} * NPR_{FT}$$

$$PV\ CAPA(kw) = NPPR_{FT} * NPR_{FT} * OUTPUT(kw)$$

$$ELE\ GEN\ (kw) = PV\ CAPA(kw) * AU\ GEN\ (kw)$$

$$REV(\$) = ELE\ GEN\ (kw) * PPV(\$)$$

$$IC(\$) = SP + INV + SB + ELEB + EPC + ST + IF + C + D$$

$$TC = AIC + O\&M$$

$$PV\Pi\ (\$) = REV(\$) - TC(\$)$$

where $NPPR_{FT}$ = Number of panels per Row of Solar Panel, $NPR_{F\ =}$ Number of Panel Row, SL_{FT} = Side Length of the four-acre square field, PW = Panel Width, PL = Panel Length, S_{FT} = Spacing between two panel rows, TNP_{FT}= Total Number of Panel, PV CAPA(kw) =

Photovoltaics Capacity(Kw), OUTPUT per panel (kw), ELE GEN (kw) = Electricity Generated, Auburn generated, REV($) = Revenue, PPV($)= Price of electricity($/kwh), TC($) = Total Cost, SP = Solar Panel Cost, INV= Cost of Inverter only, SB= Structural balance , ELEB = Electrical Balance , IC = Installation Cost, +EPC = Engineering, Procurement and Construction Costs, ST = Sales Tax, IF = Interconnection Fees, PVΠ ($) = photovoltaics profit, AIC= Annual Installation cost, O&M = Operating cost and maintenance.

Based on the aforementioned formulas, we calculate the number of panel per row to be 119 and the number of panel rows to be 30 that give us 3,570 total panels that can be placed on this 4-acre field, given the output capacity from one solar panel is about 0.545kw, therefore, solar capacity was determined by multiplying the number of panel per row multiplied the number of panel row by the output to give us 1945.65 (KW). Based on PVwatt calculator, for solar panel with 1kw capacity, the amount of electricity generated within a year in Auburn, Alabama is about 1649kwh, then we multiplied it by the total solar capacity to get $3,208,376.85(KWh/year). The electricity multiplied by the electricity price $0.035/kwh, gives us revenue: $397,838.73. The profit ($66,346.39 /year) was determined by subtracting total annual cost ($39209.20/year) from revenue.

For crop only tomato,

$R_T = Y_T * P_T$

$\Pi_T = R_t - TC_T$

$TC_T = PRE\ H_T + FC_T + PH_T + (HL_T + MA_T) * Yield$

where: R_T = Revenue from Tomato, Y_T = Yield from Tomato, P_t = Price from Tomato , Π_T = Profit from Tomato, TC_T = Total Cost from Tomato, PRE H_T = Preharvest from Tomato,

FC_T = Fixed Cost from Tomato, HL_T = Harvest Labor, MA_T = Materials, PH_T = Post from Tomato.

For crop only strawberry,

$R_S = Y_S * P_S$

$\Pi_S = R_S - TC_S$

$TC_S = PRE\ H_s + FC_s + PH_s + (HL_s + MA_s) * \text{Yield}$

where R_S = Revenue from Strawberry , Y_S = Yield from Strawberry P_S = Price from Strawberry , Π_S = Profit from Strawberry, TC_s= Total Cost from Strawberry PRE H_s= Preharvest from Strawberry, FC_s= Fixed Cost from Tomato, HL_s = Harvest Labor, MA_s = Materials, PH_S = Post from strawberry

For AV systems, which is the combination of solar panel with the crop, we thus added the profit from PV of different proportions with the crop profitability. PV system involves a high upfront capital cost and a long term investment horizon compared to crop production (Hirth & Steckel, 2016). The profitability for a representative farm scenario was investigated at 10% to 100% of the panel density on a typical PV only solar farm.

In agrivoltaics, solar panels are installed in agricultural fields to generate electricity while the land continues to be used for crop production. Specifically, no adjustment for cropping was assumed in this study, that is, the existing agricultural practices, such as the types of crops grown, planting and harvesting schedules, remain unchanged despite the presence of solar infrastructure.

To examine the profitability of AV system, we defined different AV scenarios by varying the design configuration and field geometry of 4-acre hypothetical AV farm. The initial design configuration of the AV farm was based on the following dimensions, and this is depicted in Figure 1, with a row spacing of 6ft and a height of 5ft. We compare different scenarios to investigate the profit level at different proportions. (See Table 1 for details).

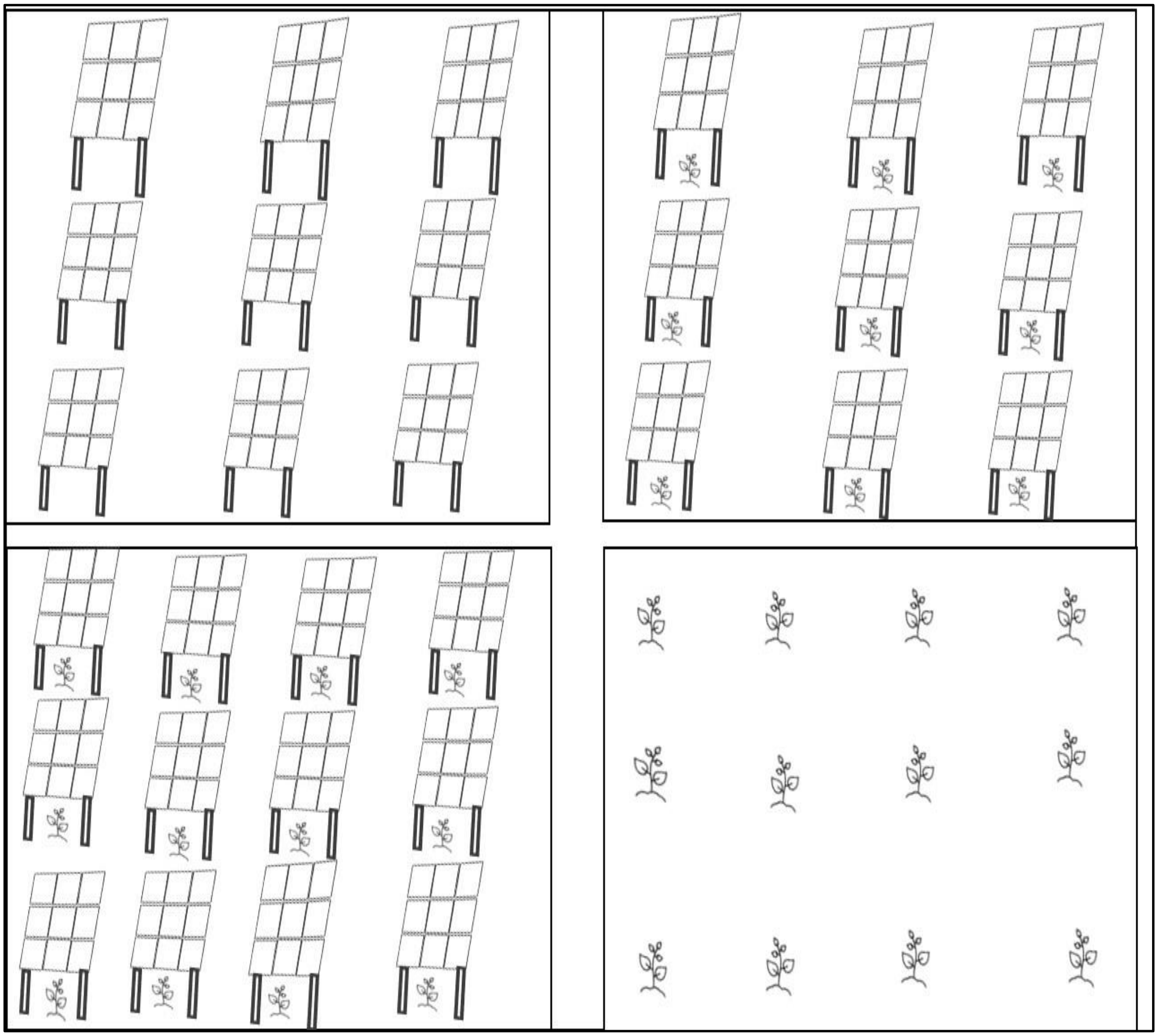

Figure 1: AV scenarios showing 4 acres of land with different patterns, with PV only, PV with different mixed levels and PV with different higher mixed level and the crop only. The figure depicts crops growing underneath the panel to maximize land use.

3.3 Data

Table 2 presents an overview of the parameters of the AV Scenarios. Data on technology parameters describing the PV scenarios are primarily from National Renewable Energy Laboratory (NREL) reports. The NREL System Advisor Model (SAM) was used to calculate the energy output of the AV/PV system. The Sam model is a techno- economic software tool that estimates electricity generation. The capacity of the AV scenarios area varies depending on the area proportion, spacing, panel length and panel width. Data on changes in crop yields were gotten from Alabama extension. These data were combined with data on production cost of the crops, prices, solar energy price, and renewable energy calculation from the PVwatts calculator to obtain the profitability of the AV scenarios (see Table 2). The life span for the PV was assumed to be 25 years, the operating and maintenance cost equals $15/kw/year, the annualized installation cost ($/year), is $10024.45982, we then add, the operating and maintenance cost ($/year) of $29184.75, the operating and maintenance cost ($/year) equals $15/kw/year multiplied by PV capacity of $1945.65/kw/year. Hence, annualized total cost equals annualized installation costs plus operating and maintenance costs. The type of panel used for the study was tracking solar panels. This helps to track the sun after which the solar panels convert the energy from the sun to electricity.

Table 2 shows the model parameters of the AV system that we used to calculate the electricity profit and some of the parameters used to calculate the crop profits for tomato and strawberry.

3. **Results and Discussion**

3.1 Profitability of AV configuration for tomato

This section examines the performance (energy and crop yield) of different AV/PV configurations. Differences in crop yield were found across AV scenarios. We obtain the benchmark crop yields and prices from crop budgets of Alabama Cooperative Extension System (see Table 2). We then vary the yields and prices from 10% to 200% of the benchmark values, with a 10-percentage-point increment. In other words, for each AV scenario and the conventional farming scenario, we consider 20 yield levels and 20 price levels, resulting in 400 yield-price combinations. For AV scenarios, we consider 10 different solar panel densities: 10%, 20%, …, 100% of the number of rows in the PV only system. The profit from an AV system is equal to the profit from solar energy production and crop production.

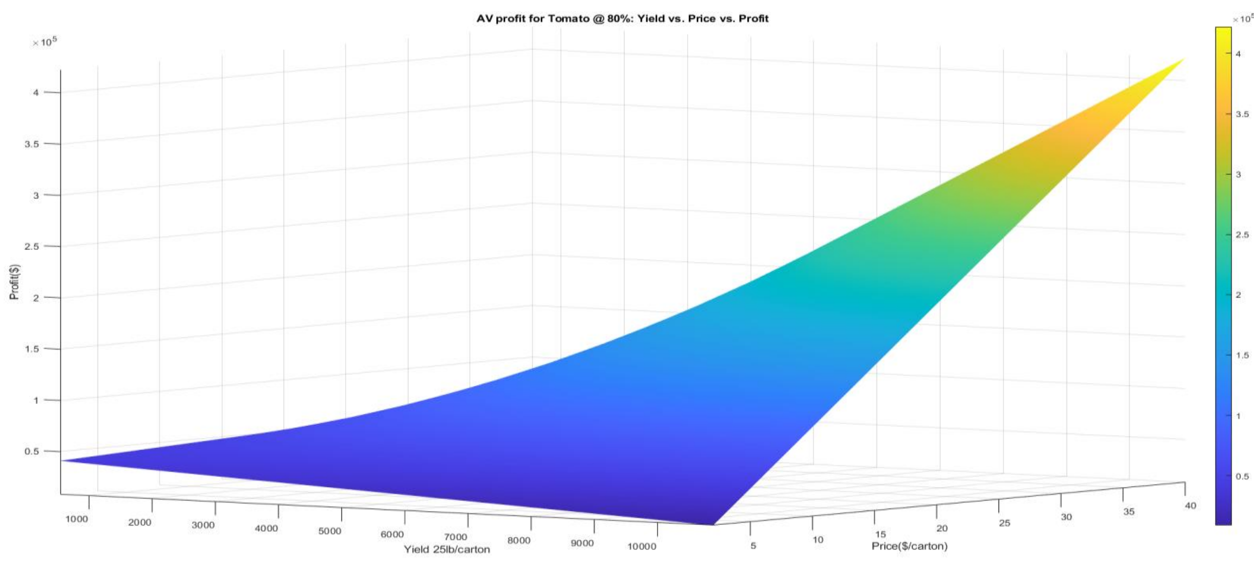

Figure 2: Profitability of AV system (80% solar panel density) with tomato under various tomato yields and prices

In Figure 2, the color gradient, which moves from blue to yellow as the profit increases, represents different levels of profit. The lower profits are shown in blue, and higher profits are shown in yellow. From the 80% plot for tomato, we observed the following. As the yield increases, the profit also increases, suggesting that higher tomato yield production leads to higher profits. As the price increases per carton increases, the profits also increase, which demonstrates that selling tomatoes at a higher price per unit carton will in turn yield a greater profit. More specifically, under the benchmark yields and prices, a 4-acre AV system with 80% solar panel density would generate profit at $123,695.92/year (see Table 3). Table 3 also presents the profitability when yields and prices are 50%, 80%, 120%, and 150% of their corresponding benchmark values. We can see that there is a wide range of profitability under these yield and price values: from $245,735.92/year to $56,055.92/year.

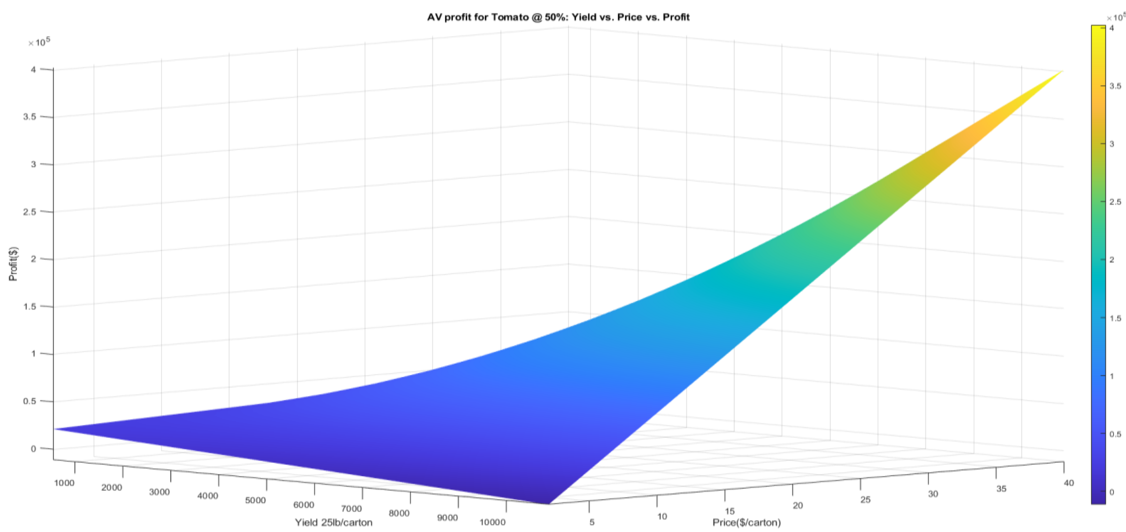

Figure 3: Profitability of AV system (50% solar panel density) with tomato under various tomato yields and prices.

It is imperative to note that Figure 3 is similar to figure 2 but the maximum value on the profit scale is lower simply because the solar density is lower.

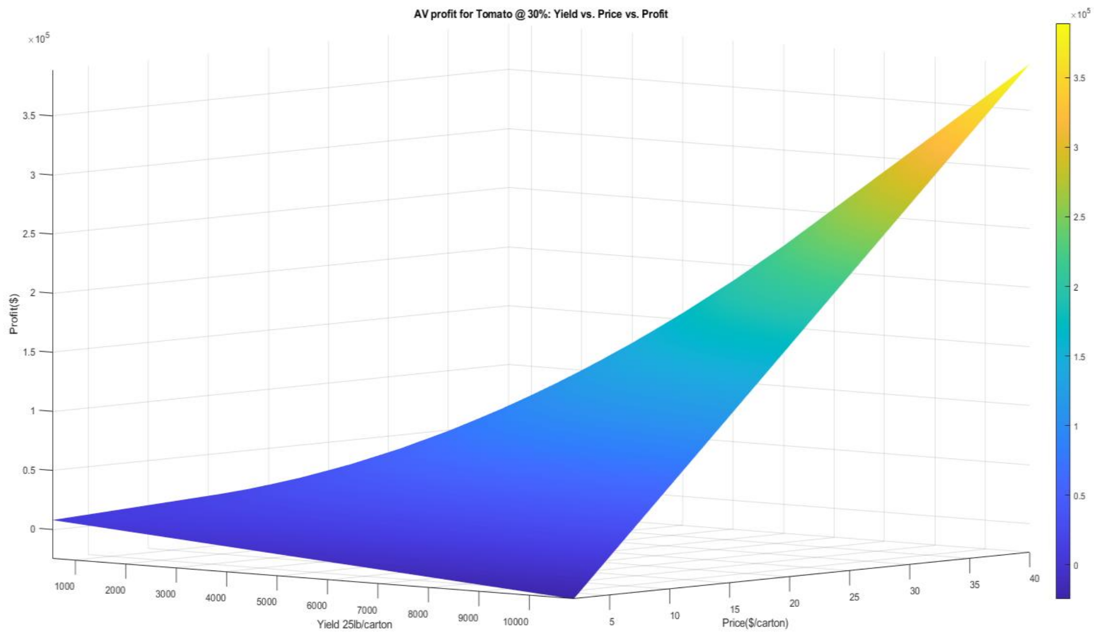

Figure 4: Profitability of AV system (30% solar panel density) with tomato under various tomato yields and prices.

The results show that AV systems have a good profitability, with profit ranging from ($0-$350,000). This visualization helps stakeholders in the agricultural sector understand how varying yield and pricing strategies can impact profitability. Figure 3 at 50% solar density, while Figure 4 at 30% solar density. This implies that the figures are meant to represent different success rates or productivity levels for tomato farming. Both images show that as price and yield increase, the profit also increases. However, the spread of the gradient is different in each figure. The 50% solar density suggests a more expansive area of higher profits, while the 30% solar density shows a steeper ascent to high-profit regions, indicating that a certain threshold in both price and yield needs to be surpassed to achieve similar profits to the 50% solar density.

3.2. Profitability of AV configuration for strawberry

AV system can create a more favorable microclimate for crops, solar panel can provide shade, reducing the temperature extremes during hot days, which can benefit tomato and strawberry since these crops are sensitive to heat stress. The results show that at a given yield, price, and solar density there exists an increase in profitability in relation to AV system for strawberry. This is consistent with (Petrakis et al., 2024) results, they opined that, strawberry is worth farming under agrivoltaic systems.

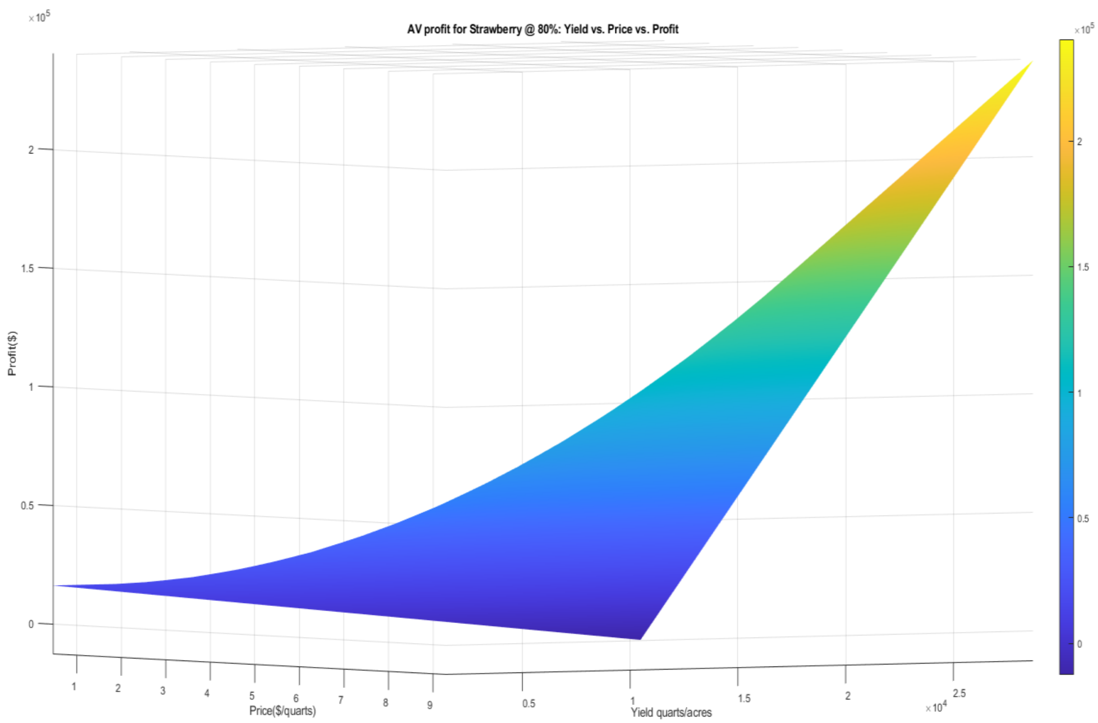

Figure 5: Profitability of AV system (80% solar panel density) with strawberry under various Strawberry yields and prices.

In Figure 5, the color gradient, which moves from blue to yellow as the profit increases, represents different levels of profit. The lower profits are shown in blue, and higher profits are shown in yellow. From the 80% solar density plot for strawberry, we observed the following. As the yield increases, the profit also increases, suggesting that higher strawberry yield production leads to higher profits. As the price increases per quarts, yield increases, the profits also increase, which demonstrates that selling strawberry at a higher price per unit quarts will in turn yield a greater profit. More specifically, under the benchmark yields and prices, a 4-acre AV system with 80% solar panel density would generate profit at $277,752/year (see Table 4). Table 4 also presents the profitability when yields and prices are 50%, 80%, 120%, and 150% of their corresponding benchmark values. We can see that there is a wide range of profitability under these yield and price values: from $23,547/year to $134,892/year.

From Figure 6 we can see that, even at 50%, combination of solar profit and crop still yields profit that is worthwhile to participate in agrivoltaics system. Figure 7 shows that the profit spans from approximately ($0-$20,000). The color gradient ranging from blue to yellow represents increasing levels of profit, with blue indicating the lower end of profit and yellow the higher end. Both images seem to show a similar range of profits, but the gradients suggest that the 50% solar density yield model reaches higher profit levels than the 30% solar density yield model, which is logical assuming other costs remain the same.

In the 50% solar density, the transition from low to high profits (blue to yellow) spans a larger area, indicating a more gradual increase in profit with increases in yield and price.

In the 30% solar density, the transition from blue to yellow is more abrupt, suggesting that there might be a more pronounced threshold of yield and price that needs to be exceeded to achieve high profits.

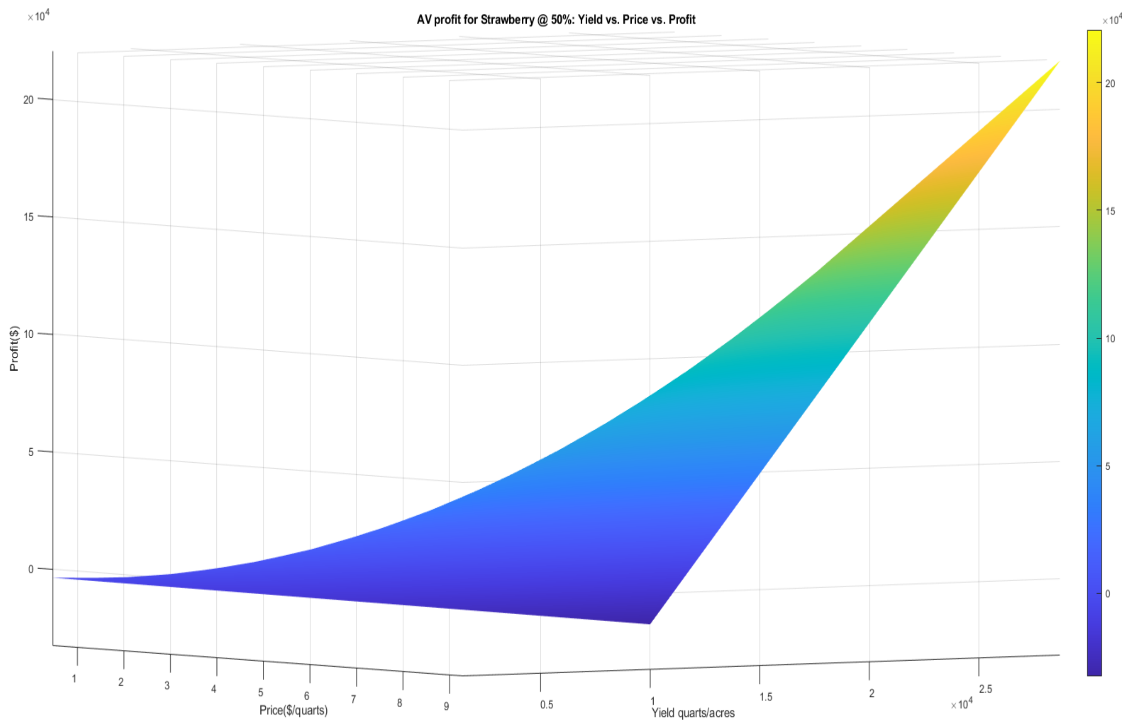

Figure 6: Profitability of AV system (50% solar panel density) with strawberry under various Strawberry yields and prices.

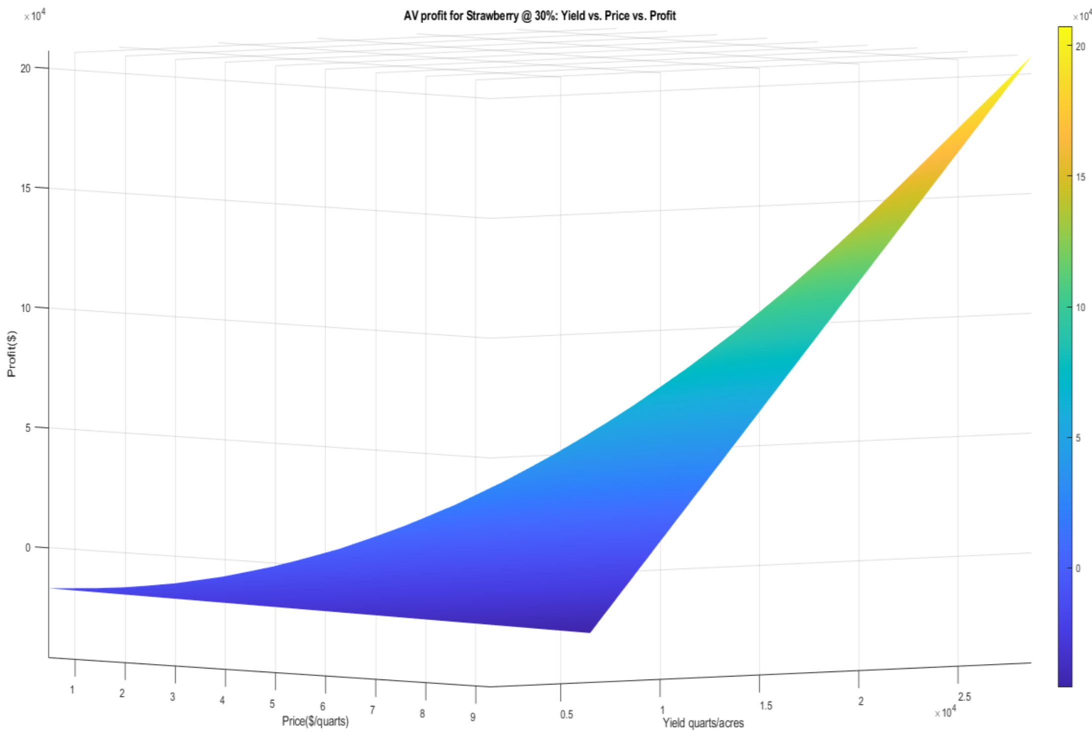

Figure 7: Profitability of AV system (30% solar panel density) with strawberry under various Strawberry yields and prices.

The transition from low to high profits seems more gradual in the 50% solar density than in the 30% solar density, which has a more pronounced transition, suggesting that the impact of price and yield on profit is different between the two scenarios.

Condition for which profit is higher than PV only, this can be when the price per quart is higher, and yield is high. Also, costs associated with producing the yield must be low enough such that when the revenue (price multiplied by yield) is reduced by these costs, the profit remains above the PV.

Condition for which AV profit can be lower than crop only: Higher costs, if the costs associated with producing the crop, such as labor, materials, are higher for the AV profit scenario than for the crop only, the overall profit would be less.

Decrease in yield, meaning fewer quarts per acre, can lead to lower AV profits if the reduction in volume is not compensated for by a higher price. Also, if the selling price per quart is lower in the AV scenario, possibly due to market conditions or inferior quality, the AV profit will be less than the crop only profit.

Table 3 above presents profit at different percentage levels on tomatoes, this clearly gives a balance and distinctive understanding as to how profitability can be achieved by

price levels and yields. At the price level of $10, from the table, it gives us a positive figure at different proportions, this gives us a clue on how we can hypothetically increase the proportion to make profit. This provides an understanding to the profitability of AV system.

Table 4 shows the profit at different percentage points on Strawberries, this clearly gives a balance and distinctive understanding as to how profitability can be achieved at different price levels. At the price level of $3.34 of strawberry from the table, it gives us positive numbers from for price at $2.32 this gives us a benchmark price, yield, and crop proportion for which a farmer and solar investor would want to make profit if all things been equal. This provides an understanding to the profitability of AV system.

Table 3 and 4 presents AV profit at 80% solar density, crop prices and yields, but it is distinctively clear that AV system under tomatoes yields more profits than strawberries combined with AV system. This could suggest more yield and varying crop prices.

4. Conclusions

The Agrivoltaics (AV) system, which is the colocation of PV energy and agricultural production, can significantly reduce the competition in land use. This can in turn increase productivity by integrating and combining agricultural and solar production. Nonetheless, few studies have investigated the costs and benefits of AV systems for specialty crops in the US. This study provides a distinctive conceptual analysis of the economics of specialty crop AV systems from a farmer's perspective and compares these systems to separate food and energy production systems at a hypothetical field in Alabama. We show the profitability of AV systems for a given crop yield, crop price, and solar panel density, which will help farmers reach informed decisions about AV system adoptions. In general, AV systems increase farmers' profitability than growing crops only. For farmers and solar investors, this demonstrate that, AV system is viable. I.e., AV systems could generate profit for farmers even with losses from crop production. With the help of agrivoltaics systems farmers can diversify their income and reduce reliance on crop production alone, which can be highly variable and weather dependent.

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Table 1: Description of the Scenarios for AV design configuration

Parameter	Value
Solar proportion (%)	1
Area Proportion (ft)	174240
Length of one side (ft)	417.42
Panel length (ft)	7.75
Panel Width (ft)	3.5
Side length (ft)	417.42
Solar panel life span (year)	25
Annual interest rate (%)	5
Solar degradation (%/year)	0.5
Annualized installation cost ($/year)	10024.45
Operating and maintenance cost ($/kw/year)	15
Number of panels per row (ft)	119
Number of Panel Row in X (ft)	30
Total number of panels (ft)	3570
PV capacity(Kw)	1945.65
Electricity generated (kwh/year)	3,208,376.85
Electricity price ($/kwh)	0.035
Revenue ($/year)	397,838.73
Total annual costs for 100% PV ($/year)	39209.20
Photovoltaics Profit ($/year)	66,346.39

Table 2: List of model parameters of the AV system

parameter	units	Value	Source
Solar component:			
Auburn solar generation	(Kwh in a year)/kw	1649	SAM https://pvwatts.nrel.gov/pvwatts.php
Electricity output per solar panel capacity	KW	0.545	SAM https://pvwatts.nrel.gov/pvwatts.php
Total annual costs for 100% PV	$	39209.20	(Horowitz et al., 2020)
Agricultural component:			
Tomato yield	25lb carton/acre	1360	Alabama Extension
Tomato price	$/carton	20	Alabama Extension
Preharvest	$/1360 carton	8955.42	Alabama Extension
Harvest Labor	$/1360 carton	1760	Alabama Extension
Harvest boxes	$/c1360 boxes	1700	Alabama Extension
Fixed cost	$/acres	1237.77	Alabama Extension
Post harvest machinery.	$/acres	86.98	Alabama Extension
Strawberry yield	quart/acres	3588	Alabama Extension
Strawberry price	$/quart	4.64	Alabama Extension
Marketing	$/3558 quart	2868	Alabama Extension
Bucket	$/quart	1671.71	Alabama Extension
Harvest Labor	$/quart	920.68	Alabama Extension
Fixed cost	$/acre	595.07	Alabama Extension
Preharvest cost	$/3588 quarts	7238.88	Alabama Extension
Post harvest machinery	$/acre	980.45	Alabama Extension

Table 3: Profit Proportion at different Yields and Prices for AV Systems with Strawberry (solar panel density: 80%)

		Price ($)				
		30	24	20	16	10
Percentage of benchmark yield (%)	**Yield (25lb carton)**					
150%	8160	$245,735.92	$196,775.92	$164,135.92	$131,495.92	$82,535.92
120%	6528	$205,151.92	$165,983.92	$139,871.92	$113,759.92	$74,591.92
100%	5440	$178,095.92	$145,455.92	$123,695.92	$101,935.92	$69,295.92
80%	4352	$151,039.92	$124,927.9	$107,519.92	$90,111.92	$63,999.92
50%	2720	$110,455.92	$94,135.92	$83,255.92	$72,375.92	$56,055.92

Table 4: Profit Proportion at different Yields and Prices for AV Systems with Strawberry (solar panel density: 80%)

		Price ($)				
		6.96	5.57	4.64	3.34	2.32
Percentage of benchmark yield (%)	**Yield /quarts**					
150%	21528	$134,892	$104,925	$84,947	$290,804	$35,002
120%	17222	$111,478	$87,504	$71,522	$282,973	$31,566
100%	14352	$80,258	$75,890	$62,571	$277,752	$29,275
80%	11482	$56,44	$64,276	$53,621	$272,530	$26,984
50%	7176	$56,844	$46,855	$40,195	$30,872	$23,547