

Economic and Environmental benefits through Agrivoltaics Systems in India

Detailed project overview report on 3-year, phase 1 activities of the 1.4MW Agrivoltaics/Fruitvoltaics project in Manwath, Parbhani and 0.5 MW Viticulture-Agrivoltaics project in Sahyadri Farms, Nashik.



Imprint

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Executive Summary

Agrivoltaics is a new technology being adopted by several nations like Germany, Italy, France, Japan, China, Australia, Israel and USA. India has also since 2018 from the national and international learnings set up around 40 pilots scaling upto 10 MW in total across the nation. In the process of enhancing and catalysing this journey, in 2021 GIZ India, Sunseed APV and Kanoda Energy Systems Pvt. Ltd. entered a joint partnership through DeveloPPP to explore the opportunities of Agrivoltaics on practical ground with MW scale installation. Two pilots were installed in Parbhani (1.4 MW) and Nashik (0.5 MW) in 2022 and 2023 respectively. Through this report several observations and learnings through these pilots are documented below:



- Land productivity in the pilot location and water savings per unit of crop yield.
- A detailed Techo-economical analysis for Manwath Agrivoltaics site.
- Capacity Building and Sensitization workshops on Agrivoltaics for more than 1000 farmers, 250 students and 30 solar project developers and investors are made aware/trained on the innovative concept of Agrivoltaics technology and farming.
- Policy & legal framework recommendations for favorable framework conditions and business model proposals for implementation of Agrivoltaics in India have been presented to the Government of India.
- At least 5 investors (i.e. developers, government institutions) are committed to replicating Agrivoltaics practices from these pilots)
- Several site visits, delegations (national and international) and upscaling studies.
- Development of a crop growth model.

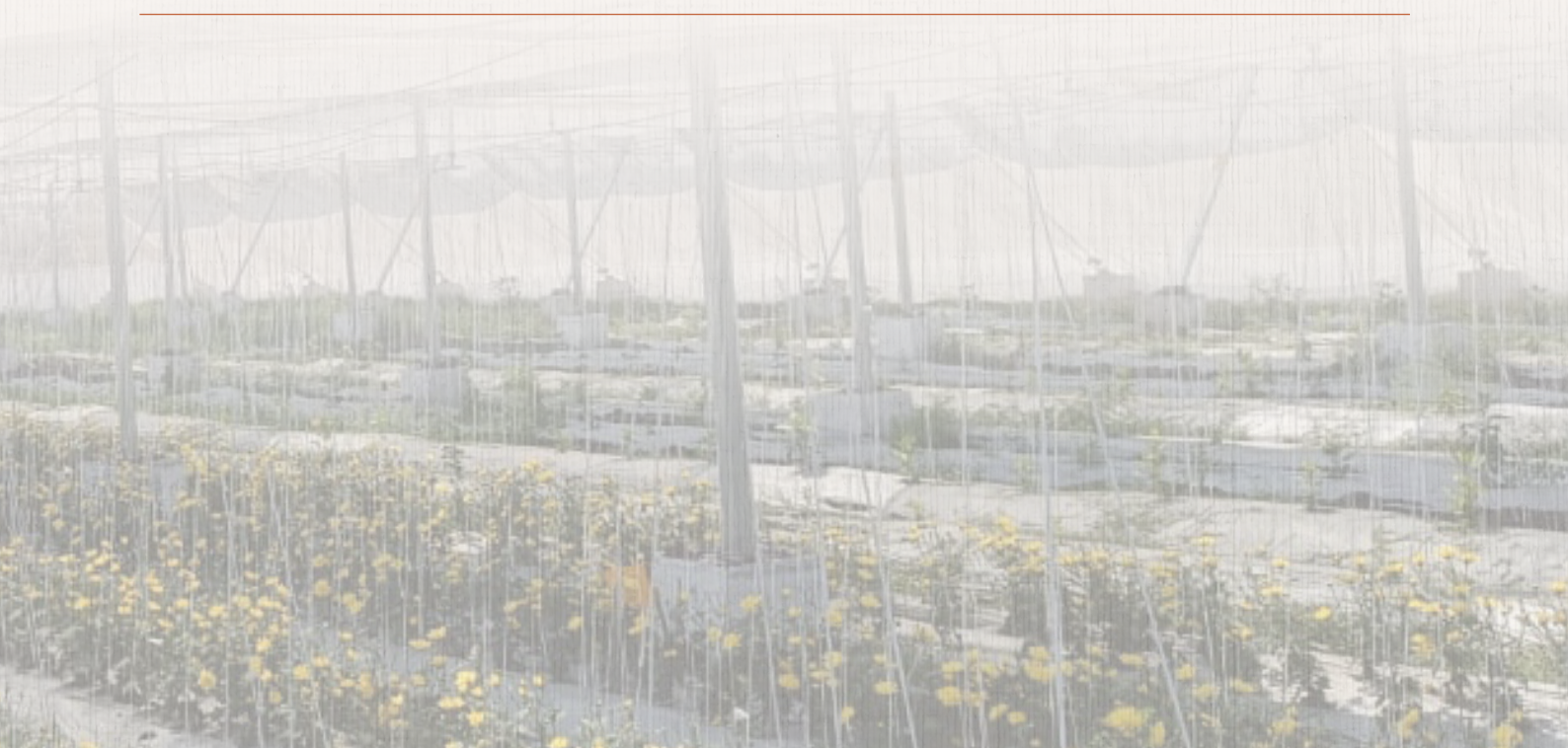
The report presents real time results of pilot projects and identifies key opportunities for agrivoltaics, providing a strong basis for future research and investment. Particularly, the learnings from the pilot sites from DeveloPPP phase 1 project can be used for better and successful implementation of ongoing DeveloPPP phase 2 and other Agrivoltaics related projects at GIZ. Additionally, these insights can serve as a valuable resource for the wider agrivoltaics community in India, fostering knowledge exchange and best practices. Upcoming pilots in the years may explore more on the extended research, innovative business models, technology innovations to strengthen the agrivoltaics ecosystem in the Indian context t. Furthermore , these learnings shall be incorporated for the successful implementation of the crop growth model being developed to help the farmer community achieve increased/dual income by proper understanding of the technology.



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1. Introduction

Agrivoltaics is a promising approach at the intersection of renewable energy, food and water security. Installing solar panels on agricultural land allows for the dual use of land: It allows the production of solar energy (climate mitigation) and agricultural activities on the same piece of land, increasing land use efficiency compared to agriculture or solar energy production in isolation. The shade provided by solar panels enables high-yield horticultural models that increase crop yields while conserving precious water resources (climate adaptation). In countries with a large agricultural economy, such as India, widespread adoption of solar energy is expected to lead to competition for land. However, Agrivoltaics has the potential to create synergies between the country's solar energy and agricultural goals.



In October 2021, GIZ India, with Sunseed APV and Kanoda Energy Systems entered a DeveloPPP project with the aim to develop Agrivoltaics pilot projects in India. The overarching goal of the project was to demonstrate the economic and ecological benefits of Agrivoltaics in India. This shall be achieved by gathering evidence and data on agriculture production under an Agrivoltaics pilot system as well as quantifying the enhancement in photovoltaic production when co-located with agriculture.

The Government of India has set an ambitious target of achieving 100 GW of solar capacity in the year 2022 of which 40 GW is expected to be solar rooftop installations while the largest share is designated for utility-scale ground-mounted PV. Considering a further increase of land scarcity in India, creative solutions must be found to resolve land requirements of both, the solar and the agricultural sector. Countries with similar land scarcity issues like Japan have launched Agrivoltaics projects in the early 2000s to improve their Land Equivalent Ratio (LER). Finally, a reduction in CO₂ by reducing local emissions from conventional power plants benefits the whole country. The current scale of Agrivoltaics in India is estimated at about 36MW installed capacity.

As a part of the DeveloPPP program two Agrivoltaics projects have been installed in Manwath of scale 1.4 MW and in Nashik of scale 0.5 MW. The first one explored several crops in different crop cycles ranging over a period of 2.5 years and the later focusing on viticulture primarily. Both the projects have followed distinguished approaches in achieving the overarching project objectives listed as KPIs of the project. Both the pilots have been conceptualised, designed, installed, operated and researched by Sunseed and GIZ with various other stakeholders.



Project objectives

- The primary goal of the project is to enhance the knowledge of public and private stakeholders within the renewable energy ecosystem (e.g., developers, investors, government authorities, agricultural industry stakeholders, farmers, etc.) regarding the economic and ecological benefits of agrivoltaics systems in India, focusing on the following aspects: The land productivity in the pilot location has increased to greater than 150% through double use of land. The target for this project is a Land Equivalent Ratio (LER) greater than 150% or 50% increase in land productivity. Typically, Agrivoltaics projects have a LER ranging from 140-160%.
- More than 1000 farmers, 250 students and 30 solar project developers and investors are made aware/trained on the innovative concept of Agrivoltaics technology and farming.
 - Farmer training: training provided to 1000 farmers on operational best practices of Agrivoltaics.
 - Student training: training conducted for 250 students on the theoretical and design aspects of Agrivoltaics.
 - Solar PV Developer knowledge sessions: knowledge sessions conducted to 30 developers on the economics and regulatory aspects of Agrivoltaics.
- 4 policy & legal framework recommendations for favorable framework conditions and business model proposals for implementation of Agrivoltaics in India have been presented to the Government of India.
- 5 investors (i.e. developers, government institutions) are committed to replicating Agrivoltaics practices from these pilots)



Water savings of
40%
per unit of crop
yield have been
demonstrated through
the both pilot sites
of this project. 40%
reduction on water
usage per unit of
crop yield in the
Agrivoltaics shade
house.



Project Overview with approach and methodology

This section is a detailed overview on both projects in Manwath and Nashik in the three-year duration of phase 1 DPPP project.



Case study of APV pilot - 1.4 MW in Manwath, Parbhani

Background

The project site is a part of a larger 50 MW solar plant located in Manwath in Parbhani district of Marathwada region in Maharashtra. The project showcases 48.6 MW ground mounted PV, whereas the remaining 1.4 MW explores benefits of co-location of agriculture and photovoltaics in 4.8 acres of land. The project aims at quantifying and qualifying both the solar yield and crop yield in comparison to the reference field. Several advanced instruments including albedometer, photosynthesis meter, PAR sensor, PCA, weather stations have been used to assess various parameters for a comparative study between areas under the panels and open reference areas. Based on data collected over time from multiple sources, a crop growth model has been developed to simulate real-time scenarios, enabling farming communities to visually understand the benefits of Agrivoltaics.

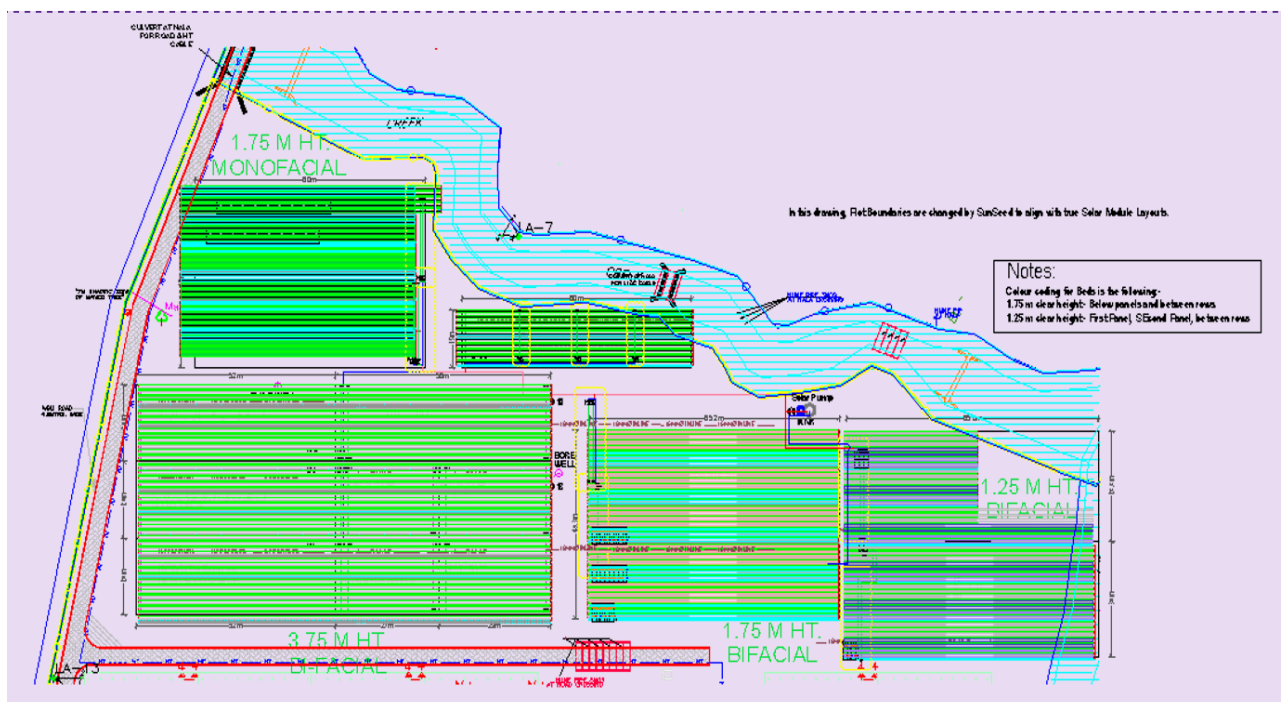
Figure 1: top view of ground mounted PV



Figure 2: Aerial view of ground mounted PV



Figure 3: Blueprint of 50MW site in Parbani





2. Approach and prefeasibility study



The site was initially visited by Agricultural experts from Sahyadri farms and solar experts from Renew, along with Sunseed APV and GIZ for a preliminary analysis. The land chosen to install the agrivoltaics is close to the water stream flowing and a well that is in the vicinity of the set up. As this region in general is water stressed, the availability of water has been taken as the top most priority for selecting the particular land area.

The three major steps have been considered here are as below:

- Collecting soil samples for a test
- Collecting water samples for a test
- Deciding the design of the installation based on light & microclimate requirements of local crops for suitable crop growth & ease of farm operations.

From the initial reports it is seen that the 3.75m elevated area has a pH of more than 8. The pH levels have been considerably brought down after soil preparation of 2 months with several hindrances as the soil was lumpy and hard to start the farm operations. The soil quality was improved by the soil mixing process with organic manures and improving the granularity.

After 6 weeks of preparation another soil test had been conducted, to further check the pH level to suit the different crops being cultivated. The 3.75m elevated has a pH of 7.91, the 1.75m elevated area has 7.95 and the last area of 1.25m has 7.64 subsequently.



3. Agrivoltaics Systems - Technology Innovation and Design



3.1 Description of different sections with specifications

The project as shown in the table below is also divided into five sections. The first section is of 3.75 m elevation with 1P configuration and bifacial panels with shadenet enclosed around the boundaries of this section. The following two sections are elevated at a height of 1.75 m and 2P configuration one mounted with monofacial panels and the other with bifacial panels. The last section is 1.25 m elevated using bifacial panels.

S. No	Elevation of the structure	Area	Configuration	Pitch	Shade-net
1	3.75 m	1.6 acre	1P - Bifacial	5.65 m	yes
2	1.75 m	0.8 acre	2P - Bifacial	10 m	no
3	1.75 m	0.8 acre	2P - Monofacial	7.5 m	no
4	1.25 m	0.8 acre	2P - Bifacial	10 m	no
5	Open field for reference	0.8 acre	No panels		no



3.2 Differences in design and reasoning

- Various heights, shade net (reasoning with albedo effect)
- Special considerations

The 3.75m section is chosen to allow for integration with net house cultivation of trellising or tall crops that are typically grown in a protected environment along with some level of climate control. This section has retractable aluminet thermal screens & foggers to help control temperature & humidity. This setup involves significant increase in structural costs & along with agriculture infrastructure costs. In some growing seasons this setup was also used without the thermal screens and foggers as an open field agrivoltaics setup growing crops typically grown in open fields.

The 1.25m bifacial section in 2P configuration is set up to demonstrate what crops can be grown with no additional structural costs as 1.25m is the ideal height for bifacial ground mount projects.

The 1.75m section is set up to demonstrate the crops that can be cultivated with a marginal increase in structure costs with 1.75m elevation for better human and machinery access as well as better space for crop growth as compared to 1.25m.

3.2.1 Season wise crops and research conducted

Each section has been experimented with almost 12 variety of crops in the first season and 8 crops in the next two seasons subsequently which will be discussed in detail in the crop section ([hyperlink the crop section here](#))

3.2 Season wise data (Period of season and strategy if any)

3.2.1 Season 1:

Date of planting: 1st Feb 2023

Date of Harvest: 31st May 2023

Land Preparation:

To prepare the soil, ploughing was done to a depth of 30-35 cm using the 10" plough attached to the mini tractor. After ploughing was completed the rotavator was used to break and churn the soil to provide aeration and make the soil granular for bed creation.

Figure 4 & 5: Concrete removal & site cleaning



Concrete removal & site cleaning

There was a lot of spilled concrete on the soil near the foundations and at other places as well. The concrete had hardened and embedded itself with the soil. Separately, there were many rocks as well. So, labor was engaged to clear the whole site off concrete and rocks using manual tools. There was a certain patch in the 1.25m bifacial section that had huge rocks deeply embedded in the soil. An excavator was needed to remove those rocks. The experience suggests that for Agrivoltaics projects concrete should either be avoided or should be taken care of not spilling it on the land.

Figure 6 : Excavator removing rocks



Water harvesting & drainage system:

Once the ploughing and rotavating was done, the land needed to be levelled and graded for two reasons: first, water does not accumulate in the farm during the rainy season, and second, that the rain water could be harvested via the natural drains. To achieve this, slopes were created by them in each project section such that the water would flow to the natural drains on the periphery of the project site via trenches. A check dam was constructed at the end of the drain so that the rain water can be harvested.

Figure 7 : Levelling of soil



Figure 8: Irrigation & Electricals installation



Irrigation system & electricals installation:

The drip irrigation & fertigation system and solar pump was supplied and installed by Jain Irrigation, but some activities part of the installation process were apparently not in Jain Irrigation's scope and new requirements were created as the installation progressed. The supply and installation of the new requirements as well as the installation of items not in Jain Irrigation's scope were done by Jai Hind Agro Services.

The irrigation systems & electrical installations included the following:

Digging of irrigation trenches for laying the pipe network using some of the trenching was done via an excavator but some of the trenches in closer vicinity to the solar structures had to be done manually. The trenches were all refilled with soil after the irrigation pipes were laid by Jain Irrigation. Foundations for the solar pump and concrete platform for the fertigation system

It was discovered that the water in the well was not getting replenished quick enough to be used for consistent irrigation. Therefore, a borewell pump was purchased and installed to replenish the water in the well via the bore well. An electricity connection was done from the ReNew control room to the GIZ office and to the borewell pump mentioned above. This included supply and installation of underground wiring, meters, MCB, etc.

Figure 9: Installation of pipes for borewell



Figure 10: Installation of borewell



Bed preparation:

After the leveling and grading was completed the rotavator was used again to aerate the soil which had become a bit compact due to the tractor movement for the leveling. In all the project sections trenches of 600mm width were made below the lower edge of the panels so that there is adequate space for placing ladders for maintenance and also so that all the rain water falling on the panels falls on the trenches and does not damage the crops. The slope then ensures that the water flows out of the cultivation area.

Figure 11: Rotavator being used to aerate the soil



After that the beds were created with a 4.5 ft center to center distance using a ridger attached to the tractor. The height of the beds is 8 inches. Preparing the beds below the panels has been challenging but was made successful via the mini tractor which could move below the panels with the tractor driver having to often bend his body to avoid collision with the structures. It was always ensured that everyone working in the farm in any capacity is wearing the required safety equipment including gum boots, helmets, and glow jackets.

Figure 12: Bed preparation



Plantation:

The plantation of the seedlings was done between the 1st to 10th February 2023 as shown in the table below. The 3.75 elevation shadehouse section was divided into five sections for cherry tomato, green capsicum, cucumber, dutch roses and chrysanthemum. The 1.75 elevated section with monofacial had basil under the panels and marigold in the interspace. The 1.75 elevated section with bifacial panels was cultivated with water melons and finally the 1.25 elevated section had spinach and muskmelon. All the mentioned crops were also grown in the control plot 1 and 2.

Section	Division	Area (m2)	Bed Length (m)	No of Beds	Rows/ Bed	Spacing (cm)	Total Crop Row (m)	Crop Name
3.75m elevation shadehouse bifacial 1P	Shadenet -1b	750	50	10.5	1	30	525	Tomato
	Shadenet -2	1000	50	14	1	25	700	Green Capsicum
	Shadenet -3	800	50	12	1	30	600	Cucumber
	Shadenet -5b	500	25	14	2	20	700	Dutch Roses
	Shadenet -6a	500	25	14	2	25	700	Chrysanthemum
1.75m elevation Monofacial 2P	Below Panel		1152		2	30	2304	Basil
	Between Rows		1024		1	30	1024	Marigold
1.75m elevation Bifacial 2P	Below Panel		885		0.6	30	506	Watermelons
	Between Rows		1285		0.6	30	734	Watermelons
1.25m elevation	Below Panel	150					150	Spinach
	Between Rows	975	650		1	30	650	Muskmelon
Control Plot 1 & 2	Control -1A		218	16	1	30	218	Cucumber
	Control -1B		232	16	1	25	232	Green Capsicum
	Control -1C		191	16	1	30	191	Tomato
	Control -2B		168	4	2	20	336	Dutch Roses
	Control -2C		272	6	2	25	544	Chrysanthemum

Harvest of Season 1:

The harvest was done between 1st Feb 2023 to 31st May 2023

The yields of the crops are shown below

S. No	Crop	Agrivoltaics Section	Agrivoltaics Yield (Kg)	No of Plants	Yield/ plant	Open Field Yield (Kg)	No of Plants	Yield/plant
1	Capsicum	3.75m	2008	2800	0.72	372	928	0.4
2	Cucumber	3.75m	3356	2000	1.68	1320	725	1.82
3	Tomato	3.75m	2510	2330	1.08	596	637	0.94
4	Chrysanthemum	3.75m	260	2800	0.09	144	2176	0.07
5	Roses	3.75m	71.2	3500	0.02	27	1680	0.016
6	Marigold	1.75m	1350	3413	0.4	225	550	0.41
7	Basil	monofacial	6912	7680	0.9	2419.2	2304	1.05
8	Watermelons	1.75m bifacial	5335	4134	1.29	1649	1010	1.63
9	Muskmelons	1.25m bifacial	2500	3247	0.77	929.2	1010	0.92

The relative yields of the Agrivoltaics sections are compared with the open field control yields without any solar panels. As you can see the relative yields are significantly higher than open field for all the crops in the 3.75m section but are less than open field for crops grown in the 1.75m sections. Marigold yields are the same and that's because it was grown in the interspace only. The yields in the 3.75m section are higher because of the climate protection achieved from the panels and foggers and at the same time the high height and 1P configuration ensured enough light was available to the crops. In the 1.75m 2P sections there were big patches under the panels which were always under shade and therefore had reduced photosynthesis which could not be overcome by the reduced temperatures.

However, the absolute yields in both sections were not good as severe pest attacks happened that could not be controlled and the crops had to be removed. Different crops were in different phases at that time and some had many cycles of harvesting yet to happen. There were two primary reasons for the pest attack. First, both flowers and vegetables were being grown together which attracts a lot of pests. Second, crop cultivation was being done on that land after 2-3 years which also attracted a lot of pests. Also, all the crops being grown were very pest susceptible and needed expert growers. It seems that the expertise required for growing such crops was also not available at the farm. However, the gain in yields wrt to open field till the harvest latest is significant and provides confidence in technical viability of Agrivoltaics if the light & microclimate are managed well.

Figure 13: Collecting the farm produce



Figure 14: Horticulture production under the panel



Figure 15: Overhead PV



Figure 16: *Momordica charantia* production under the panel



Figure 17: Closer view of *Momordica charantia*



Figure 18: Aerial view of under the panel crop production



Figure 19: Tomato production under the PV panel



Figure 20: Capsicum produce of the farm



Figure 21: Total tomato production



3.2.2 Season 2: 1st July 2023 to 15th December 2023

In the second season VNMKV Parbhani along with GIZ and Sunseed had extensive discussions on the experiences so far and planned the crops for the next season. Similar crops were considered for the third season as well. The below sections discuss the details of each of the crops:

S.No	Crop	Area
1	Soya	Shadehouse and interspace
2	Pigeon Pea	Shadehouse and interspace
3	Banana	Shade house
4	Turmeric	Shadehouse and interspace
5	Cabbage	Shadehouse and interspace
6	Bittergourd	Shade house
7	Ginger	Shadehouse and interspace
8	Onion	Shadehouse and interspace
9	Coriander	In smaller sections
10	Fenugreek	In smaller sections

Soybean

Soybean was planted in the following sections in the 2023 kharif season

T1: below panels in 3.75m elevation section

T2: between panels in 3.75m elevation section

T3: below panels in 1.75m (bifacial panels) section

T4: between panels in 1.75m (bifacial panels) section

T5: open field with no solar panels

Date of planting: 04 July 2023

Date of harvest: 12 Dec 2023

A pre-selected random sample of 20 plants from each section were considered for the growth analysis and yield calculation. The yields had been presented on a per plant and per hectare basis. The actual yields of each of the full sections may have been different from the sample selected.

- The growth and yield of soybean was significantly lower in the sections below the solar panels. This result aligns with the reduced availability of light for a relatively higher light requiring crop.
- The harvest index is similar on all sections and is overall within the range for Soybean cultivation. The shaded sections 1 & 3 have grown longer.
- This elongation is an attempt at adaptation of crops as they search for more light if they are not able to get enough light. Soybean in T3 took more days for flower initiation as compared to T2 & T4 followed by T1. It cannot be concluded from this if flower initiation was affected by the shade
- The leaf chlorophyll content of sections under shade T1 & T3 is higher than the sections receiving more light. Chlorophyll indicates photosynthetic capacity. This could also be a plant attempt at adaptation as it tries to compensate for lower light.

Growth and yield parameters of Soybean as influenced by APV conditions

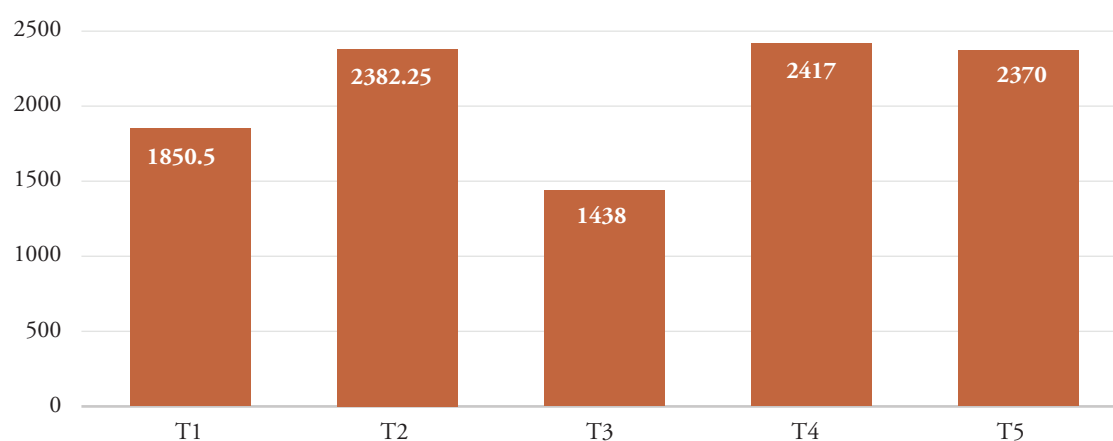
Treatments	Plant height(cm) 90 DAS	Dry matter /plant (g)	Seed yield/ plant (g)	SPAD Chlorophyll
T1:Soybean below panel overhead 3.75m	118.37	10.61	3.46	49.5
T2: Soybean between interspaces of panel overhead 3.75m	107.45	12.65	5.57	47.54
T3:Soybean below panel overhead 1.75m	112.62	8.32	4.39	50.29
T4: Soybean between interspaces of panel overhead 1.75m	102.56	13.21	5.68	48.34
T5: Open space cultivation	104.26	13.39	6.04	48.87
S.Em.±	2.40	0.24	0.11	
C.D. at 5 %	7.81	0.83	0.40	

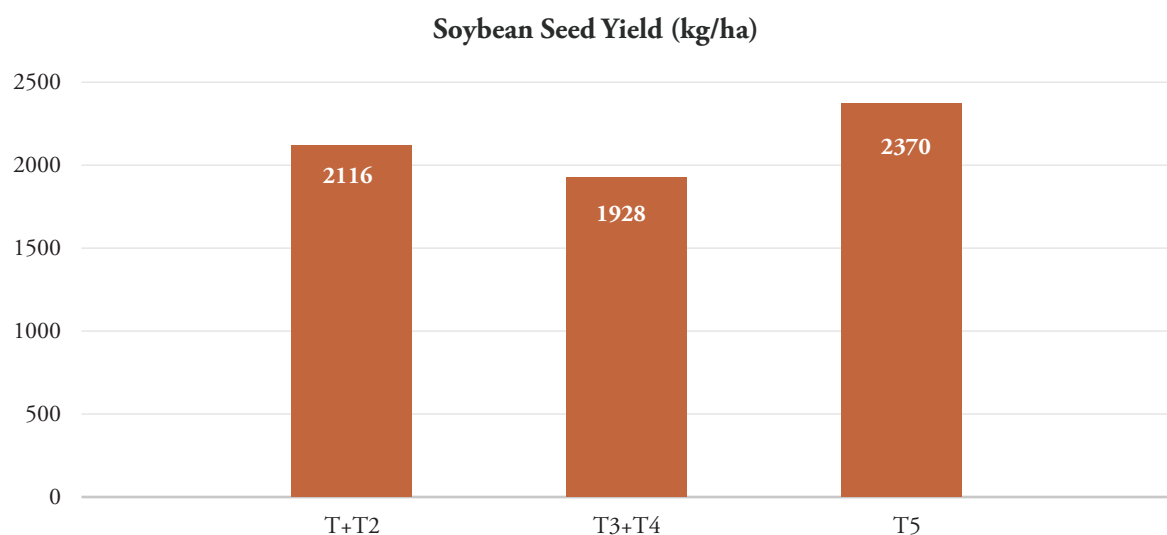
The **harvest index (HI)** of soybeans is the ratio of grain yield (economic yield) to total above-ground biomass (biological yield). It is expressed as: Seed yield/Biological yield. For soybeans, the harvest index typically ranges between **0.30 and 0.45**, depending on the variety, environmental conditions, and management practices.

Soybean seed, straw and biological yield as influenced by APV conditions

Treatments	Soybean Seed Yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)
T ₁ : Soybean below panel overhead 3.75m	1850.50	2651.00	4501.50	41.11
T ₂ : Soybean between interspace of panel overhead 3.75m	2382.25	3192.25	5474.50	43.52
T ₃ : Soybean below panel overhead 1.75m	1438.00	2142.25	3580.25	40.16
T ₄ : Soybean between interspace of panel overhead 1.75m	2417.00	3362.75	5779.75	41.82
T ₅ : Open space cultivation	2370.00	3424.25	5898.25	42.28
S.Em.±	46.72	63.13	109.32	
C.D. at 5 %	144.16	194.57	336.92	

Soybean Seed Yield (kg/ha)





Pigeon pea

Pigeon Pea was planted in the following sections in the 2023 kharif season

T1: below panels in 3.75m elevation section

T2: between panels in 3.75m elevation section

T3: below panels in 1.75m (monofacial panels) section

T4: between panels in 1.75m (monofacial panels) section

T5: open field with no solar panels

Date of planting: July 2023

Date of harvest: Nov 2023

A pre-selected random sample of 20 plants from each section was considered for the growth analysis and yield calculation. The yields had been presented on a per plant and per hectare basis. The actual yields of each of the full sections may have been different from the sample selected. The growth and yield of Pigeon Pea was significantly lower in the sections below the solar panels. This was expected as Pigeon Pea requires a significant amount of light for its growth.

Seed, straw and biological yield of Pigeon pea as influenced by APV conditions

Treatments	Pigeon pea seed yield (kg/ha)	Straw yield(kg/ha)	Biological yield(kg/ha)	HI(%)
T ₁ : below panel with overhead 3.75m	1325.25	2850	4175.25	31.74
T ₂ : between interspace of panel with overhead 3.75m	1892.45	3642	5534.45	34.18
T ₃ : below monofacial panel with overhead 1.75m	905	2018	2922.75	30.90
T ₄ : between interspace of monofacial panel with overhead 1.75m	1726.23	3250	4876.23	35.40
T ₅ : Open space cultivation	1902	3540	5467.5	35.25
S.Em.±	67.06	61.35	101.16	
C.D. at 5 %	206.65	189.05	311.74	

Growth & yield attributes of Pigeon pea as influenced by APV conditions

Treatments	Dry matter accumulation /pt(g) (at harvest)	Plant height (cm) 90 DAS	branches/pt	No. of Leaves/pt
T1: below panel with overhead 3.75m	59.75	193.5	13.25	312.33
T2: between interspace of panel with overhead 3.75m	74.00	177.75	10.50	285
T3: below monofacial panel with overhead 1.75m	41.40	180.25	9.50	215.33
T4: between interspace of monofacial panel with overhead 1.75m	72.59	174.25	9.75	201.33
T5: Open space cultivation	77.00	176.84	10.44	289.12
S.Em.±	1.60	4.76	0.942	13.60
C.D. at 5 %	4.92	15.20	3.01	43.51

Figure22: Production of coriander seeds



Figure 23: Plantation in between the panels



Turmeric

Turmeric was planted in the following sections in the 2023 kharif season

T1: 3.75m elevation section without making any distinction of below or between panels

T5: below panels in 1.75m (bifacial panels) section

T6: between panels in 1.75m (bifacial panels) section

T7: open field with no solar panels

Date of planting: July 2023

Date of harvest: Nov 2023

Sections	Chlorophyll content (Spad units)	Crop duration (Days)	Rhizome yield (kg/plant)	Rhizome yield (MT/acre)	Dry Rhizome yield (MT/acre)
T1	35.3	283	0.615	15.40	3.13
T2	31.4	304	0.495	12.40	2.21
T3	28.8	272	0.400	10.02	2.04

The growth and yield of turmeric was significantly higher in the 3.75m sections lower in the sections below the solar panels. This result aligns with the reduced availability of light for a relatively higher light requiring crop.

Figure 24: Plantation of turmeric under the panels



Figure 25: Production of turmeric



Figure 26: Below the panel production



Figure 27: Banana production under the panel



Banana

Figure 28: Front view of banana production under the panel



Section	No. of days to flowering (days)	Crop duration (days)	No. of hands per bunch	Yield per Plant (kg)	Lodging (%)	% loss in yield due to lodging	Yield MT/acre
T1	280.6	401.2	10.42	17.96	0.6	0.63	29.1
T2	271.2	390.2	10.33	17.72	0.8	0.83	28.7
T3	X246.67	366	11.06	17.1	18.2	17.66	22.8

Figure 29: View along the panel of banana plant



Figure 30: Fresh look of raw banana produced under the panel



Figure 31: Total production of banana



Cabbage

Sections	Head diameter (cm)	Head weight (yield/ plant) kg	Days required for harvesting	Yield (MT/acre)
T1	13.52	1.33	89.5	21280
T2	12.67	1.06	89.67	16960
T3	11.04	0.85	97.33	13600
T4	12.72	1.09	93.17	17440
T5	13.45	1.24	91.53	19840
T6	12.82	1.22	90.67	19520
T7	11.79	1.03	89.5	16480

Figure 32: View of freshly grown cabbages with pv on the site



Figure 34: Side view of cabbages with pv



Ginger

Sections	Plant height (cm)	Days to maturity	Shoot and leaves biomass (g)	No. of primary rhizomes	Length of primary rhizomes (cm)	Rhizome yield plant-1 (g)	Rhizome yield /acre (MT)
T1	70.69	288.62	870.6	7.48	6.43	313.53	7.8
T2	50.99	250.92	738.5	5.63	5.45	252.66	6.3
T3	44.92	254.74	624.8	4.29	3.94	230.4	5.8
T4	43.92	240.24	654.8	5.29	4.04	198.8	5.0
T5	72.69	296.22	898.6	8.86	8.23	344.13	8.6
T6	68.69	261.62	840.6	6.48	5.93	283.24	7.1
T7	38.2	220.82	560.4	3.69	3.54	190.8	4.8

3.3 Observations

3.3.1 End of first season

- Light distribution within the 3.75m shade house in line with predictions with light simulations. Light distribution is not homogeneous but still enough below the panels for optimal photosynthesis. The shade net helps in diffusing the light. Tomato, capsicum growth is observed to be better in rows under the panels than those between the rows.
- As can be observed the relative yields of the Agrivoltaics sections with respect to the open field control sections are mixed - mostly higher for crops grown in the 3.75m elevation shadehouse, and a bit lower for the crops in the lower elevation sections of 1.75m and 1.25m. This was mostly on expected lines based on initial analysis.
- The absolute yields for almost all the crops has been quite less than expected because they had a massive pest attack in the beginning of May which they tried hard to control with varying degrees of success for the different crops. However, the pest attack eventually became uncontrollable so they had to abort operations and remove all crops by the end of May. Therefore, most crops had significantly shortened season yields. This happened across the farm in the APV sections as well as the open field control sections.
- The quality of the produce was very good till the crops survived in all sections:
 - Roses & Chrysanthemums were surely bigger in the Agrivoltaics sections as compared to those in the control environment.
 - The Tomatoes and Capsicum in open field sections saw scalding of the fruit while the ones in APV sections were fine
- In retrospect, the pest attack was heavy because of the presence of both flowers & vegetable crops in such close vicinity - something that professional practitioners never do. Flowers attracted pests which affected the vegetables which led to more pests which then affected the flowers as well. In season 2 they are not growing any flowers.
- The light distribution below the panels in 1.25m & 1.75m 2P configuration is very low. The crops did well at about 80% yield, but the light was low for them – lankiness of the plant and thinning of leaves was observed which is a symptom of search for light and reduced photosynthetic capacity.

3.3.2 End of second season

The first season had a generic approach in observation and analysis. Whereas, the second season was concluded with crop wise observation and analysis.

4. Research and Analysis



Overview of Instrumentation and procurement at both sites

S.No	Name of the instrument	No of devices	Research and purpose of the device
1.	Albedometer	4	An albedometer is an instrument used to measure the albedo (reflecting radiation) of a surface. An albedometer is mostly used to measure the reflectance of earth's surface. Often it consists of two pyranometers: one facing up towards the sky and one facing down towards the surface.
2.	Photosynthesis meter	2	The CI-340 Handheld Photosynthesis System is a portable, single-handed tool that measures photosynthesis, respiration, transpiration, stomatal conductance, PAR and internal CO₂. The LI-6800 Portable Photosynthesis System simultaneously measures photosynthetic gas exchange and chlorophyll <i>a</i> fluorescence over the same area in plants and aquatic samples, revealing additional insights into photobiology. Highly extendable, it is capable of measuring gas exchange from soil, insects, and many other sample types for countless experiments.
3	Weather stations	12	Weather stations use a variety of instruments and sensors to collect data about atmospheric conditions, including temperature, humidity, air pressure, wind speed and direction, and precipitation. This data is crucial for weather forecasting, climate monitoring, and various applications where understanding weather patterns is essential for crop conditions.
4	PAR sensor	1	With the PAR sensor (photosynthetic active radiation), you can measure light to create the right balance in your photosynthesis process. This results in a higher quality and quantity of your crop.
5	Plant canopy analyser	1	The plant canopy analyzer system uses field measurements of Photosynthetically Active Radiation (PAR) in crop canopies to provide valuable information about Leaf Area Index (LAI) and biomass production.
6	Spectroradiometer	1	Spectroradiometer (APOGEE PS 300) measures solar radiation spectrally resolved , it includes input optics and calibrations that allow the spectrometer to take calibrated readings of power, intensity, and irradiance/radiance in optical units or lux/nm, lumens/nm, watts/nm, W/cm ² /sr/nm etc.
7	Surface panel temperature sensors	12	Surface panel temperature sensor device used to monitor the surface temperature of solar panels, a key component in improving the efficiency and reliability of solar power systems, which can help to optimize the performance and extend the service life of solar panels.
8	Infrared radiometer	2	Infrared radiometers are used to measure the infrared radiation emitted by an object, which is then used to determine its temperature without physical contact.
9	Temperature loggers	2	Temperature loggers monitor temperature conditions, and some versions can also measure the relative humidity.
10	Drip irrigation system	1	Drip irrigation systems are used to efficiently water plants by delivering water directly to the root zone through a network of tubes and emitters. This method minimizes water waste through evaporation and runoff, reduces weed growth, and allows for the precise application of water and nutrients. Such a system is an economically viable system to deliver a measured quantity of water at the root zone of each plant at regular intervals. This is to ensure that the plants do not suffer from stress or strain of less and over watering.
11	Solar water pump	1	Solar-powered water pumps work by converting the sun's rays to electricity that will operate the water pump. It uses solar panels to collect the photons (units of light) from sunlight, producing the direct current (DC) that provides the energy for the motor to pump water out from its source. An inverter is used if the pump motor needs alternating current (AC) rather than DC.

S.No	Name of the instrument	No of devices	Research and purpose of the device
12	Shade net	1	The most significant role of Shade nets is shielding crops from intense sunlight and heat, which can cause wilting, sunburn, and reduced productivity. By filtering sunlight and regulating temperature, shade nets create an optimal growing environment, supporting healthy crop growth and higher yields. In this case an aluminet shade net was used ,placed 0.5 m below panels, also supported in the albedo effect due to use of bifacial panels.
13	One Plus Phone	1	Pictures to be used for crop growth modelling
14	Pix4D	Software	Fast in-field drone mapping & on-demand satellite data included.PDF Reports for record keeping and Share to Cloud for phone based scouting. Analyze crop health with vegetation indices and Magic Tool for better crop management

The instruments were used to measure a lot of data that has resulted in much deeper understanding of changed light & microclimate under the different sections and their effect on photosynthesis and other physiological aspects of plant growth. The analysis will result in more optimized designs & cropping strategies to be developed.

3.75m elevation Shade house in 1P Configuration

- Light distribution within the shade house in line with predictions of light simulations with Helios. Light distribution is not homogeneous but still enough below the panels for optimal photosynthesis.
- Inadequate air flow inside the shade net – natural ventilation not enough as height may be insufficient. They are exploring installation of air circulation fans to resolve this. Additionally, they are considering changing the closed weave net with an open weave net.
- Even though the radiation was 50% as compared to ambient, the air temperature did not reduce in the shade net and was almost the same. This is probably due to the partial greenhouse effect of the close weave shade net.
- Even though the air temperature was around the same, the lesser direct radiation caused the leaf temperatures to be 3-7 degrees lower in the shade house thereby enhancing the photosynthesis rates.
- Use of foggers reduced air temperatures by 4-5 degrees inside the shade house but that requires very frequent small duration (10s every 1-2 minutes) fogging which they were not able to implement consistently. They are looking to add IoT based automated fogging to make this possible.



5. Techno-economic analysis

5.1 Energy generation insights:

For the period of 2 years 2023 & 2024, the AgriPV plant, comprising five inverters (200kW each) across four distinct PV configurations, recorded a cumulative energy generation of 4.53 GWh and a total specific generation of 16,848 kWh/kW. The system configuration includes one inverter connected to a **1.75m elevation (ground clearance) monofacial array**, two inverters linked to **3.75m elevation bifacial arrays**, one inverter assigned to a **1.75m elevation bifacial array**, and one inverter associated with a **1.25m elevation bifacial array configuration**. All sections had a 40% panel ground coverage ratio. The 3.75m elevation system had a 1P configuration while all the others had a 2P configuration.



Figure 1 Specific Energy Generation for years 2023, 2024 for different APV configurations

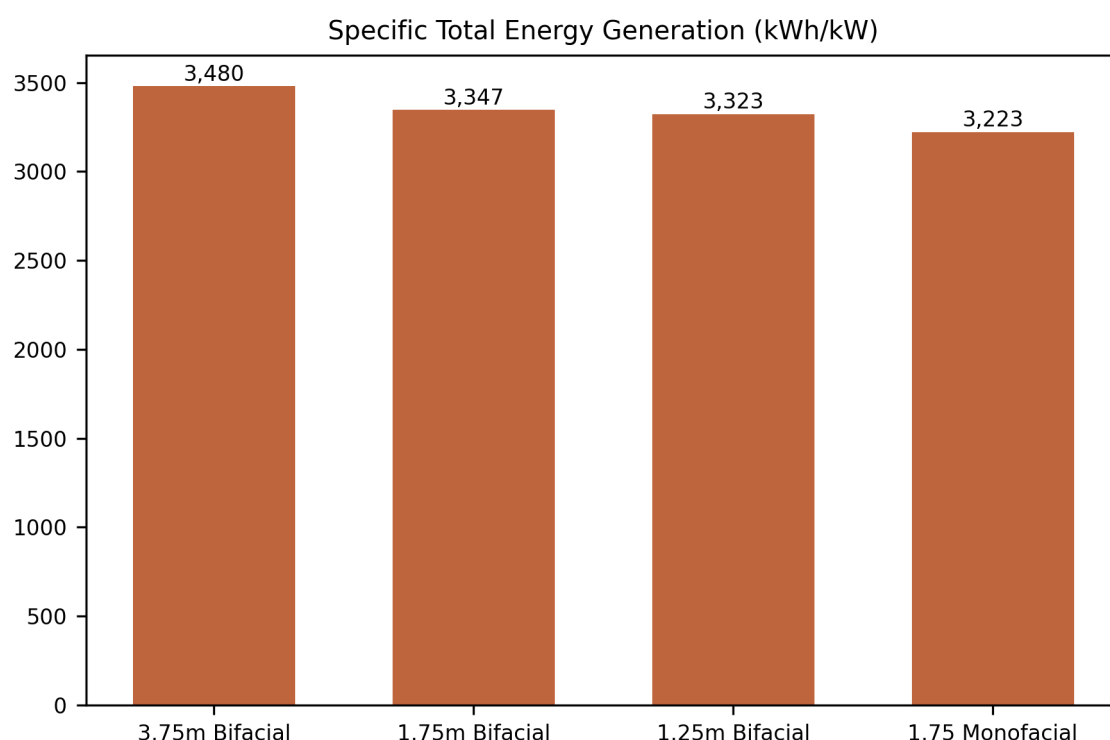


Table 1 Percentage Increase/Decrease Compared to 1.75 MW Monofacial

Configuration	Inverter No	Generation (kWh/kW)		% Difference from 1.75 Monofacial		Total
		Year 1	Year 2	Year 1	Year 2	
3.75 MW Bifacial	2	1766	1714	9.8%	6.2%	8.0%
	3	1764	1712	9.6%	6.1%	7.8%
1.75 MW Bifacial	4	1691	1656	5.1%	2.6%	3.8%
1.25 MW Bifacial	5	1672	1650	3.9%	2.2%	3.1%

The comparative analysis of inverter-specific generation data reveals a clear performance advantage of bifacial photovoltaic configurations over the monofacial setup. Taking the **1.75 m monofacial configuration (Inverter 01)** as the baseline, the **3.75 m bifacial systems (Inverters 02 and 03)** show the highest gain in yield, with an approximate **8% increase in specific generation**, demonstrating the combined effect of increased module height, a slightly higher albedo, and 1P configuration on the bifacial gain. The **1.75 m bifacial setup (Inverter 04)**, which matches the baseline in height but differs in module type, registers a **3.85% improvement**, indicating the standalone benefit of bifacial technology. Meanwhile, the **1.25 m bifacial system (Inverter 05)**, despite having the shortest height, still achieves a **3.1% increase** over the monofacial counterpart.

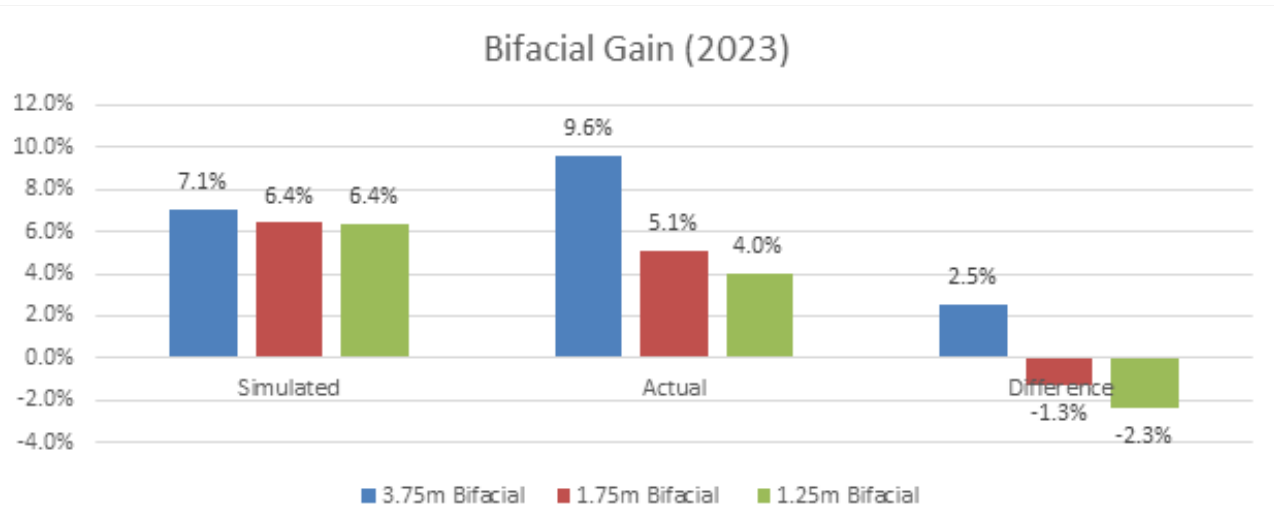
As can be observed, there is a significant difference between the bifacial gain in year 1 Vs year 2 specially in the 3.75m section. This could primarily be attributed to the presence of reflective mulches on the crop beds on all sections and the use of 20% reflective shade nets in 3.75m sections which were sometimes drawn and sometimes retracted as per the crop needs. This brings to light how synergies can be created between crop cultivation & solar generation. Infrastructure that is primarily used for agriculture can help increase solar generation. The shade nets were drawn during peak day time in the summer months to prevent heat stress to the crops and at the same time provided 4-5 % extra generation in these summer months. As per discussion with SunSeed, they are developing crop specific algorithms that would alter the panel tracking and govern automated shade net retraction to maximise the crop + solar revenues. These algorithms would be based on a digital twin strategy based on IoT sensors providing live data that is then used by SunSeed's simulation models to provide actionable input for the trackers & shade nets. The simulation models are discussed in another chapter of this report.

The effect of increased energy generation may have been more pronounced due to the integration of mulching papers underneath the panels to aid the agricultural activities. The 3.75m installations with the mulching papers demonstrate that structural and agricultural investment in elevated mounting may pay dividends through improved performance. The height advantage is most pronounced during summer months, suggesting better heat dissipation, increased gain due to reflection caused by mulching papers and reduced ground interference.

Bifacial gain due to mulching papers:

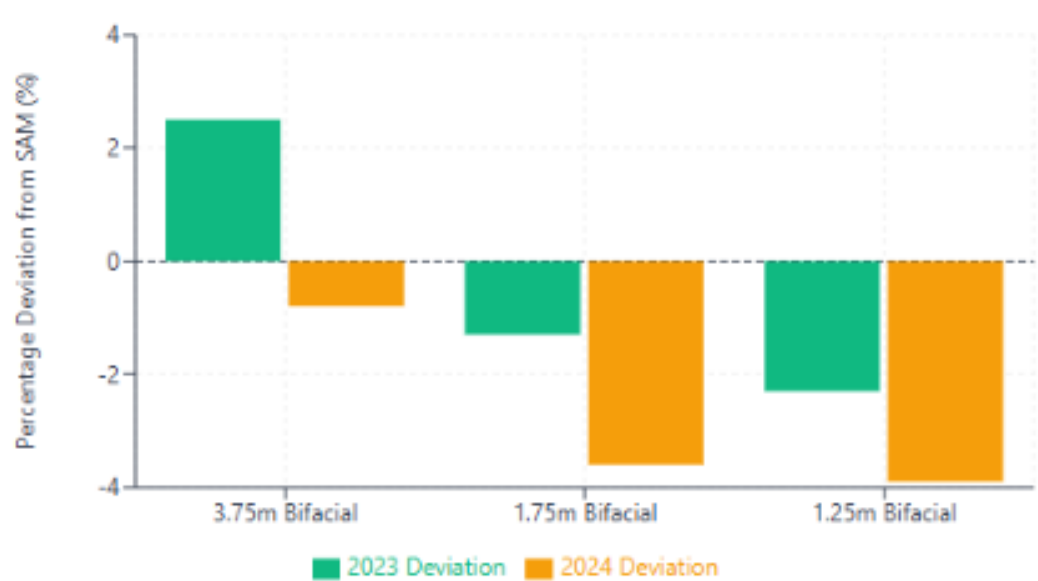
This analysis compares bifacial photovoltaic performance predictions from NREL’s System Advisor Model (SAM) with actual field measurements from an AgriPV installation over two years (2023-2024). Bifacial gain is calculated as the percentage increase in energy yield compared to equivalent monofacial modules, accounting for rear-side irradiance contribution. The SAM model utilised standard meteorological data and fixed albedo assumptions, while actual measurements were collected from inverter-level production data across multiple measurement points.

Figure 2 Simulated vs actual bifacial gain values



The higher mounting (3.75m) demonstrates superior actual performance and smaller prediction errors compared to the simulated values due to the additional gain because of the mulching papers. The lower mounting heights are more susceptible to soiling, dust accumulation, and ground-level environmental effects, reducing bifacial performance.

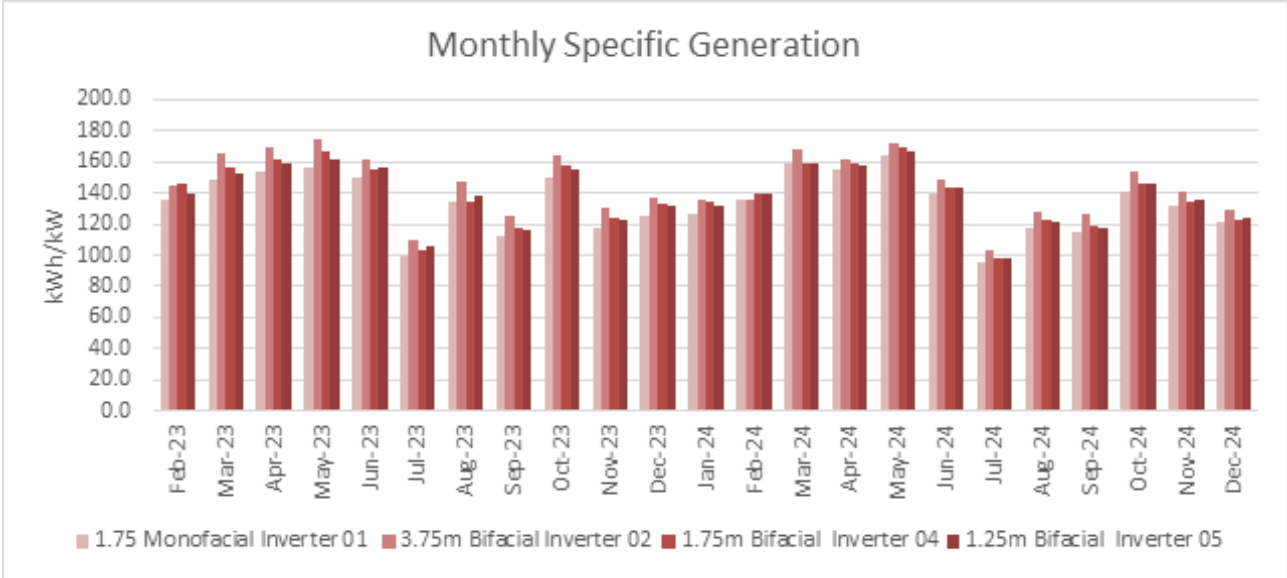
Figure 3 Average annual percentage deviation from SAM predictions



The ~8% efficiency improvement from bifacial technology translates to approximately **128 additional kWh/kW annually**. Over a 25-year system lifespan, this represents 3200 kWh/kW of additional generation, providing substantial economic value that likely justifies higher initial investment costs.

Height plays a crucial role in performance optimization. The 3.75m installations consistently outperform lower heights by ~5%. This suggests that elevated installations are able to capture substantially more radiation and may have also benefited from improved air circulation.

Figure 4 Monthly Specific Generation for the AgriPV Configurations



Among the operational months, **May 2024** witnessed the highest generation, while **July 2024** registered the lowest, contingent on the influence of seasonal irradiance. Seasonal variations are pronounced, with July month showing dramatic drops in generation across all configurations as this is the peak of the monsoon in this region. The highest generation is in the peak of the summer season in May which is consistent with the radiation data.

The CUF (Capacity Utilization Factor) data provides a clear illustration of seasonal and configuration-based performance trends across the five inverters at the agrivoltaics site. Overall, **bifacial systems consistently outperform the monofacial setup**, with the **3.75 m bifacial structures (Inverters 02 and 03)** achieving the highest CUFs throughout the year. These systems recorded peak efficiencies of over **23%** during high-irradiance months such as **April and May 2024**, indicating the combined benefit of increased panel height and bifacial gain. The **1.75 m bifacial system (Inverter 04)** demonstrated moderate performance, outperforming the monofacial configuration while staying slightly below the taller bifacial systems. Even the **1.25 m bifacial system (Inverter 05)**, despite its lower elevation, consistently delivered better CUFs than the monofacial setup, validating the technology’s advantage. Across all configurations, the **lowest CUFs were observed in July**, with values dipping as low as **12.8%** for the monofacial system, primarily due to **monsoonal cloud cover**. Conversely, the **highest CUFs occurred between March and May**, aligning with periods of maximum solar availability. These trends underscore the importance of both **panel technology and structural design** in optimizing solar energy output in agrivoltaic systems.

Table 2 Monthly CUF values for each configuration

Months	Inverter 01	Inverter 02	Inverter 03	Inverter 04	Inverter 05
Feb-23	20.2	21.5	21.7	21.7	21.2
Mar-23	20.0	22.2	22.0	21.0	20.9
Apr-23	21.3	23.6	23.4	22.4	22.1

Months	Inverter 01	Inverter 02	Inverter 03	Inverter 04	Inverter 05
May-23	21.1	23.5	23.7	22.5	21.7
Jun-23	20.8	22.4	22.6	21.6	21.8
Jul-23	13.4	14.7	14.4	13.9	14.2
Aug-23	18.0	19.8	19.5	18.1	18.6
Sep-23	15.5	17.4	17.0	16.4	16.1
Oct-23	20.1	22.2	21.9	21.2	20.8
Nov-23	16.4	18.1	18.1	17.2	17.1
Dec-23	16.8	18.3	19.0	17.9	17.8
Jan-24	17.0	18.2	18.5	18.0	17.7
Feb-24	19.5	19.4	19.8	20.0	20.1
Mar-24	21.4	22.7	22.1	21.4	21.4
Apr-24	21.5	22.4	22.6	22.1	21.9
May-24	22.0	23.1	23.3	22.8	22.5
Jun-24	19.3	20.7	20.5	20.0	19.9
Jul-24	12.8	13.8	13.8	13.2	13.2
Aug-24	15.7	17.3	17.1	16.4	16.4
Sep-24	15.9	17.5	17.2	16.5	16.3
Oct-24	19.0	20.7	20.6	19.7	19.7
Nov-24	18.3	19.6	19.7	18.7	18.8
Dec-24	16.3	17.3	17.4	16.6	16.7

Based on the table, the **average CUF** values for each inverter across the recorded period are as follows:

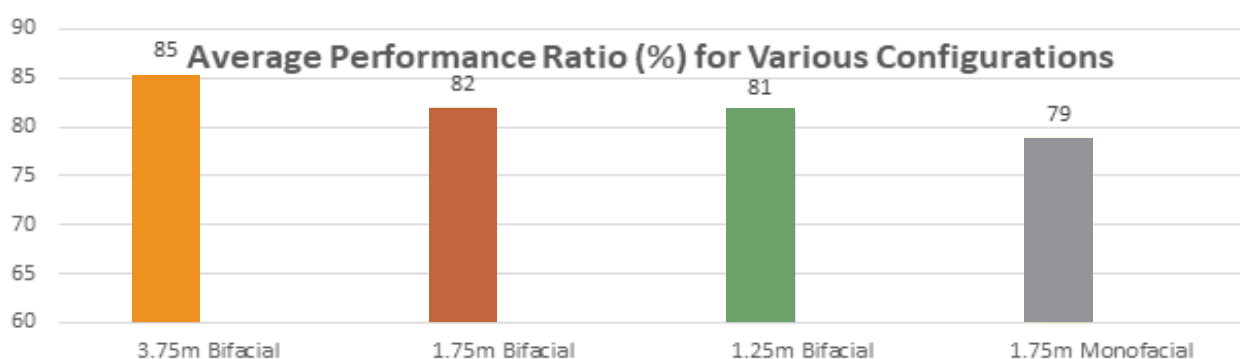
Table 3 Average CUF for each configuration

Inverter	Configuration	Average CUF (%)
Inverter 01	1.75 m Monofacial	18.4%
Inverter 02	3.75 m Bifacial	19.9%
Inverter 03	3.75 m Bifacial	19.8%
Inverter 04	1.75 m Bifacial	19.1%
Inverter 05	1.25 m Bifacial	19.0%

Height Optimisation Benefits: The 3.75m installations achieve the highest CUFs, validating the investment in elevated mounting structures. The height advantage provides approximately **1.4% better CUF** compared to similar technology at lower heights, likely due to:

- Better bifacial radiation capture with increased height
- Better bifacial radiation capture due to 1P configuration
- Higher effective albedo due to mulches & reflective shade nets
- Better air circulation for temperature management

Figure 5 Average performance ratio for each of the AgriPV configuration



Performance ratio insights:

The performance ratio of the systems is calculated using the actual energy generated divided by the capacity multiplied by the plane of array irradiance values for Parbhani, Maharashtra. Based on the average values of the performance ratio, the 3.75 m bifacial configuration performs the best, with an 85% performance ratio—a 7.59% increase from the 1.75 m monofacial configuration. This may be attributed to a combination of factors, including bifacial gain, increased height of structures, and the addition of mulching papers for the farming underneath that results in an increase in albedo effect and subsequent increase in generation. **Based on the monthly values of PR**, the 3.75m bifacial configurations (Inverters 02 and 03) consistently deliver the highest performance ratios compared to the 1.75 m monofacial configuration, making them the optimal choice for maximising energy yield.

Table 4 Monthly performance ratio values for each of the AgriPv configurations

Months	1.75m Monofacial	3.75m Bifacial	3.75m Bifacial	1.75m Bifacial	1.25m Bifacial
	Inverter 01	Inverter 02	Inverter 03	Inverter 04	Inverter 05
Feb-23	75	80	81	81	79
Mar-23	68	76	75	72	71
Apr-23	74	82	81	78	77
May-23	78	87	88	83	80
Jun-23	98	106	107	102	103
Jul-23	80	89	87	84	85
Aug-23	97	107	105	97	101
Sep-23	78	88	86	83	81
Oct-23	93	103	102	98	97
Nov-23	69	76	76	72	72

Months	1.75m Monofacial	3.75m Bifacial	3.75m Bifacial	1.75m Bifacial	1.25m Bifacial
	Inverter 01	Inverter 02	Inverter 03	Inverter 04	Inverter 05
Dec-23	67	73	75	71	70
Jan-24	66	71	72	70	69
Feb-24	76	75	77	77	78
Mar-24	73	77	75	73	73
Apr-24	74	78	78	77	76
May-24	81	85	86	84	83
Jun-24	91	97	97	94	94
Jul-24	77	83	83	80	79
Aug-24	85	93	92	89	88
Sep-24	80	88	87	83	82
Oct-24	88	96	95	91	91
Nov-24	77	82	83	79	79
Dec-24	65	69	69	66	66
Jan-25	73	77	77	73	73

5.2 Key Observations on Bifacial gain

- The average generation increase of the bifacial sections with respect to the monofacial section in the first year is as follows:
 - 3.75m bifacial: 8.85%
 - 1.75m bifacial: 4.88%
 - 1.25m bifacial: 3.81%
- The difference between 3.75m bifacial is significantly higher than the 1.25m bifacial section showing a 5% gain. This can be attributed to the following factors:
 - Higher elevation captures more reflected radiation
 - More air flow in the 3.75m section due to higher elevation and 1P configuration as compared to 1.75m section which has 2P configuration.
 - Possibly higher albedo as the 3.75m section as it had a Aluminet shade net reflecting light in the first 3-4 months.
- A 5% gain in electricity generation translates to INR 2.5 lakhs per year. The NPV at 10% discount rate is 22.5 lakhs which is approximately 50% of the additional structure INC cost. If the solar generation alone can compensate for 50% of the additional structure INC cost then it becomes much easier for the balance amount to be recovered from profitability from the agriculture operations
- Diffuse radiation provides a higher bifacial gain as compared to normal radiation.

The summer months in year 1 when the shade net was mostly drawn during the day had 10-11% higher gain as compared to 1,75m mono facial section and 7-8% higher bifacial gain as compared to 1.25m bifacial section.

6. Techno-Commercial Analysis

6.1 Introduction

This financial analysis examined the three AgriPV configurations of the plant against the baseline conventional solar installation to evaluate their economic viability and investment attractiveness. The study encompasses various mounting technologies, including fixed-tilt ground systems, elevated structures, and tracking systems, each designed to optimize both energy production and agricultural compatibility.



To compare the performance of these systems, two key financial indicators are used: the levelized Cost of Electricity (LCOE) and Project Internal Rate of Return (IRR). LCOE provides a measure of the average cost of electricity generated over the system's lifetime, while IRR indicates the project's profitability and return potential for investors. **By applying a consistent financial model across all configurations**, this study ensures a **fair comparison of cost efficiency and investment appeal**. The cost assumptions used in the model are based on current market prices for equipment and services; however, actual costs incurred on the ground may vary due to location-specific, temporal, or logistical factors.

The four configurations analysed include: a conventional ground-mounted fixed-tilt system (baseline), an AgriPV ground mount with fixed tilt, an elevated AgriPV with fixed tilt, and an elevated AgriPV with tracker system. These configurations reflect varying levels of technical complexity, investment requirements, and land-use efficiency.



6.2 Methodology & Assumptions

01 Financial Modelling Approach

A standardised financial model was employed to evaluate the techno-economic performance of the four solar PV configurations. The model operates over a 25-year project life and calculates key financial metrics, including the LCOE and Project IRR. It is based on the Discounted Cash Flow (DCF) methodology, incorporating all relevant capital and operational costs, debt servicing, depreciation, and energy generation throughout the project's operational life.

LCOE is calculated as the present value of total lifecycle costs divided by the present value of total energy generated. This makes it suitable for comparing different technologies on a common cost-per-kWh basis. IRR is the discount rate that makes the net present value (NPV) of future cash flows equal to zero, serving as a key indicator of investment attractiveness.

The model used cost inputs reflective of current market prices for equipment and services. However, it is important to note that real-world implementation costs may vary depending on site conditions, logistics, or changes in input pricing.

Table: Common Assumptions Across All Configurations

Parameter	Value/Assumption
Installed Capacity	1MW
Project Life	25 years
Wind speed	39 m/s
Debt-Equity Ratio	70:30
Loan tenure	15 Years
Interest Rate on Debt	10%
O&M Escalation Rate	4%
Annual Degradation Rate	0.50%

The capital cost of each configuration includes engineering, procurement, and construction (EPC) expenses. In line with current GST treatment for renewable energy projects, **GST at 12% on EPC and 18% on Structural and AgriPV Costs has been considered a pure cost to the developer.** As solar projects qualify as exempt supplies under GST law, **Input Tax Credit (ITC) is not available.** Thus, the GST paid on procurement and services must be capitalized and is included in the total EPC cost.

	Normal Project Ground Mount FT	Agri PV Ground Mount FT	Agri PV Elevated FT	Agri PV Elevated Tracker
Ground Clearance (m)	0.5	1.75	4.0	4.0
Configuration	2P	2P	1P	1P
Land Use (acres)	2.5	2.75	3.5	3.5
Base Solar EPC (Ex Structures)	2,50,00,000	2,50,00,000	2,50,00,000	2,50,00,000
Structure Costs				
Structure Weight (MT)	21.0	28.5	55.0	62.5
Steel Price (INR/kg)	85	85	95	95
Structural Steel Cost (INR)	17,85,000	24,22,500	52,25,000	59,37,500
Foundations Cost (INR)	6,00,000	7,50,000	17,50,000	17,50,000
Electronics Cost (INR)				25,00,000

	Normal Project Ground Mount FT	Agri PV Ground Mount FT	Agri PV Elevated FT	Agri PV Elevated Tracker
Installation Cost (INR)	3,00,000	3,00,000	7,50,000	7,50,000
Total Structure Cost (INR)	26,85,000	34,72,500	77,25,000	1,09,37,500
Total Cost w/o AgriPV	2,76,85,000	2,84,72,500	3,27,25,000	3,59,37,500
Structural Cost including GST	34,83,300	36,25,050	43,90,500	49,68,750
Total Cost Inc GST	3,11,68,300	3,20,97,550	3,71,15,500	4,09,06,250
Additional APV costs (INR)				
Additional Civil works		50,000	3,00,000	3,00,000
Tractor & Farm implements		7,50,000	7,50,000	7,50,000
Drip Irrigation system		3,00,000	3,50,000	3,50,000
Total Additional APV Costs (INR)	0	11,00,000	14,00,000	14,00,000
Total Project Cost (INR)	2,76,85,000	2,95,72,500	3,41,25,000	3,73,37,500
GST	34,83,300	38,23,050	46,42,500	52,20,750
Total Project Cost Inc GST (INR)	3,11,68,300	3,33,95,550	3,87,67,500	4,25,58,250

In this model, **agriculture-related capital and operational costs have been excluded from the LCOE calculation**. This is because LCOE is intended to reflect only the cost of electricity generation; incorporating agricultural inputs would distort the energy economics. Hence, only core solar EPC components (excluding drip irrigation, farm implements, etc.) are considered in LCOE.

However, for Project IRR calculations, the full project cost includes agriculture-related components, and has been incorporated in the AgriPV configurations. This approach provides a holistic view of financial viability from an investor's perspective, especially in AgriPV applications.

02 Capital Structure and Working Capital

The capital structure in this model is aligned with the financial principles outlined in the Central Electricity Regulatory Commission (MERC) Renewable Energy Tariff Regulations, 2024. These norms guide the structuring of renewable energy projects in the state.

A normative debt-to-equity ratio of 70:30 has been applied. The cost of equity has been considered at 17% for the first 20 years and 19% for the last 5 years of the project lifecycle. The loan tenure is assumed to be 15 years with quarterly repayments starting from the commencement of commercial operations. An interest rate of 10% is used for debt.

Working capital requirements are estimated as per MERC guidelines:

Working Capital Assumption	Value
Receivables	60 days
O&M Provision	30 days
Maintenance Spares	15% of O&M
Interest on Working Capital	10%

03 Analysis and Interpretation

This section evaluates and interprets the financial and technical performance of the four selected configurations: Conventional Ground Mount Fixed Tilt (FT), AgriPV Ground Mount FT, AgriPV Elevated FT, and AgriPV Elevated Tracker. The assessment considers project cost, energy output, and key financial indicators such as LCOE and Equity IRR.

04 Capital Cost Assessment

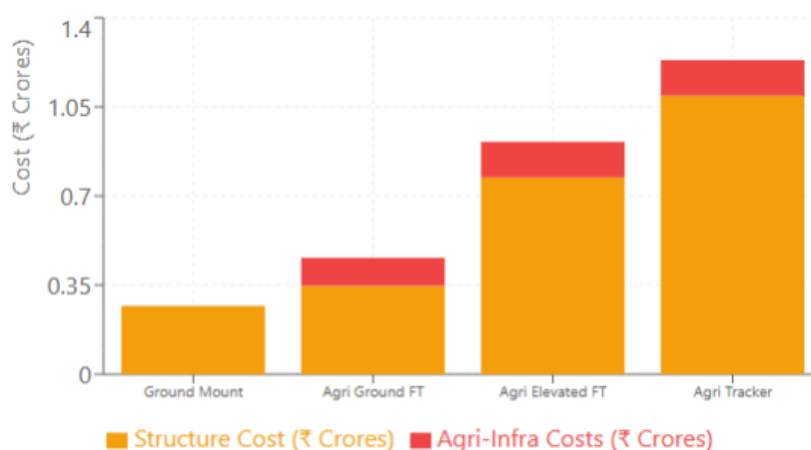
- The **total capital cost (including GST)** for the baseline Ground Mount FT system stands at ₹3.12 Cr/MW. With AgriPV integrations and more advanced structural features, this cost progressively increases across the other configurations:
- **Agri PV Ground Mount FT:** ₹3.34 Cr/MW
- **Agri PV Elevated FT:** ₹3.88 Cr/MW
- **Agri PV Elevated Tracker:** ₹4.26 Cr/MW

This upward trend in cost is primarily driven by the **addition of agricultural infrastructure** (such as drip irrigation systems, farm implements, and civil works) and more **complex structural requirements** for elevated and tracker-based designs. In particular:

- **Elevated structures** require more steel, deeper foundations, and heavier installations, all contributing to a marked increase in structural costs.
- **Tracker systems** add further complexity and cost, including motors, control electronics, and mounting mechanisms.
- **Land lease costs** also show a modest rise due to the increase in land required to accommodate agricultural co-usage.

In order to isolate the cost of electricity generation, **the LCOE calculation uses the capital cost exclusive of agricultural infrastructure**. Thus, for LCOE analysis, the project cost considered for each configuration is the EPC-only value:

Cost Component Breakdown



Structure Costs:

Ground Mount:
Agri Ground FT:
Agri Elevated FT:
Agri Tracker:

₹0.27 Cr
₹0.35 Cr
₹0.77 Cr
₹1.09 Cr

Agri-Infra Costs:

Ground Mount:
Agri Ground FT:
Agri Elevated FT:
Agri Tracker:

₹0.00 Cr
₹0.11 Cr
₹0.14 Cr
₹0.14 Cr

In terms of percentile cost differentials, Agri PV Ground Mount FT shows the most modest increase at **6.8%** over the baseline ground mount system; **Agri PV Elevated FT** represents a significant step up at **24.3%** higher cost and finally **Agri PV Elevated Tracker** has the highest i.e.**36.6%** increased positioning it as the high-end solution that combines elevated installation with solar tracking technology for maximum energy yield and agricultural flexibility.

This distinction ensures that the **cost of co-located agricultural infrastructure** does not artificially inflate the generation cost metrics. Since agricultural revenues are separate from power generation, it is methodologically sound to exclude such costs from the LCOE framework.

05 LCOE Analysis

This distinction ensures that the **cost of co-located agricultural infrastructure** does not artificially inflate the generation cost metrics. Since agricultural revenues are separate from power generation, it is methodologically sound to exclude such costs from the LCOE framework. The baseline Ground Mount FT system maintains the lowest LCOE due to its relatively lower capital expenditure. Conversely, the Agri-PV elevated FT and tracker configurations display higher LCOE values, which result directly from the elevated upfront costs, notwithstanding improvements in energy generation. This reinforces a critical insight: **higher capital cost—even if accompanied by greater energy yield—does not automatically translate into lower per-unit cost.**

Several factors explain these LCOE patterns:

(a) Capital Expenditure (CAPEX):

This is the most influential driver. Elevated structures and tracking mechanisms result in **incremental CAPEX of up to 31%** compared to the baseline, because these costs are incurred upfront, they have a strong compounding effect on discounted lifetime costs.

(b) O&M Costs:

O&M expenses include fixed annual outflows for cleaning, security, and equipment maintenance. While O&M costs are modest in this analysis, they escalate annually by 4%, in line with sectoral norms and MERC guidelines. This cumulative effect slightly impacts long-term cost calculations.

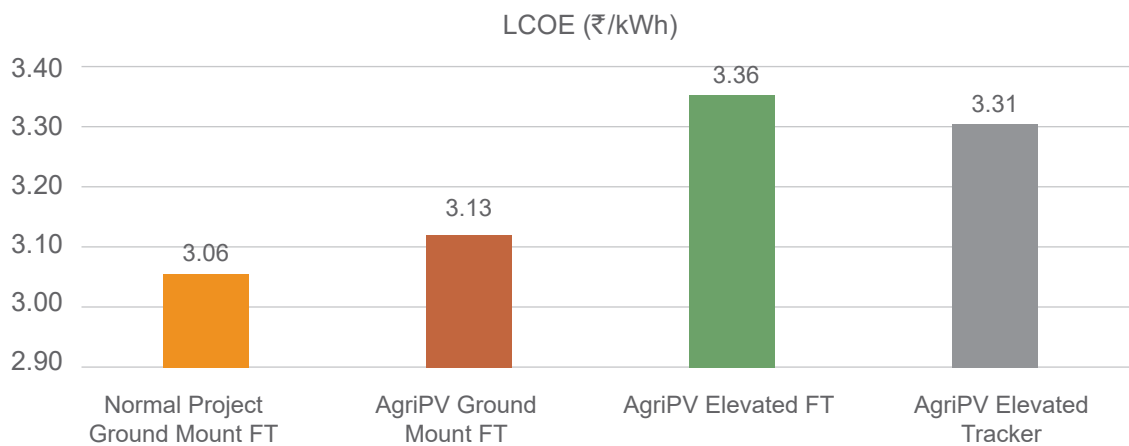
(c) Goods and Services Tax (GST):

GST is treated as a **non-creditable expense** in this model because developers operating under exempt or non-taxable revenue structures are **ineligible to claim input tax credit (ITC)**. Therefore, GST becomes a real and direct cost added to the capital investment, affecting both LCOE and return metrics.

(d) Discounting Future Costs:

The LCOE framework applies a discount rate reflecting the project’s weighted average cost of capital (WACC). Higher capital costs disproportionately increase the present value of expenses, which pushes the LCOE higher despite potential generation gains.

Figure: LCOE for Different Configurations

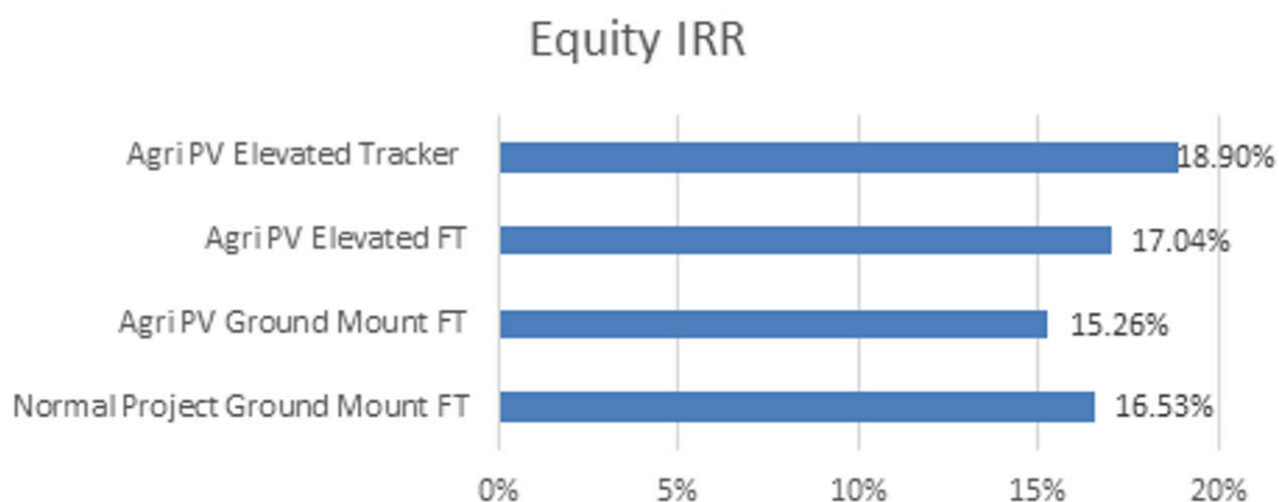


It is critical to note that **agricultural infrastructure costs have been deliberately excluded from the LCOE computation**. This approach is grounded in financial logic: LCOE is a generation-centric metric. Since **agricultural income and expenses are non-electricity related**, they should not influence the cost per unit of electricity.

However, these **AgriPV-specific costs are included when calculating Equity IRR**, as IRR reflects the overall project-level return, including both electricity and agriculture-related revenues and costs.

06 Project Viability Analysis

The variation in Equity IRR across the four configurations is primarily driven by differences in capital cost, additional agri-related income, and generation performance, all of which influence the cash flow accrued to equity investors:



1. Normal Ground Mount FT

This configuration has the lowest capital cost and no agricultural component. The higher Equity IRR here is mainly due to a lower equity requirement (because of lower total project cost) and no additional operational burden from agriPV infrastructure. The return is primarily from electricity sales.

2. Agri PV Ground Mount FT

Although it introduces agri-related income, the capital cost increases slightly due to APV-related infrastructure. However, the gain in energy generation and agricultural revenue is modest, which compresses the margins for equity holders, resulting in a slight dip in Equity IRR compared to the baseline.

3. Agri PV Elevated FT

This configuration demands a significantly higher investment due to elevated structures but also generates higher revenues from both electricity and agricultural activities. The improved CUF contributes to stronger operational income, leading to a noticeable rise in equity returns, despite higher upfront costs.

4. Agri PV Elevated Tracker

Despite being the most capital-intensive, this setup achieves the highest Equity IRR due to a combination of the highest CUF (driven by tracking technology) and enhanced agri-revenue from better land usability. The tracker mechanism boosts generation throughout the day, increasing revenue and improving cash flows for equity investors.

7. Conclusion

This techno-commercial analysis illustrates the strategic potential of AgriPV technologies as a dual-use model for optimising land and solar energy infrastructure in India. By comparing a conventional ground-mounted fixed-tilt system with three AgriPV configurations - Ground-Mounted FT, Elevated FT, and Elevated Tracker—this study evaluates their viability through metrics such as Levelized Cost of Electricity (LCOE) and Equity Internal Rate of Return (IRR). The model applies a uniform financial framework across all configurations, ensuring comparability and transparency in the economic assessment. Importantly, the analysis disaggregates energy-specific and agriculture-specific costs to reflect the actual generation cost (LCOE) and investor returns (IRR) more accurately.

The findings reveal a nuanced trade-off between capital expenditure and return. Although the AgriPV configurations, especially the elevated and tracker systems, require significantly higher upfront investment due to structural complexity and agricultural integration, they deliver proportionally higher energy output and ancillary agri-revenue. For instance, the AgriPV Elevated Tracker configuration, despite being the most capital-intensive, achieves the highest Equity IRR of 18.90%, showcasing the ability of sun-tracking technology to enhance daily energy capture and optimise land utility. Meanwhile, the AgriPV Elevated FT system presents a balanced profile with a competitive LCOE and strong financial returns, suggesting its appropriateness for scalable deployment where cost efficiency is a priority.

Overall, the study underscores that AgriPV—when thoughtfully engineered and location-optimised—can be economically competitive with conventional solar while offering co-benefits such as agricultural productivity and rural employment. The narrow band of LCOE values across all configurations (₹3.06–₹3.36/kWh) affirms the economic soundness of AgriPV models. For policymakers, developers, and investors alike, these results reinforce AgriPV's potential as a strategic pillar in India's renewable energy growth and sustainable land-use planning, especially in states like Maharashtra facing acute land-use pressures.



7.1 Key outcomes and findings

- The first season was an experimental approach with experiments on almost 14 crops. Few crops like cherry tomato, capsicum, cucumber, marigold, chysanthemum yielded almost equal to the reference area.
- LER of above 100 % was seen in the first season, further on in the next seasons there was an increase upto 140 % and water savings were particularly noticed in the shade-net environment compared to the open areas. Total water savings of 5780000 lt was observed.
- The crops grown together in the shadehouse environment were flowers and vegetables. The treatments given to both the crops were the same. Thus resulting in unexpected pest attacks from floricultural plants on horticultural plants and vice-versa. However, this was a great learning that was considered for the planning of next seasons.
- Soya, Banana, Turmeric, Cabbage and Pigeon pea yielded fairly well in comparison with the reference area yield.
- Sunseed and VNMKV focused on the locally grown crops and its market in the planning and implementation by the farmer and the University
- The dry-cleaning mechanism designed for the panels elevated in the 3.75 needs attention to maintain cleaner panels for effective energy yields. Due to the adjustment required to suit the size of the dry cleaning rail, the effective panel cleaning is mildly achieved during dust deposition. As in Indian conditions dry-cleaning in most of the regions due to water scarcity.
- All the farming related activities with heavy tractors and equipment were not hindered due to structures. However, it needs care so the underground cables (at least 2 m below ground level) are not damaged.
- The system design especially in the shade-net environment was developed considering the PAR requirements of the horticultural crops. The retractable shadenets and 1P configuration enhanced the micro-climate to suit the growth of certain crops like tomato, capsicum, soya, pigeon pea, banana and turmeric particularly.
- In the research so far only the agri yields have been measured. Additionally, active research is required on albedo effect and micro-climatic conditions using weather stations, PCA, Spectro radiometers, Photosynthesis devices. This can help validate results in a more effective way, with proven results to farming and the larger Agri community.
- As this set-up is a part of a larger 50 MW solar plant, site regulations on general safety measures were sometimes seen as difficult for the farmers to follow. I.e.: Wearing safety kits, heavy boots and helmets while doing the farming operations. This aspect has to be mitigated to ensure both comfort and safety for the farmers.
- The active usage of panel surface temperatures sensors, temperature loggers, infrared radiometers was missing due to the prioritisation of other tasks and squeezed deadlines. The next phases could include results from this instrumentation too.
- As agricultural scientific communities suggest investigating at least for 3-4 years to study the effects of the partial or complete shading on the crops, the research further shall be active for at least another two years for proven results.
- As most of the procurements and services were interlinked with the long tendering procedures, better planning is required to achieve the results in restricted time-frames. The delays in the processes had a significant role in the overall project management and in achieving the desired results.
- Active step-wise results from PIX4D software, Simulation software with an example of an Indian context would be beneficial for more farmer reach out in the phase 2
- Involvement of plant physiologists and hydrologists in the simulation software in next phases would be crucial to have better input on the agriculture related parameters. As understood there would be a constant updating of the software and for better holistic versions more agriculture parameters are also recommended in the software.
- Phase wise planning of farmer workshops is necessary with upgraded versions of the training content. It needs several additions catering to the understanding levels of the farmer communities.
- The project has contributed to several policy advocacy suggestions in phase 1, ongoing experiences will also contribute to major policy suggestives in this realm.

- Other models like rooftop, hydroponics, cattle grazing, fruitovoltaics etc along with technology innovation (tracking systems, semi transparent panels, mounting structures) shall be explored in the next phases for longer and sustainable solutions.
- For the next phase it would be beneficial if the pilots fit into a certain business model (Developer, FPO etc) to prove the financials and benefits in a better way.





Case Study of Nashik

Background

The project is located in the research campus of India's biggest FPO Sahyadri farms in Nashik, Maharashtra. This is built on a smaller scale of 0.5 MW at an elevated height of 4 m with embedded single axis tracking systems. The goal of this project is to explore the opportunities of such systems on Fruitovoltaics, particularly on Viticulture (grapes) farming. This project particularly is an FPO based model, where they have a connection to over 3000 farmers. The success rate of such projects can ramp up the interest amongst the registered farmers in the FPO to have similar installations. Similar research is conducted in the pilot too on generating photosynthetic curves. Simultaneously, studying both quantitatively and qualitatively.

Figure 35: Tilted panel view for the crops



Figure 36: panels at 180 degrees



Figure 37: Under the panel view



Figure38: Under the panel crop's view



02 Approach followed and prefeasibility study if any (Site analysis, soil test, water test, surveys)

As the pilot was constructed on the research test bed of Sahydri farms which experiments on viticulture plants, pomegranate and citrus production like oranges, sweet lime, etc no specific soil and water test was conducted like in the case of Parbhani plant. The soil and water requirements were in tact for growing the aforementioned crops

03 Agrivoltaics Systems - Technology Innovation and Design

Description of different sections with technical specifications

The 250 kW agrivoltaics plant integrates solar energy production with agriculture, specifically designed for growing grapes and citrus fruits. The plant features solar panels mounted 3.5 meters high, equipped with trackers that follow the sun's movement, ensuring optimal energy capture throughout the day. This elevated setup not only maximizes solar power generation but also provides enough space beneath the panels for the crops to grow. An expected increase upto 30% in the solar generation is expected which is to be further studied over a period of time. The site was functional from February 2024, but the generation was halted in between due to pending liasoning works. The same will be studied over the next few months for a consolidated overview on the actual percentage improvement with trackers.

The pilot site also employs extensive instrumentation to support research and development in crop cultivation and solar energy. The research aims to develop scientific approaches for the design and adaptation of agrivoltaics projects, while exploring specific cultivation strategies for agrivoltaics systems.

The monthly solar generation from February 2024 to July 2024 are as below:

Month	Generation (kWh)
February	34900
March	51333
April	51224
May	52203
June	36906

The data for the subsequent months is yet to be collected and visualised in the similar way as it has been done for the Parbhani set-up. It is interesting to see the effect of trackers and albedo particularly on viticulture plants. Studies have been published in the European context with great focus on grape plantations. It would be path breaking to study the same for the Indian context.



8. Policy advocacy through farmer, student, developer and DISCOM workshops

Overview of workshops

The below tables give an overview of the achieved farmer, student and developer workshops and training sessions conducted as one of the most important KPI. Through these workshops around 1000 farmers have been made aware of Agrivoltaics across India. The training material was prepared by the Skill Council for Green Jobs as a part of the DeveloPPP project. The initial few trainings were streamlined by them after which GIZ and SunseedAPV have taken over after a Trainer of Trainer session by coherent understanding of the training.

Figure 39: Women workforce



Figure 39: Interaction with farmers



Figure 40: Workshop and interaction sessions



Figure 41: Site visit



S. No	Place	Partner	Number of farmers	AgriPV site visit	Date
1	Nasik	FPO	80	Yes	18th April 2024
2	Dhule	Developer	135	Yes	12th May 2024
3	Narayangaon	KVK	38	Yes (Irrigation)	15th May 2024
4	Hyderabad	KVK	35	Yes	10th June 2024
5	Jodhpur	KVK	37	Yes	26th June 2024
6	Ludhiana	KVK	35	No	4th July 2024
7	New Delhi	IAA	40	Yes	17th July 2024
8	Akola	FPC	250	No	26th July 2024
9	Himachal Pradesh	KVK	135	No	29th July – 1st August 2024
10	Hyderabad	Aghub	221	Yes	6th – 9th August 2024
	Total		1006		

Figure 42: Session interactions



S. No	Place	Number of students	AgriPV site visit	Date
1	IARI	15	No	15th Dec 2022 – 10th Jan 2023
2	TERI	145	No	14th March 2024
3	VNMKV	60	Yes	15th–17th May 2024
4	IARI	100	Yes	20th Sept 2024 (anticipated)
	Total	320		



S. No	Place	Participant	Number of attendees	AgriPV site visit	Date
1	Pune BAIF campus	DISCOM	5	No	27th August 2024
		Developer	20	No	
	Total		25		

8.2 Feedback collected from farmers

The below are few major take aways from the Farmer Workshops that could work to enhance Solarization of Agricultural lands and Agrivoltaics scenario in India.

- Many farmers seem interested in the DISCOM / Developer owned model, where the land can be leased out with an agreement. The income earned through land lease can additionally benefit the farmer apart from the sale of the crop yield.
- In the DISCOM / Developer owned model, individual land pieces may be considered as a single project. (i.e.: If the two lands of 2.5 acres each are at 1 km distance and combinedly a 1MW installation would be done on it will this be a single project).
- The tariff rates in PPA may be dynamic, i.e. the tariff rate at which the electricity is sold be increased over a period based on the PPA made. This was highlighted because the value of the unit rate after 25 years would be almost zero or negative (i.e.: In Telangana if the unit rate is Rs.4 as of today, 25 years later it would have no value). In this case, the suggested period was suggested to be increased every 5 years.
- The minimum tariff price be at least Rs 5 nationwide to ensure economic viability of solar plants. Lower Tariff rates lead to high payback periods, which is unfavorable. Since high upfront costs of Agrivoltaics plants was highlighted as a major issue, it is suggested that farmers have access to collateral free and low-interest rate loans (suitably less than 8 %).
- To encourage inclusivity under the PM-KUSUM scheme, it is suggested that the plant capacity permitted, ranging from 0.5 MW to 2MW under the scheme, be changed to 0.25 MW to 2MW, as this would enable small-scale farmers to also install under this scheme.
- KUSUM component A may be combined with component B or C and has been now included under Agricultural Infrastructure fund (AIF), to enable easy and cheaper access to credit for farmers and avoid infrastructure costs upto 2 Cr INR.
- Animal attacks on crops is a big issue for farmers across India. Provision of subsidy for installation of solar fencing may be included under PM-KUSUM schemes.
- Subsidy/ central financial assistance may be provided for installing water harvesting systems, along with Agrivoltaics plants, to ensure conservation of water in drought prone areas.
- The farmers suggested issuance of Standard Operating Procedure for Sale of Electricity, ensuring consistency in process throughout the country.
- Assistance may be provided for adoption of technological innovations, to solve issues such as dust deposition on panels, water shortage for maintenance etc. in Agrivoltaics plants. The farmers suggested the establishment of multiple model APV plants to convey its benefits practically to farmers. Precisely a website to register and show interest.
- A document focusing on 'Best Practices Guidelines' for installing Agrivoltaics plants, under PM-KUSUM Comp-A may be published. They also suggested including a financial template for 1 MW/500 MW installation in the same document, crop suitability, i.e. list of region-wise crops suitable for Agrivoltaics plants all across the country.



- What will happen to the Agrivoltaics installation after 25 years? The farmers mentioned that this should be mentioned in the contract clearly and should not result in any conflict. Particularly keeping land grabbing in mind, which is a major concern amongst the farmers.
- More research on technology intervention to ensure no crop yield loss scenario is required. Panel technologies allowing more light (semi-transparent, glass panels with strips) maybe made commercially viable for large scale installations.
- Dedicated sessions on AIF, MIDH, PM-SKY and possible integration of the same with KUSUM A.
- Clarity on maximum number of farmers that would be selected in the bidding process per state, per district, per taluka etc. Many farmers have requested that the bidding process should be eliminated, allowing more farmers to avail the benefits from the policy.
- Clarity on the difference in tariff when sold to the grid, industry and commercial usage, captive usage combined with net metering system is required with proper dissemination in the field.



8.3 Recommendations after DISCOM workshops based on consolidated feedback from farmers

- KUSUM A has no obligations on Capacity Utilization Factor (CUF), but for B and C it is up to 90 % CUF. Domestic Content Requirement (DCR) panels could be of greater interest to Agrivoltaics systems. KUSUM (A+C) could be a good combination for Agrivoltaics installations. In case of distance more than 5 km, the feeder level at 33 kV can be integrated in Maharashtra.
- Tariff rate is determined by headquarters, based on public hearings. This depends on transmissions losses, geographical locations and cost incurred in the project. At an average cost of 4 INR (Maharashtra) in the agricultural sector, additionally the tariff burden cost from rural areas plays a major role in defining the tariff. The operation and maintenance are also crucial to ensure efficiency of the installations. Also, in the open access scenario cross subsidy plays a very crucial role.
- Combination of different RE sectors based on the installed states is one of the key factors to decide the tariff rate. State regulators intervention with the Central regulatory board is critical depending upon the generations annually. States that provide free electricity to farmers are crucial on how the tariff rate is determined. There is no clear approach to this. DISCOMs look at Agrivoltaics as a good medium to the RE goal especially in Punjab but with several alterations made on different levels.
- Having standard operational procedure and standard tariff across the nation could be possible. CERC generally evaluates the tariff on the operational demand and power trading market. Green energy open access (100 kW) escalation can play a crucial role in defining a standard tariff. More defined SOPs based on landscape-based regulations and market demand will be crucial. Incentive based mechanisms depending on the state also play a crucial role in defining the procedure and tariff. Apart from these natural calamities, affected states might have different regulations.
- Timely payments to the PPAs beneficiaries were a concern earlier due to the financial status of DISCOMs earlier. However, all the DISCOMs are assuring a streamlined payment mechanism. Several online portals have been worked upon for settling the bills. Navratna companies that are the Top tier among Public Sector Undertakings (PSUs) because of their remarkable financial and operational accomplishments are currently the beneficiaries serving as an example indicating the timely payment of the bills raised. Both SERCs and CERCs are also working on a streamlined way of working.
- If the transmission line is laid at 5 km for 33 kV per km is 0.35 %. The greater the voltage, the fewer the losses. DISCOMs generally list the available substation centres (load available, day availability, transformer capacity, feeder length) at the time of bid. It is not economical for building a dedicated transformer based on requirement. There are no subsidised mechanisms to support farmers on establishing a new evacuation point. DC overloading plays a crucial role also and defining the losses and the layout. Probable inclusion of the range of DC overloading can be helpful. DISCOM or State governments are generally the decision makers in having a new transformer.
- Separate land pieces and different farmers can collectively be treated as one project and such collective projects can be considered as a single project. DISCOMs are generally not responsible for power outages, they only take the responsibility for natural calamities in most of the states. Insurance companies in a few states guarantee the power compensation on black out days in a few states, a closer look at such policies is required.
- Safety standards and locations define the insurance coverage terms particularly that are more prone to natural calamities. This defines the range of coverage based on the sensitivity like cyclones, wind speed, heat outages etc. The order of power purchase gives priority to green power primarily followed by the others. However, this again is defined by the share of RE absorption, based on adjustment capacity keeping in mind co-generation guidelines. This has a major impact on the price deciding factors. Global green markets and export demands can also be crucial in deciding the tariff in the years to come keeping in mind the soft power trade that is picking up momentum. ACS-ARR Gap which is an inverse measure of a Discom's profitability calculated as the difference between Average Cost of Supply (ACS) in Rs/kwh and Average Realizable Revenue (ARR) is finally the factor that allows the regulatory bodies to define the price. Distributed energy generation could be the most feasible solution instead of a centralized plant especially in the Agrivoltaics sector.

8.4 Recommendations after Developer workshops based on consolidated feedback from farmers

- The cost of a 1 MW plant with ground mounted system 25 lakhs with elevated structures going up to 2 crores. Different models can be explored by the developer and the farmer together on the whole objective of the project, this could differ from project to project. The suggestions from the farmers need to be collected in several stages of the initial project phases to ensure that the farming practices are not harnessed.
- The cost variation between the ground mounted and elevated is dependent on the structure cost and panel technology (installation, foundation, DC cabling etc). 20 tons of steel around 30 lakhs per MW for a ground mount system and around 60 tons for 4 meters elevation. However, the steel requirements might differ with ranging heights and design specifications. Again, an increase in height would increase the cost of foundation and several other factors that need to be considered. However, mono-facial panels are completely obsolete in this discussion considering bifacial panels are the future technology. Specifically, the design considerations shall be made keeping the minimum Land Equivalent Ratio (LER) and availability of the maximum photosynthesis rate to the crop. Adding prisms would substantially increase the energy and the crop yield.
- Leasing land requires some procedure to be followed, the agreement is usually for 25 years and hence would require several permissions. However, this would differ from state to state. The solar insurance in this scenario is also mostly covering the losses incurred by weather related events like cyclones, earthquakes etc.
- Operation and Maintenance of panels particularly with respect to dust deposition is crucial to ensure efficiency and optimal generation. Henceforth the panels need to be cleaned regularly, this can be done through automated cleaning systems that are available in the market. Particularly in the case of bifacial panels and tracking systems, the panels can be tilted for an easy clean on the rear side of the panel. The cost for the cleaning shall be more on an understanding between the farmer and developer. This responsibility lies majorly with the Developer, but farmers would have to essentially support in the process of access to water, walkway, labor etc. The farmer would have to understand the synergy between the solar system and crop for an effective functionality of the plant. Involving the newer generation of farmers in this case would not just bring awareness but can also create employment for the near vicinity be it rural / urban / semi urban.
- Vertical bifacial panels have higher bi-faciality compared to the regular bifacial plants. There would be several additional costs in terms of specific foundations being laid. The orientation is key here. However, there would be certain shading of the crops, also as a fence there might be damaged. Generally, there would be certain losses in power generation, sometimes up to 20 %.
- The land lease agreement is done for 27 years, the state regulatory body decides on the rent without any negotiation from either the farmer or by the Developer with a 3 % increase in the lease rate per year. Especially in Maharashtra, MSSEDCL has waived the legal cost that is incurred in the process to Developer and have made a very clear SOP on the guidelines that is very clear to understand and follow. The ownership after the lease agreement stays with the Developer. The agreement could either end or continue based on mutual agreement. However, to maintain the quality of soil lesser concrete structures shall be used in the upcoming installations.
- Economics for viable installations should be worked upon by trying different combinations and structures based on requirement. The overall synergy understanding is needed through awareness camps, more advanced approaches with series of sessions are required for better understanding. Government subsidies are crucial in the scale up of Agrivoltaics projects in the years to come. The definition of Agrivoltaics is crucial in the days to come to having a clear framework defining all the parameters like LER, GCR etc.
- The land lease agreements confine the farmer from taking further loans for agricultural processes. This could be very important to have more clarity on how the land legalities could be worked out.

8.5 Policy advocacy

- **Ease of Financing:** As observed in multiple farmer workshops, high upfront costs were stated as a major hindrance in adoption of Agrivoltaics on their farms. Since multiple farmers groups stated their interest in farmer-led models of adoption via FPOs, access to easy debt financing instruments became a necessity for implementation. Policy intervention to incentivize financial institutions, such as NBFCs, Micro-finance Institutions (MFIs), Small Finance Banks (SFBs) and Public Sector Banks to provide credit to individual farmers and farmer groups, through instruments such as credit guarantee schemes, interest subvention schemes etc. will enable farmers to undertake credit. The Ministry of New and Renewable Energy has issued “Lending guidelines under Component-A of PM KUSUM. It is essential to enforce adherence to these guidelines, thus ensuring clarity and an easy process for farmers, including minimal/easy documentation, and low margin, and acceptable security (not the farmland) for the loan.
- **Land Legalities:** The lack of clarity in land regulations post installing a Solar PV plant on agricultural land was also brought up as a significant issue by developers and farmers as well. Therefore, consistent nation-wide regulations for categorization of agricultural land post installation of solar PV plant should be issued. These regulations should recognize agricultural practice underneath the solar panels, thus enabling farmers to access agricultural benefits (farm loans etc.), while availing benefits through solar energy generation. The issue of commercial taxations on agricultural land should also be addressed, as lack of clarity may lead to misuse of existing rules. The generation of energy through multiple renewable energy sources, such as solar, biogas etc. should be addressed by the relevant regulatory authority. In addition, consistency in the regulatory framework nation-wide is essential for wide-spread adoption of Agrivoltaics. Wider inter-ministerial consultations and regulatory bodies are required to achieve the same. An updated study on land legalities as an extension to the current one is required to understand state wise approach.
- **Stakeholder Consultations between Farmers, DISCOMs, Developers and State Nodal Agencies:** It was observed through the farmer training workshops that it is essential to conduct wider stakeholder consultations with DISCOMs and Developers on the same platform. This is essential in bridging the gap between the 3 partners and to address concerns raised by farmers. Issues with DISCOMs such as delay in billings, payments, load shedding and high transmission losses may be addressed through these consultations, and DISCOMs must share their initiatives to address these issues. Appointment of a regional nodal officer by SNAs will ease dissemination of such information amongst farmers, while providing easy resolution of their issues.
- Similarly, concerns regarding leasing of land, disposal of PV panels post 25 years, lease rent etc. need to be addressed by developers to promote confidence for adoption of this model amongst farmers.
- **Promoting Inclusion:** The adoption of Agrivoltaics in India rests on inclusion of the most marginalized groups in farming, i.e. women farmers, small & marginal farmers. Hence, appropriate steps should be taken to incentivize wider adoption of Agrivoltaics amongst these groups. One such measure proposed is allowing smaller capacity Agrivoltaics plants under PM-KUSUM Comp A scheme, which requires smaller sized land, and lower capital for installations, thus allowing small and marginal farmers to install APV plants. Cheaper debt financing to women has also proven to be instrumental for wider economic growth in rural regions and creation of jobs.
- **Research and Development:** An impetus towards the research and development in the field of Agrivoltaics is essential for its widespread adoption. While installation of Model PV plants in all states of the country has been recognized as an important step towards familiarizing farmers towards Agrivoltaics, further research on suitability of various crops (especially staple crops), reducing yield penalty, and new technologies for maintenance of solar panels were widely discussed. In addition, involvement of State Agricultural Universities for research in this field, will also lead to solutions to region specific issues, such as cultivation of paddy crops in agriculturally intensive states, and cleaning of panels with minimal use of water in arid/semi-arid regions etc. Suitable dissemination of best practices through suitable institutions amongst farmers, in regional language through farmer networks, such as KVKs, will also lead to increase in familiarity.
- **Convergence of suitable schemes,** such as PM-KUSUM, Mission for Integrated Development of Horticulture Scheme, PM-Krishi Sinchayee Yojana, and Agricultural Infrastructure Fund, implemented by Ministry of New and Renewable Energy and Ministry of Agriculture and Farmer's Welfare is essential for holistic approach towards achieving widespread

adoption of Agrivoltaics in India. Currently, the farmers are apprehensive about losing benefits towards agricultural schemes, if they adopt for installation of solar panels on their fields. In addition, since Agrivoltaics requires investment for micro-irrigation systems, farming of fruits and vegetables, and may require installation of Agri-infrastructure (such as solar fencing to ward off animals, water tanks etc.), convergence of multiple schemes provides ease towards implementation by its beneficiaries.

- As Agrivoltaics gains traction in the country, multiple stakeholders have emphasized the importance of developing standards for Agrivoltaics. This will enable further commercial adoption of Agrivoltaics, enabling farmers' confidence towards efficiency of solar panels, its durability and obtaining maximum advantage through suitable farming on the same land. These standards will also enforce essential safeguards for agricultural and arable-lands.

List of scoping studies

S.No	Study	Implemented by
1	Scoping the AgriPV Landscape in India	NSEFI and Auroville
2	Assessing upscaling opportunities for AgriPV Systems in India	Vasudha Foundation
3	Strengthening gender transformative approaches in Agrivoltaics sector in India	Amita Bhaduri, Independent consultant
4	Agrivoltaics in India : Challenges and opportunities for scale	IISD
5	Agrisolar best practices guidelines India	Solar Power Europe
6	Legal aspects of Agrivoltaics in India	NSEFI
7	Setting up of Optimum Design Parameters for Agrivoltaic Power Plants in Indian Geo-Climatic Conditions	GSES

Site visits and reach out

No	Place	Visitors	Number of participants	Purpose of Visit	Date
1	Manwath AgriPV Plant	Max Trommsdorff (Fraunhofer ISE) GIZ-staff	4	Showcasing AgriPV	25 th of March 2023
2	Manwath AgriPV Plant	Parbhani Agri University incl. Vice Chancellor	7	Showcasing AgriPV	20th of April 2023
3	Manwath AgriPV Plant	MNRE, IARI, GIZ, PEDDA, IIT Ropar, NSEFI, KfW, CEEW, SunSeed, IWMI-Tata, CEEW, IREDA, SECI, MEDA, UNDP, MahaTransco	30	Delegation Visit, Showcasing AgriPV	08 th of May 2023
4	Manwath AgriPV Plant	CGIAR	2	Showcasing AgriPV	30 th of June 2023
5	Manwath AgriPV Plant	Student from Parbhani Agri-University	25	Training „Control environmental photosynthesis response curves for APV systems“	6 th of June 2023
6	Manwath AgriPV Plant	Kosher Climate, Hemakshi, Aurandathi	7	Discuss learning from 1 st farming season	11 th of July 2023

No	Place	Visitors	Number of participants	Purpose of Visit	Date
7	Manwath AgriPV Plant	Mahindra	8	Showcasing AgriPV	22 nd August 2023
8	Manwath AgriPV Plant	GSES	4	Midterm Review	8 th of September
9	Manwath AgriPV Plant	VNMKV-Research Team		Record of observation	28 th of September
10	Manwath AgriPV Plant	VNMKV – Research Team and Fontal Development Foundation (Amita Bhaduri)	14	Record of Site progress (VNMKV) and Women-Study interviews (FDF)	22 nd of November 2023
11	Manwath AgriPV Plant	Sunbiosys	3	Showcasing AgriPV Plant	9 th of January 2024
12	Manwath AgriPV Plant	IKI Team (GIZ, IWMI), Sunseed, VNMKV (Researcher and Vice Chancellor)	23	Learning and understanding of plant set-up	1 st of February 2024
13	Manwath AgriPV Plant	VNMKV	15	Inauguration & Launching of “GIZ - VNMKV Agriphotovoltaics” Research Project	11 th of March 2024
14	Manwath AgriPV Plant	GIZ	6	Video documentation on GIZ energy projects	5 th of June 2024
15	Manwath AgriPV Plant	VNMKV	10	Site visit season 3 planning	19 th of June 2024
16	Sahyadri Farm	Government of Orissa	14	Government of Orissa visited the Sahyadri farms and are planning to replicate similar APV installation	26 th of June 2024
17	Manwath AgriPV Plant	VNMKV	14	VNMKV Visit for scientific analysis	2 nd of July 2024
18	Manwath AgriPV Plant	Auroville, GIZ India	5	Site visit by Martin Scheffler from Auroville	18 th of July 2024
19	Nashik AgriPV Plant	Angela Heinssen, GIZ	2	Site visit to Nashik AgriPV Plant With Angela Heinssen	26 th of July 2024

9. Software simulation

To enable scalability of agrivoltaics it is important to have simulation models and decision support tools that can be used by both solar project developers and farmers alike to be able to design the projects appropriately and for predictability of their cash flows going forward. Henceforth, the data that has been collected from the DeveloPPP projects and other projects have been incorporated into making a crop growth model to help farming communities have an overview of a similar setup in their farmland.

The Agrivoltaics Decision Support Software & yield forecasting tool is based on Deep-tech simulation models based on scientific first principles.

Uses crop specific data generated from our research farms & from literature

Delivers intelligence for creating the best possible system design & development of crop specific

The software helps in making the following decisions for optimized Agrivoltaics design:

Solar Decisions	Agriculture Decisions
Agrivoltaics system selection: ➤ South facing Fixed Tilt ➤ E-W Single Axis Tracker ➤ E-W dual slope canopy ➤ Vertical PV ➤ APV Greenhouse	Detailed crop layout ➤ Distance between crops beds ➤ Crop bed orientation ➤ Bed position wrt to solar columns ➤ Bed width & Intra row crop spacing
Detailed design of the solar installation: ➤ Degree of transparency of the panels ➤ Dimensions-length & breadth ➤ Pitch between rows of panels ➤ Height of the panels ➤ Azimuth of the panels ➤ Panel configuration - 1P, 2P, 1L, 2L ➤ Intra row gaps between panels	Crop planning: ➤ Crop selection for all seasons ➤ Intercropping strategy ➤ Selection of climate screens- shade nets, poly sheets, ➤ Crop water requirements ➤ Integration of elements for microclimate control - foggers, fan-pads, etc ➤ Understanding the potential for changes in crop phenology

9.1 Introduction to crop growth models

Agrivoltaics commercial installations along with innovative research prototypes have picked up pace, as per a report by Fraunhofer ISE [1], worldwide installed capacity of agrivoltaics installations is at least 14 GW. Various countries are in process or have already enacted first generation policy measures to regulate and support agrivoltaics projects. DIN SPEC 91434:2021-05 Agri-photovoltaic systems - Requirements for primary agricultural use was created by collaboration of Fraunhofer ISE and Germany as one of the early policy frameworks for agrivoltaics projects. The Czech government introduced new legislation in 2024, approving agrivoltaics on 6 crop types, min. height of system to be 2.1m and keep min. of 95% area of project as agriculturally significant. In April, 2024 – Spain Govt. via the Department of Climate Action, Food and Rural Agenda (DACC) released guidelines for the deployment of agrivoltaic facilities –for Catalonia region only.

All such above guidelines/technical specifications would ultimately put some constraints on key infrastructure variables like min ground clearance of solar , ground coverage ratios, approved crop types, agriculturally significant area of project, and may even need agriculture output to be a fixed percentage of open land agriculture.

Developers, farmers and other stakeholders would need to evaluate various strategies that comply with the regulations set, and provide them with the highest chance of success or financial returns. Hence, there is need for a tool – that can be used for evaluating various cropping strategies w.r.t. the inputs or levers available that can change project efficiency. There are already some efforts on this. KU Leuven [3] released a free-to-use calculator – that allows the user to add latitude, longitudes, basic PV variables like module length/width/bifaciality factor, azimuth, tilt height, pitch – and select crops from a dropdown, then give yearly PV and agri yields.

However this tool has a limited crop set – and is based on outputs of a single study for crop behavior towards shade. The inputs w.r.t. crops are also limited – with no features for sowing dates, multi-cropping cycles in a year, bed-wise different crops which can create innovative strategies.

One crucial feature of any such a tool/platform would be an agile response to a developers requirement for a new crop that is not yet a part of the library. If one relies on standard crop simulation packages like APSIM or STICS , new crops take years of research to be added to these crop libraries – as they cover all aspects of plant growth like water, carbon, nitrogen fixation, fruiting/flowering - while in agrivoltaics the only major factor that changes is the light availability w.r.t. a non-agrivoltaic open field installation.

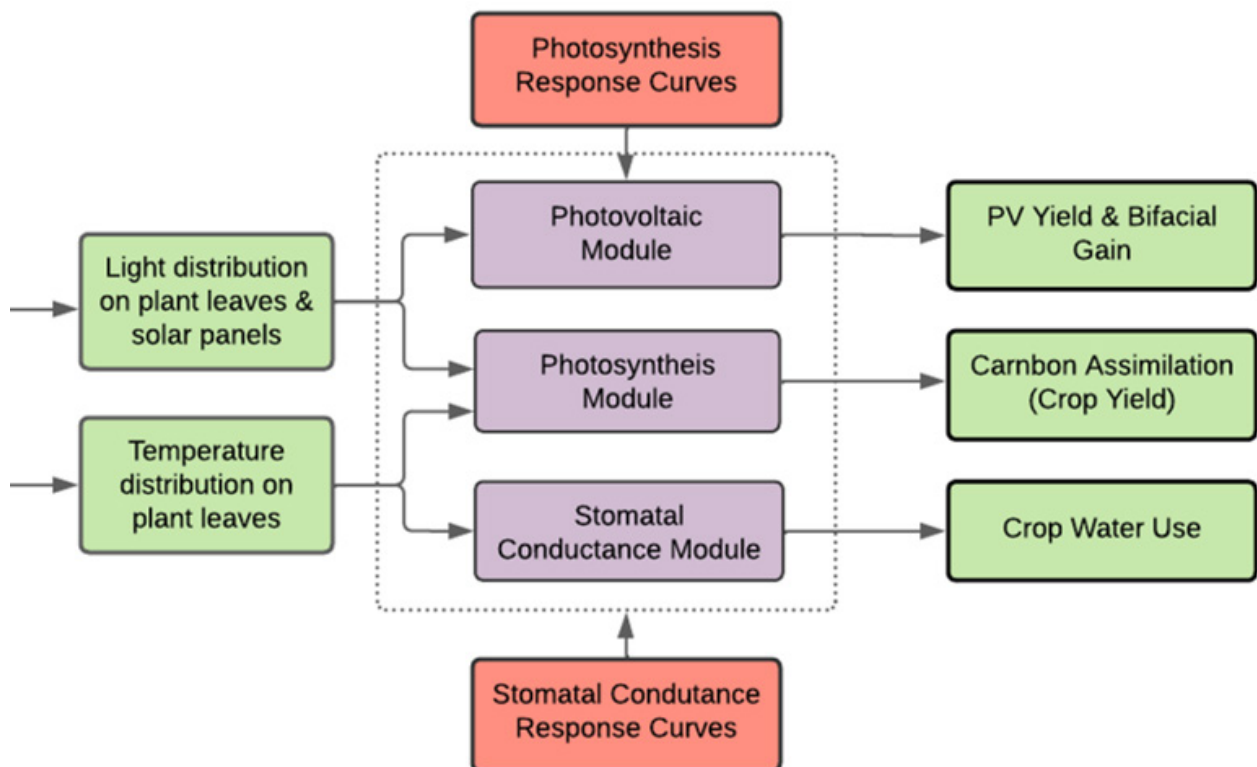
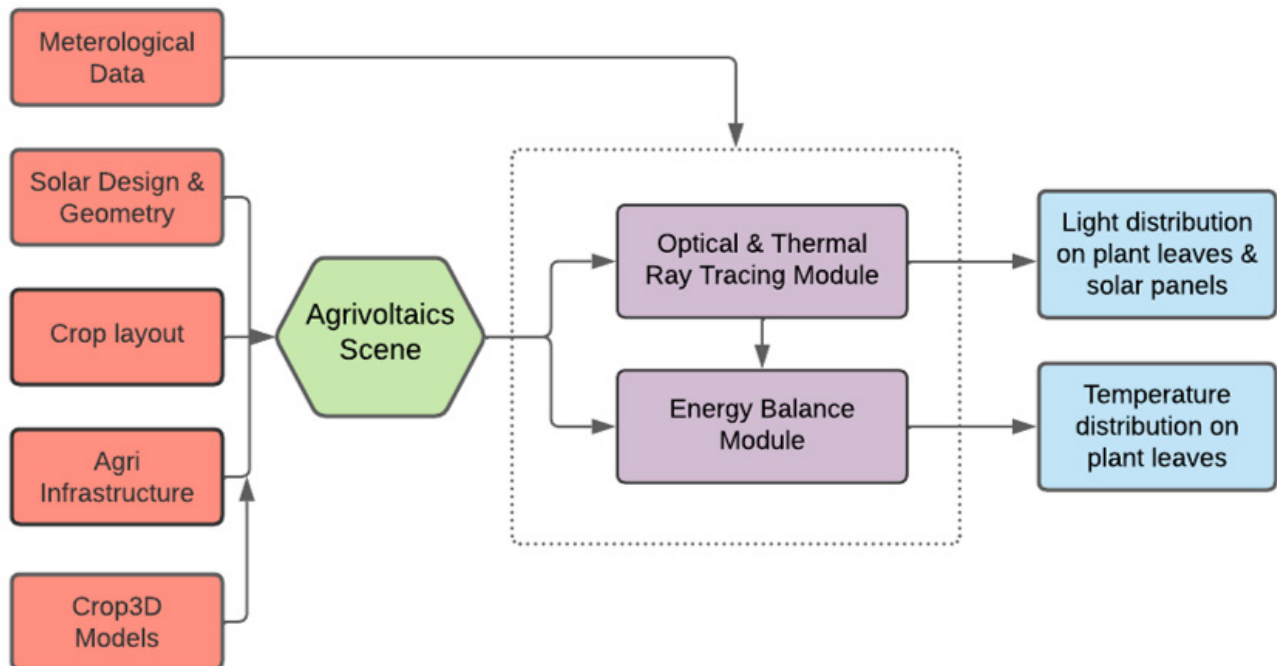
Hence, in the light of the above, it was concluded to subscribe to a carbon assimilation model based on a scientifically rigorous and widely accepted model for photosynthesis – the Farquhar, von Caemmerer and Berry model , henceforth called FvCB model for calculations. With this, in a matter of weeks to months – new crops can be profiled and added to the calculation set, thereby making the approach suitable for testing new crops and strategies. The paper describes the calculation approach and outputs of the tool, with its expected use-cases in APV scenarios.

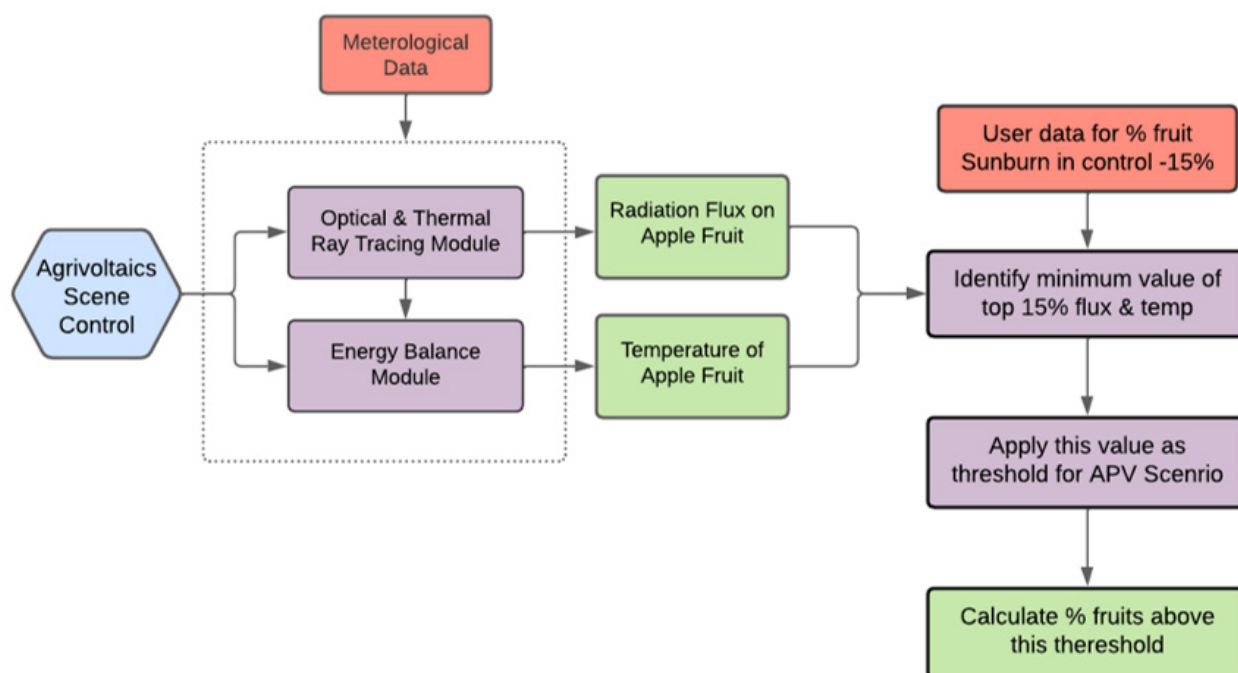
Further, carbon assimilation model has the following advantages –

- Hourly Shading can be accurately captured
- Light Saturation where leaves are absorbing light but not photosynthesizing, and hence resulting in inefficiency – this effect can be explicitly captured
- Temperature calculation of objects leads to bonus output – which can be used for further decision making on fruit-scalding
- PV Output can be captured that explicitly captures effect of plant canopy below in terms of reflected light
- Inter-plant shadow can be captured to arrive at efficient bed spacings

9.2 Approach followed (Introduction to light simulations, algorithm, digital twins)

With the above background, a cloud-based simulation tool was developed that allows users to create multiple simulations in 1 project that capture input related to almost all critical infrastructure variables – and provide a yearly output of various requisite parameters.





Method to estimate amount of sunburn & scalding

9.3 Farmcontroller, solar parameters and micro-climate

Each Project has a number of simulations which can be run together or simply just as 1 sim. A sim works out key quantities for the whole year ,starting from any arbitrary date. It has planting schedules that determine when a crop is planted. The life of the crop determines when the next schedule can be introduced. If a perennial crop is planted, the entire year's schedule is blocked for it. For each simulation, the below inputs are required from the user.

Table 2 List of Inputs for each simulation

Input Name	Description
PV-SIDE	
Location	To download Met data for simulation
Tilt	For orienting PV
Azimuth	For orienting PV
Configuration	Portrait, Landscape and numbers, for PV modules
Tracking/Ft	Type of technology used
Masking	To make one or more modules disappear after a set number
Height	Height from centre of PV chord line
Pitch	Distance between 2 rows of PV
Module	Module database pick – to take electrical properties
Agri-Side General	
Climate Screen	Polysheet or Shadenet screens to block and disperse/diffuse light
TEMPERATURE CONTROL	Whether temperature of air should be artificially restricted to certain limits
BED SPACINGS	For orienting crops
CROP CYCLE	To start and end crops in 1 calendar year, as one simulation

Input Name	Description
CROP TYPE	Selecting crop from the database
CROP SPACING	For orienting crops
ECONOMIC PARAMETERS	
Input Cost of Crop	This to be given w.r.t. 1 control simulation
Reference Yield of Crop	This to be given w.r.t. 1 control simulation
Reference Tariff for Solar	Hourly tariff numbers may be provided

This implies looking inside a single simulation and checking its results over an hour, day or year.

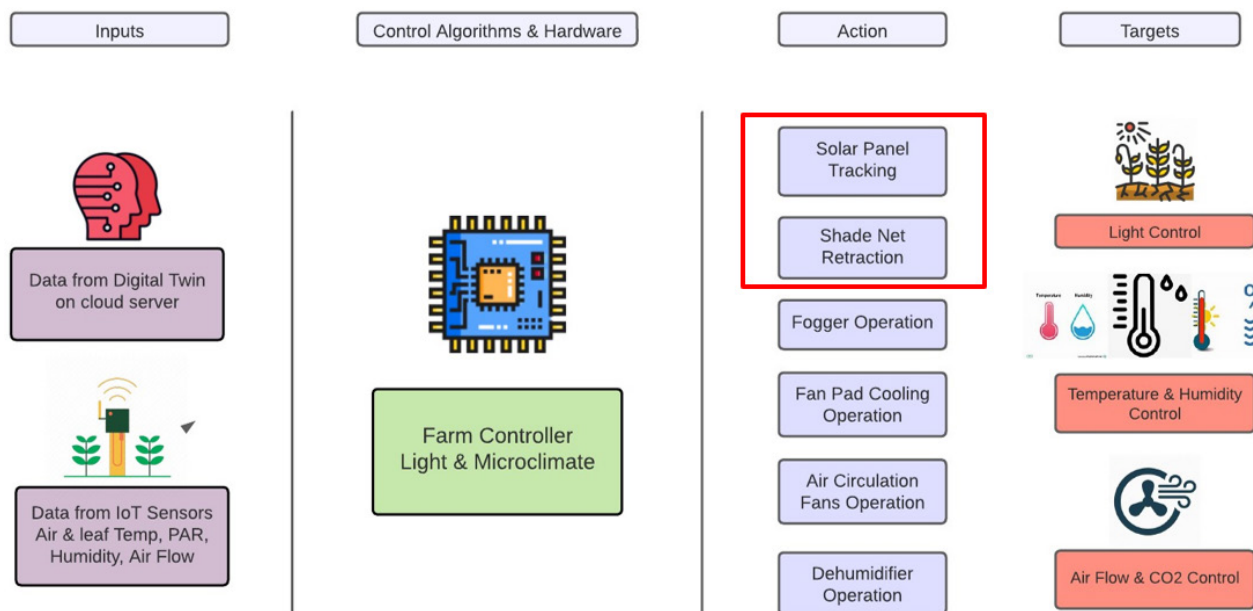
Table 3 Key Output Table

Output Name
3D Outputs
Daily Carbon Assimilation
3D APV Scene visualization
PPFD/DLI on ground
2D Outputs
Hourly Leaf Temperature
Hourly Carbon Assimilation
Bifacial Gain
MET Data Visualization
1D Outputs
Rate of Carbon Assim/plant
Average Leaf Temp
%Sunlit leaves/plant
Light Absorbed/plant
Penetration Efficiency
Saturation Extent/plant
Hourly PV DC Production

This implies comparing multiple simulation results to gain intelligence on relative performance. One of the simulations would be marked as control sim – to get economic study done considering that simulation as a reference.

Table 4 Key Output Table

Output Name
1 D Outputs
Cumulative Carbon Assimilation
Cumulative Transpiration
Cumulative PV DC Production
Average Bifacial Gain w.r.t Time
System Economics
Average Daytime Leaf Temperatures



Crop specific dynamic management of light & microclimate

9.4 Salient features of the simulation tool:

Thermal ray tracing combined with energy balance computations that accounts for crop transpiration calculates how heat is exchanged between the plant, soil, sky and PV modules and resolves the temperature distribution of the leaves.

The model uses real spectral properties of all the surfaces measured by a spectroradiometer to provide accurate absorption & reflection of the rays. Captures plant scale heterogeneity via the crop 3D model. It is important to quantify leaf-level variability in photosynthesis to understand how individual elements contribute to canopy level behavior.

A Study conducted by INRAE showed permanent photosynthetic capacity reduction by 25% in leaves which had more than 50% shade during the leaf development phase.

Plant photosynthesis data is being generated at SunSeed's research farms via Leaf-level gas exchange measurements collected using the LI-6800 portable photosynthesis system. 3 series of curves are sampled for actual plants: A-Ci curves, A-Q curves, and stomatal conductance VS light curves; all at a series of different temperatures. This data is used to derive coefficients for the FvCB (1980) mechanistic model for photosynthesis. The FvCB model is the most commonly used over the past four decades to study the response of C3 photosynthesis to the environment. The model predicts net photosynthesis rate (A) at any given environmental condition given by light flux & temperature provided by the ray tracing along with CO2 concentration and humidity.

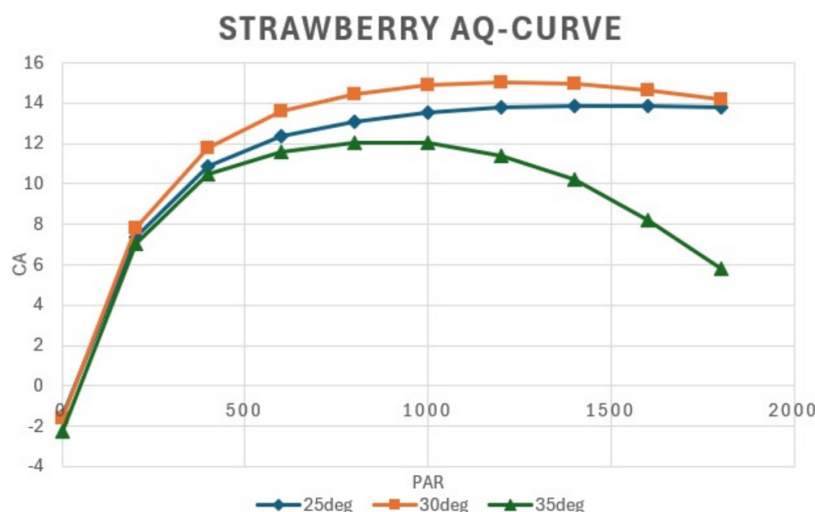


Figure 43: Machinery used

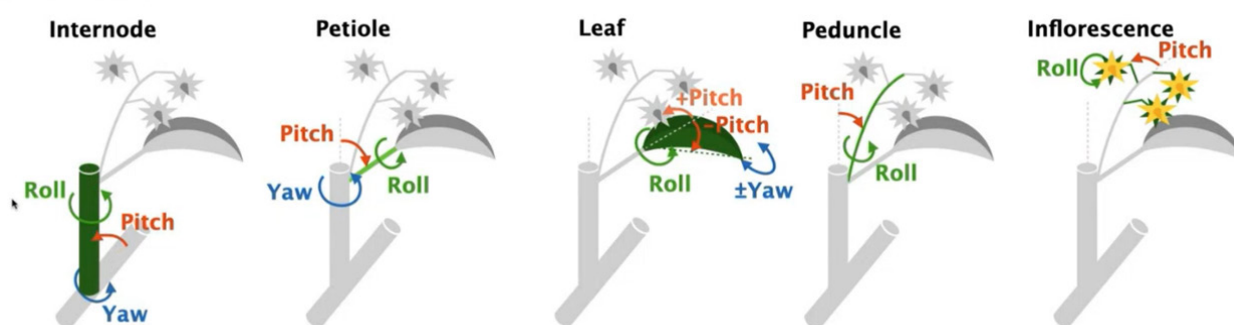


Sample curves generated for strawberries for modeling in the software

Plant Architecture model features

Agrivoltaics scene includes Plant Architecture 3D models developed using a combination of photogrammetry techniques, and a procedural plant generation software that requires real measurements of various plant parameters as inputs.

The model covers key organs: leaves, shoots, flowers and fruits, along with complex phenomena like dormancy to flowering, bud break probabilities and a statistical way of generating each part to ensure randomness that mimics the real world.



Internode Traits

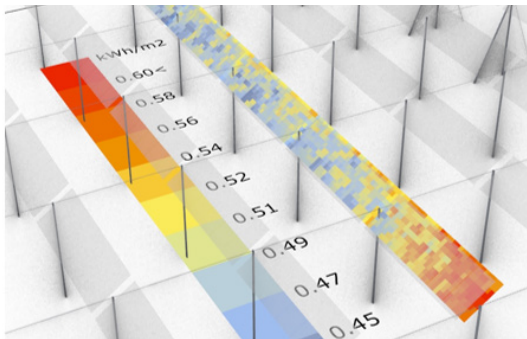
- Pitch, Phyllotactic angle
- Max buds, Probability of bud break
- Petiole traits:
 - Pitch, Radius, Length, Taper
 - Leaves, Petiole
 - Pitch, Yaw, Roll
 - Peduncle traits
 - Length, pitch, radius, roll

- Shoots traits:
 - Internode radius
 - Insertion angle
 - Roll, yaw
 - Flower, Fruit, Leaf
 - 3D photogrammetry image
- The plant models are not static, the model incorporates growth parameters of the plant including shoot and branch formation, number of leaves, leaf sizes as per the growth phase of the crop. The phenological threshold values (e.g., time to flowering) are also incorporated in the plant model



real vs model created strawberry plants

Output: The photovoltaic module delivers solar energy generation from the front surface of the panels, along with additional bifacial gain, calculated on an hourly basis.



The light distribution reaching the rear side of the panels is accurately converted into electricity generation using PVLlib — an open-source Python toolbox developed by Sandia National Laboratories.



The real-life modeling of the Agrivoltaics scene – with the 3D crop models, Agri infra, and optical properties of all the surfaces. This is not possible in PVSyst as albedo is an input to their bifacial calculation.

As a further detailed look, here is a graphic below that describes some more micro-modules and their interactions with each other. The real-life modelling of Agrivoltaics scene with 3D crop models can be seen in the above picture. This cannot be achieved on other popular Softwares that are currently available. The uniqueness of this software is to see the albedo effect and calibrate the electricity generation on the back side of the panels due to the light distribution.

9.5 Screenshots of step wise procedure showing inputs and outputs

The paper presents a reference run done w.r.t. a realistic sample scenario for planning an apple project in Israel.

Figure 44 : Scene visualization - Apple trees seen in the simulation, with leaf level details

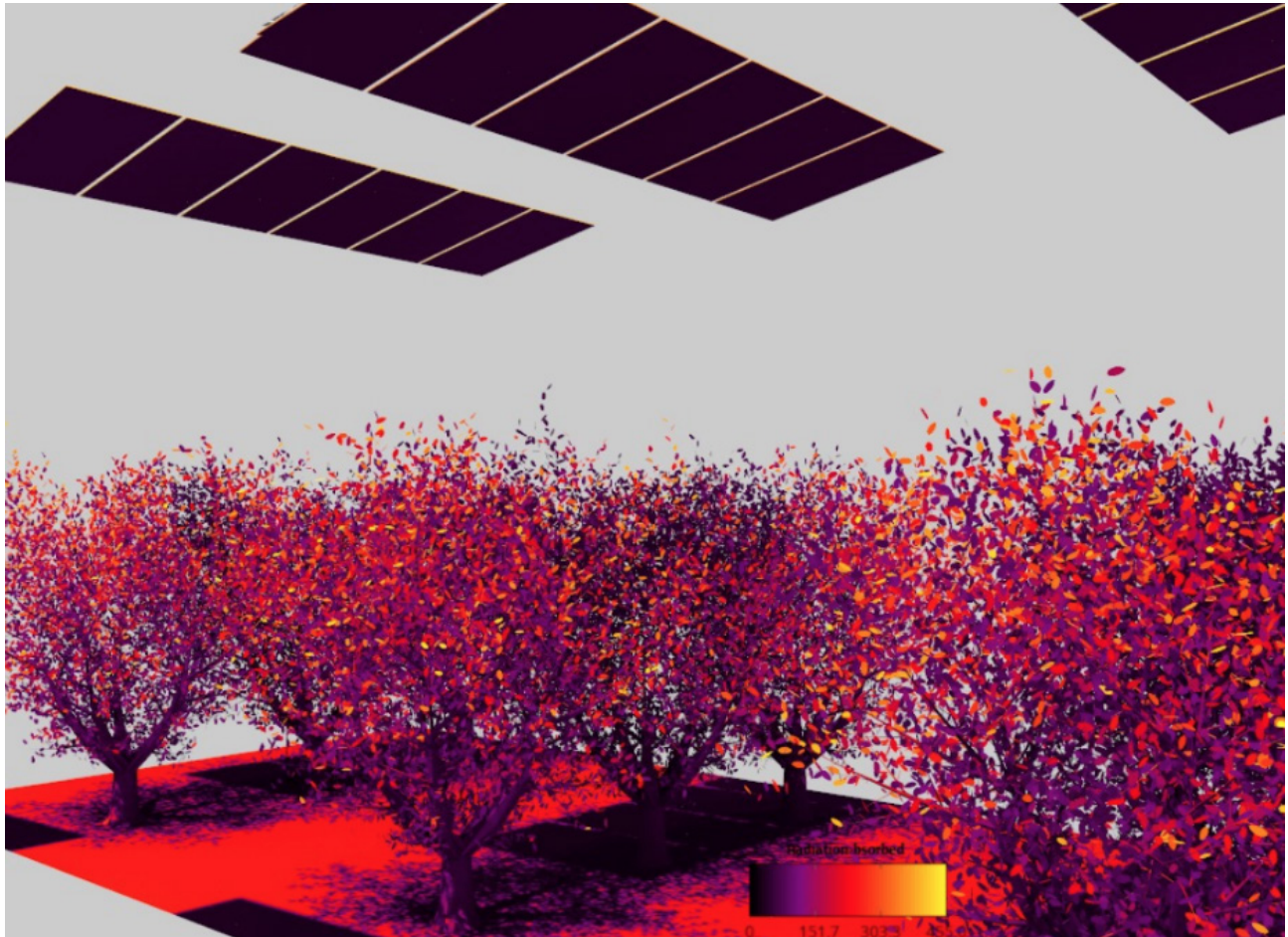


Figure 45 Carbon Assimilation Output – it is seen that open field output is not matched by any APV sims

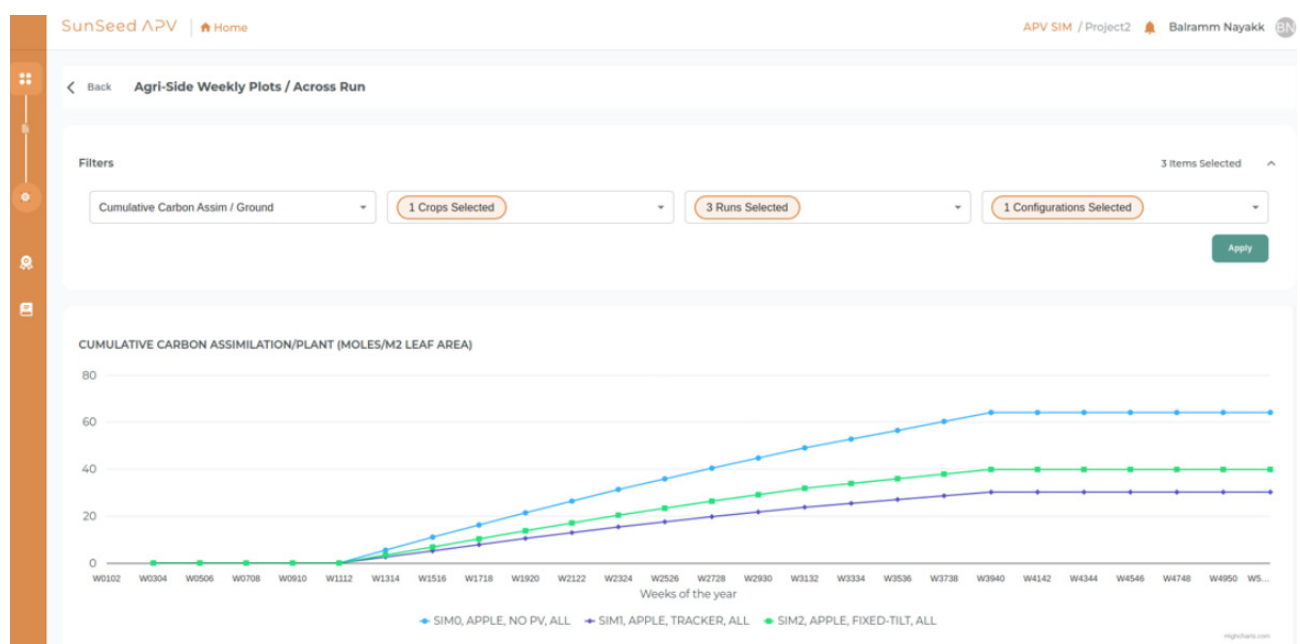


Figure 46 : Transpiration that gives an idea of differential water requirements – approx 20% water saving seen.

Leaf-Averaged Hourly Rate of Carbon Assimilation Across The Year (μ mole / m^2 / s)

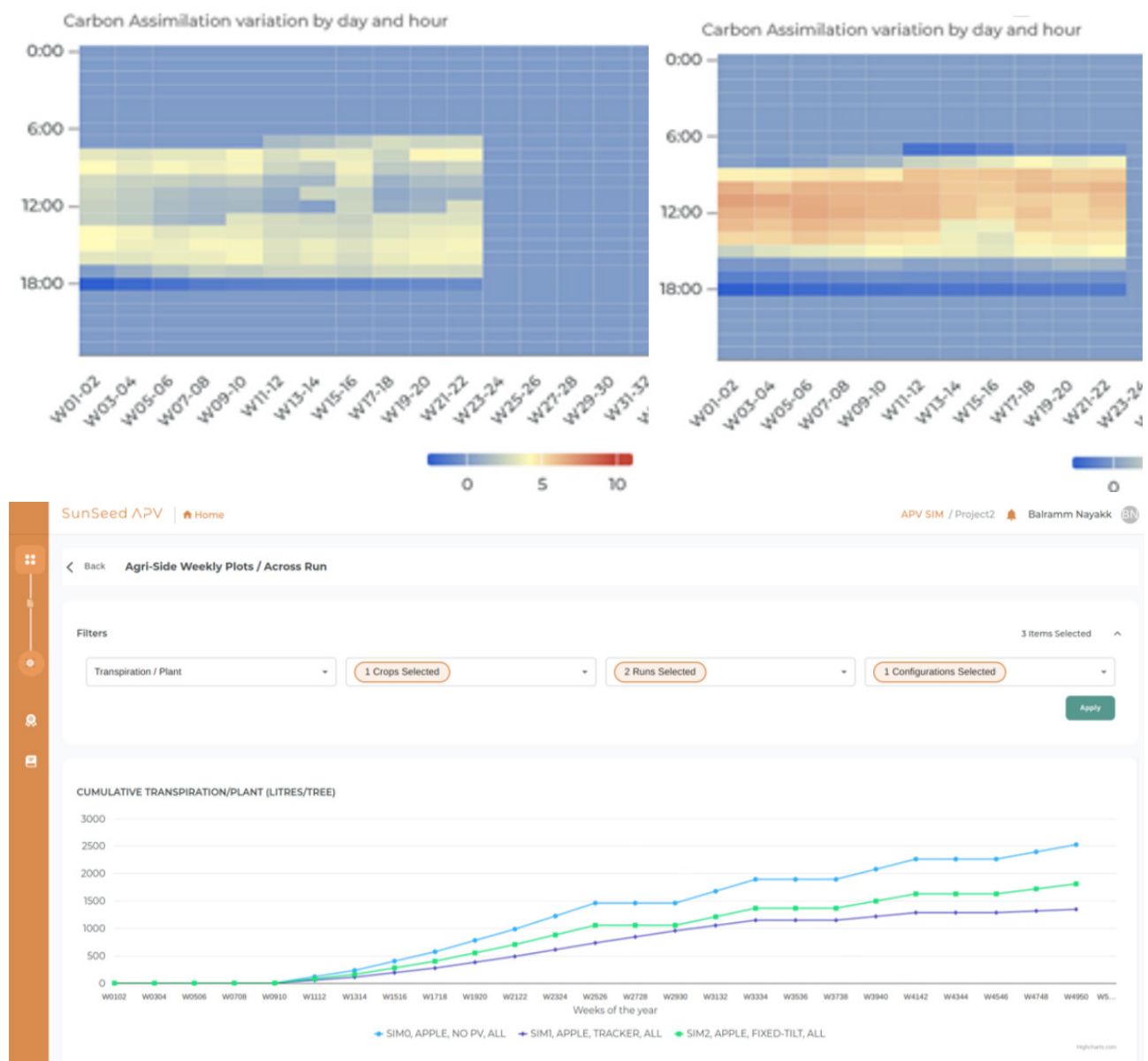
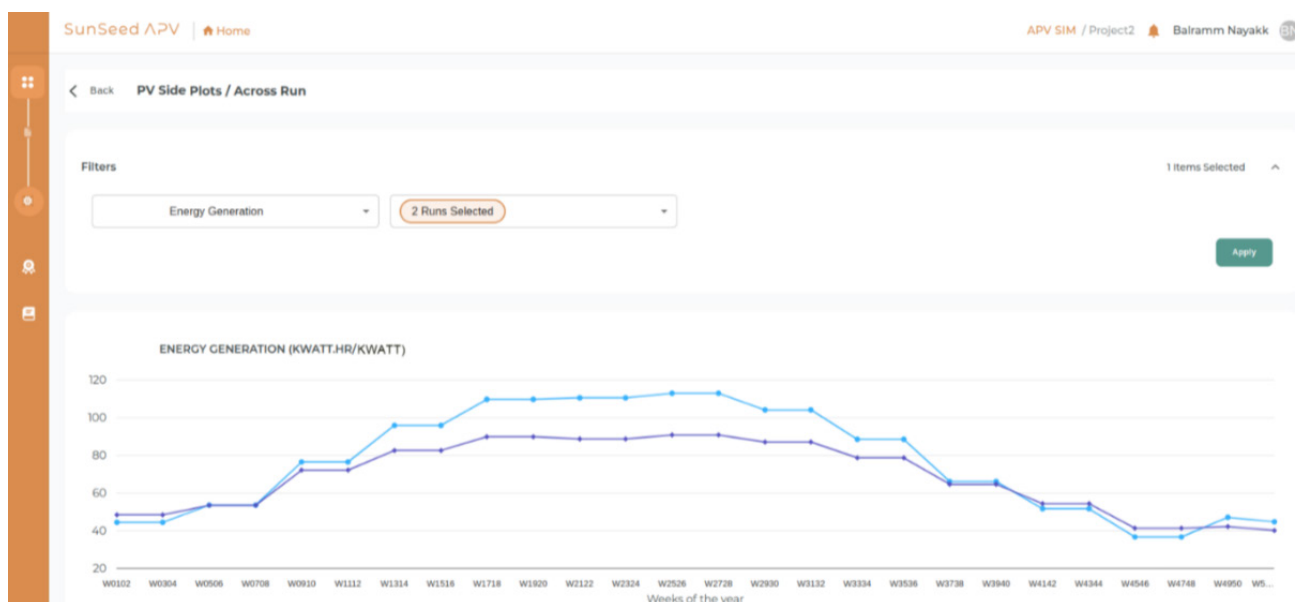


Figure 47: Energy Generation Daily – as expected tracker generates higher production



Annexure

The core algorithm and module descriptions are provided below in Fig and Table .

```

FOR EACH DAY OF THE YEAR
    FOR EACH HOUR OF THE DAY
        GENERATE SCENE
            CREATE MODULES AT APPROP TILT (IF TRACKED)
            CREATE PLANTS ON BEDS, AS PER EXPECTED GROWTH ON
            THE DAY OF SIM
            CREATE GROUND
            CREATE CLIMATE CONTROL SCREENS
        RUN RAY-TRACER AS PER DAY'S HISTORIC RADIATION
        RUN ENERGY BALANCE TO GET TEMPERATURE OF ALL OBJECTS
        RUN PHOTOSYNTHESIS ENGINE
        RE-RUN ENERGY BALANCE, IF REQD.
    GENERATE OUTPUTS AND PRESENT
  
```

Base Algorithm of the tool

Table 1 Core Scientific Modules

Ray-Tracer	This module is a backward ray tracer, with capabilities to accept spectrum level optical properties, and ability to run the analysis in separate bands, for PAR, NIR, LW
Energy-Balancer	Since carbon assimilation is dependent on temperature as a major input – energy balancer creates leaf energy balance models that output leaf temperature
Plant Architecture Generator	The plant is modelled in terms of its entire structure – leaf, petiole, phytomer, internode and entire shoots, with randomness assigned to each plant that is generated
Photosynthesis Engine	This collects the outputs of earlier modules, and with stomatal conductance calculations, provides a best estimate of carbon assimilation or photosynthesis rate for that hour of simulation.

Parameters	Unit	Normal Project Ground Mount FT	Agri PV Ground Mount FT	Agri PV Elevated FT	Agri PV Elevated Tracker
Total Project Cost Inc GST	₹ Cr/MW	3.12	3.34	3.88	4.26
Land Rent	₹ Cr/MW	0.0125	0.01375	0.0175	0.0175
CUF	%	18.26%	18.54%	19.45%	21.92%
LCOE	₹/kWh	3.06	3.13	3.36	3.31
Tariff	₹/kWh	3	3	3	3
Project IRR	%	12.83%	12.31%	13.41%	14.11%
Equity IRR	%	16.53%	15.26%	17.04%	18.90%

Sahyadri Farmers Producer Company Ltd - FFC LAB

Gat No-314/1,314/2/1, Mohadi - Dindori Road,
At Post-Mohadi, Tal-Dindori, Nashik, - 422207,
Maharashtra, India Email- ffclab@sahyadrifarms.com
Toll Free No.: 1800 212 00 2020 / 7066045937



SOIL TEST REPORT

Date of Sample Receipt :	12/08/2022	Test Report No :	FFCLAB/22/TR-01639
Customer Name :	Sunseed Agro		
Address :	AP Zari Tal Pathari Dist Parbhani		
Sample Description/Type :	Mango Tree Side	Contact No. :	8308998084
Sample ID :	SL/08/22/01	Sample Drawn By:	Nilesh Magar
Date of start Analysis :	14/08/2022	Date of Reporting :	16/08/2022
Sample Quantity/Packing :	1 KG	Invoice No. :	99030579
Batch Code :	NA	Gat No./ Plot No. :	NA

Sr. No.	Parameter	Result	Unit	LOQ	Limits	Test Method	Equipment used for Analysis
1	pH (पी. एच.)	8.25	NA	NA	6.5-7.5	SF/FFCLAB/TM/SL-03	pH METER
2	CEC (सी.ई.सी.)	34.6	meq/100g	NA	NA	SF/FFCLAB/TM/SL-13	NA
3	Electrical Conductivity (ई.सी.)	0.2	ds/m	NA	<1	SF/FFCLAB/TM/SL-04	EC METER
4	Organic Carbon (ऑर्गेनिक कार्बन)	1.11	%	NA	1.01-3.0	SF/FFCLAB/TM/SL-11	WET ANALYSIS
5	Organic Matter (संक्षिप्त घटक)	1.91	%	NA	4.0-10.0	SF/FFCLAB/TM/SL-11	WET ANALYSIS
6	Available Nitrogen (एवलेबल नाइट्रोजन)	72.8	PPM	NA	75-150	SF/FFCLAB/TM/SL-14	KJELDAL
7	P - Phosphorus (फॉस्फोरस)	19.1	PPM	NA	50-70	SF/FFCLAB/TM/SL-12	ICP-OES
8	K - Potassium (पोटेशियम)	150	PPM	NA	386-1143	SF/FFCLAB/TM/SL-12	ICP-OES
9	Ca - Calcium (कैल्शियम)	2359	PPM	NA	3928-10653	SF/FFCLAB/TM/SL-12	ICP-OES
10	Mg - Magnesium (मैग्नेशियम)	2204	PPM	NA	396-973	SF/FFCLAB/TM/SL-12	ICP-OES
11	S - Sulphur (सल्फर)	137	PPM	NA	30-50	SF/FFCLAB/TM/SL-12	ICP-OES
12	Fe - Ferrous (फेरस)	106	PPM	NA	40-200	SF/FFCLAB/TM/SL-12	ICP-OES
13	Mn - Manganese (मैंगनीज)	203	PPM	NA	30-100	SF/FFCLAB/TM/SL-12	ICP-OES
14	Zn - Zinc (ज़िंक)	2.71	PPM	NA	05-10	SF/FFCLAB/TM/SL-12	ICP-OES
15	Cu - Copper (कॉपर)	8.76	PPM	NA	02-07	SF/FFCLAB/TM/SL-12	ICP-OES
16	B - Boron (बोरॉन)	146	PPM	NA	01-03	SF/FFCLAB/TM/SL-12	ICP-OES
17	Mo - Molybdenum (मॉलिब्डेनम)	0.99	PPM	NA	0.5-2	SF/FFCLAB/TM/SL-12	ICP-OES
18	Na - Sodium (सोडियम)	937	PPM	NA	50-183	SF/FFCLAB/TM/SL-12	ICP-OES
19	Cl - Chlorides (क्लोराइड)	1042	PPM	NA	<350	SF/FFCLAB/TM/SL-05	WET ANALYSIS
20	Calcium Carbonate (चूना)	10.45	%	NA	<3	SF/FFCLAB/TM/SL-06	WET ANALYSIS
21	Carbonate (कार्बोनेट)	NII	meq/kg	NA	NA	SF/FFCLAB/TM/SL-07	WET ANALYSIS
22	Bi-carbonate (बायकार्बोनेट)	420	meq/kg	NA	NA	SF/FFCLAB/TM/SL-07	WET ANALYSIS
23	Pb-Lead (शिसे)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
24	Cd-Cadmium (केडमियम)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
25	Co-Cobalt (कोबाल्ट)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
26	Si-Silica (सिलिका)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES

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HIGH
OPTIMUM
LOW

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Authorised Signatory

Page 1 of 1

Test Report No. : FFCLAB/22/TR-01639

Sahyadri Farmers Producer Company Ltd - FFC LAB

Gat No-314/1,314/2/1, Mohadi - Dindori Road,
At Post-Mohadi, Tal-Dindori, Nashik, - 422207,
Maharashtra, India Email- ffclab@sahyadrifarms.com
Toll Free No.: 1800 212 00 2020 / 7066045937



SOIL TEST REPORT

Date of Sample Receipt :	12/08/2022	Test Report No :	FFCLAB/22/TR-01640
Customer Name :	Sunseed Agro		
Address :	AP Zari Tal Pathari Dist Parbhani		
Sample Description/Type :	Shed Nett Side	Contact No. :	8308998084
Sample ID :	SL/08/22/02	Sample Drawn By:	Nilesh Magar
Date of start Analysis :	14/08/2022	Date of Reporting :	16/08/2022
Sample Quantity/Packing :	1 KG	Invoice No. :	99030579
Batch Code :	NA	Gat No./ Plot No. :	NA

Sr. No.	Parameter	Result	Unit	LOQ	Limits	Test Method	Equipment used for Analysis
1	pH (पी. एच.)	8.22	NA	NA	6.5-7.5	SF/FFCLAB/TM/SL-03	pH METER
2	CEC (सी.ई.सी.)	33.8	meq/100g	NA	NA	SF/FFCLAB/TM/SL-13	NA
3	Electrical Conductivity (ई.सी.)	0.2	ds/m	NA	<1	SF/FFCLAB/TM/SL-04	EC METER
4	Organic Carbon (ऑर्गेनिक कार्बन)	0.76	%	NA	1.01-3.0	SF/FFCLAB/TM/SL-11	WET ANALYSIS
5	Organic Matter (सैद्धय घटक)	1.31	%	NA	4.0-10.0	SF/FFCLAB/TM/SL-11	WET ANALYSIS
6	Available Nitrogen (एवलेबल नाइट्रोजन)	84	PPM	NA	75-150	SF/FFCLAB/TM/SL-14	KJELDAL
7	P - Phosphorus (फॉस्फोरस)	27.3	PPM	NA	50-70	SF/FFCLAB/TM/SL-12	ICP-OES
8	K - Potassium (पोटेशियम)	231	PPM	NA	386-1143	SF/FFCLAB/TM/SL-12	ICP-OES
9	Ca - Calcium (कैल्शियम)	2354	PPM	NA	3928-10653	SF/FFCLAB/TM/SL-12	ICP-OES
10	Mg - Magnesium (मैग्नेशियम)	2030	PPM	NA	396-973	SF/FFCLAB/TM/SL-12	ICP-OES
11	S - Sulphur (सल्फर)	113	PPM	NA	30-50	SF/FFCLAB/TM/SL-12	ICP-OES
12	Fe - Ferrous (फेरस)	101	PPM	NA	40-200	SF/FFCLAB/TM/SL-12	ICP-OES
13	Mn - Manganese (मैंगनीज)	245	PPM	NA	30-100	SF/FFCLAB/TM/SL-12	ICP-OES
14	Zn - Zinc (ज़िंक)	3.2	PPM	NA	05-10	SF/FFCLAB/TM/SL-12	ICP-OES
15	Cu - Copper (कॉपर)	6.5	PPM	NA	02-07	SF/FFCLAB/TM/SL-12	ICP-OES
16	B - Boron (बोरॉन)	144	PPM	NA	01-03	SF/FFCLAB/TM/SL-12	ICP-OES
17	Mo - Molybdenum (मॉलिब्डेनम)	0.99	PPM	NA	0.5-2	SF/FFCLAB/TM/SL-12	ICP-OES
18	Na - Sodium (सोडियम)	1037	PPM	NA	50-183	SF/FFCLAB/TM/SL-12	ICP-OES
19	Cl - Chlorides (क्लोराइड)	695	PPM	NA	<350	SF/FFCLAB/TM/SL-05	WET ANALYSIS
20	Calcium Carbonate (चूना)	12.35	%	NA	<3	SF/FFCLAB/TM/SL-06	WET ANALYSIS
21	Carbonate (कार्बोनेट)	Nil	meq/kg	NA	NA	SF/FFCLAB/TM/SL-07	WET ANALYSIS
22	Bi-carbonate (बायकार्बोनेट)	535	meq/kg	NA	NA	SF/FFCLAB/TM/SL-07	WET ANALYSIS
23	Pb-Lead (शिसे)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
24	Cd-Cadmium (केडमियम)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
25	Co-Cobalt (कोबाल्ट)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
26	Si-Silica (सिलिका)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES

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Page 1 of 1

Test Report No. : FFCLAB/22/TR-01640

Sahyadri Farmers Producer Company Ltd - FFC LAB

Gat No-314/1,314/2/1, Mohadi - Dindori Road,
At Post-Mohadi, Tal-Dindori, Nashik, - 422207,
Maharashtra, India Email- ffclab@sahyadrifarms.com
Toll Free No.: 1800 212 00 2020 / 7066045937



SOIL TEST REPORT

Date of Sample Receipt :	12/08/2022	Test Report No :	FFCLAB/22/TR-01641
Customer Name :	Sunseed Agro		
Address :	AP Zari Tal Pathari Dist Parbhani		
Sample Description/Type :	Cannel Side	Contact No. :	8308998084
Sample ID :	SL/08/22/03	Sample Drawn By:	Nilesh Magar
Date of start Analysis :	14/08/2022	Date of Reporting :	16/08/2022
Sample Quantity/Packing :	1 KG	Invoice No. :	99030579
Batch Code :	NA	Gat No./ Plot No. :	NA

Sr. No.	Parameter	Result	Unit	LOQ	Limits	Test Method	Equipment used for Analysis
1	pH (पी. एच.)	8.21	NA	NA	6.5-7.5	SF/FFCLAB/TM/SL-03	pH METER
2	CEC (सी.ई.सी.)	30.4	meq/100g	NA	NA	SF/FFCLAB/TM/SL-13	NA
3	Electrical Conductivity (ई.सी.)	0.2	ds/m	NA	<1	SF/FFCLAB/TM/SL-04	EC METER
4	Organic Carbon (ऑर्गेनिक कार्बन)	0.93	%	NA	1.01-3.0	SF/FFCLAB/TM/SL-11	WET ANALYSIS
5	Organic Matter (सैद्धि घटक)	1.60	%	NA	4.0-10.0	SF/FFCLAB/TM/SL-11	WET ANALYSIS
6	Avilable Nitrogen (एवलेबल नायट्रोजन)	78.4	PPM	NA	75-150	SF/FFCLAB/TM/SL-14	KJELDAL
7	P - Phosphorus (फॉस्फोरस)	26.8	PPM	NA	50-70	SF/FFCLAB/TM/SL-12	ICP-OES
8	K - Potassium (पोटेशियम)	159	PPM	NA	386-1143	SF/FFCLAB/TM/SL-12	ICP-OES
9	Ca - Calcium (कैल्शियम)	2352	PPM	NA	3928-10653	SF/FFCLAB/TM/SL-12	ICP-OES
10	Mg - Magnesium (मैग्नेशियम)	1594	PPM	NA	396-973	SF/FFCLAB/TM/SL-12	ICP-OES
11	S - Sulphur (सल्फर)	122	PPM	NA	30-50	SF/FFCLAB/TM/SL-12	ICP-OES
12	Fe - Ferrous (फेरस)	118	PPM	NA	40-200	SF/FFCLAB/TM/SL-12	ICP-OES
13	Mn - Manganese (मैंगनीज)	229	PPM	NA	30-100	SF/FFCLAB/TM/SL-12	ICP-OES
14	Zn - Zinc (ज़िंक)	3.18	PPM	NA	05-10	SF/FFCLAB/TM/SL-12	ICP-OES
15	Cu - Copper (कॉपर)	6.86	PPM	NA	02-07	SF/FFCLAB/TM/SL-12	ICP-OES
16	B - Boron (बोरॉन)	148	PPM	NA	01-03	SF/FFCLAB/TM/SL-12	ICP-OES
17	Mo - Molybdenum (मॉलिब्डेनम)	0.98	PPM	NA	0.5-2	SF/FFCLAB/TM/SL-12	ICP-OES
18	Na - Sodium (सोडियम)	1132	PPM	NA	50-183	SF/FFCLAB/TM/SL-12	ICP-OES
19	Cl - Chlorides (क्लोराइड)	869	PPM	NA	<350	SF/FFCLAB/TM/SL-05	WET ANALYSIS
20	Calcium Carbonate (चूना)	9.50	%	NA	<3	SF/FFCLAB/TM/SL-06	WET ANALYSIS
21	Carbonate (कार्बोनेट)	NIL	meq/kg	NA	NA	SF/FFCLAB/TM/SL-07	WET ANALYSIS
22	Bi-carbonate (बायकार्बोनेट)	499	meq/kg	NA	NA	SF/FFCLAB/TM/SL-07	WET ANALYSIS
23	Pb-Lead (शिसे)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
24	Cd-Cadmium (केडमियम)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
25	Co-Cobalt (कोबाल्ट)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES
26	Si-Silica (सिलिका)	NA	PPM	NA	NA	SF/FFCLAB/TM/SL-12	ICP-OES

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outside farm



भारतीय कृषि अनुसंधान परिषद, नवी दिल्ली पुरस्कृत आणि जीवन ज्योत चॅरिटेबल ट्रस्ट, परभणी संचालित

कृषि विज्ञान केंद्र

जितुर रोड, परभणी ४३१४०१ फोन : (०२४५२) २२३०४५



मृदा परिक्षण अहवाल

पावती क्र: ११२१

दिनांक २३/१०/२०२२

शेतकऱ्यांचे नाव : मधुकर राधाधु शेदेगे

सर्व्हे नं / गट क्र.: ५५१/२

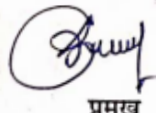
गांव : मागवत तालुका : मागवत

जिल्हा : परभणी

अ. क्र.	गुणधर्म	निरीक्षण	स्पष्टीकरण
१	सामु (पी.एच.)	८.००	चांगले
२	क्षारता (इसी) डेसी सायमन /मी	०.२५	चांगले
३	संद्रीय कार्ब (टक्के) (ऑर्गॅनिक कार्बन)	०.५५	मध्यम
४	उपलब्ध नत्र (कि./हे.) (N)	२२६.५	मध्यम
५	उपलब्ध स्फुरद (कि./हे.) (P)	१.५	कमी
६	उपलब्ध पालाश (कि./हे.) (K)	५६९.६	अर्बुद (अधिक)
७	मुक्त चुना (टक्के) (CaCO ₃)	८.३८	चुनायुक्त मृदा
८	उपलब्ध गंधक (S) (पीपीएम)	६.००	कमी
९	उपलब्ध जस्त (Zn) (पीपीएम)	०.९१०	मध्यम
१०	उपलब्ध बोरॉन (B) (पीपीएम)	०.३१५	कमी
११	उपलब्ध लोह (Fe) (पीपीएम)	१०९५	कमी
१२	उपलब्ध मंगल (Mn) (पीपीएम)	१५.५०	कमी
१३	उपलब्ध तांबे (Cu) (पीपीएम)	—	—

अ. क्र.	पीक	हंगाम	शेणखत (गाडया / हे.)	शिफारस केलेली मात्रा कि. / हेक्टर		
				नत्र	स्फुरद	पालाश

अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा	अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा
१	गंधक (S)		४	लोह (Fe)	
२	जस्त (Zn)		५	मंगल (Mn)	
३	बोरॉन (B)		६	तांबे (Cu)	



Krusha Vigyan Kendra
Jintur Road, Parbhani

प्रमुख
माती आणि पाणी परिक्षण प्रयोगशाळा,

वरिष्ठ शास्त्रज्ञ व प्रमुख
कृषि विज्ञान केंद्र, परभणी

विशेष शिफारस : सेंद्रिय व हिरवळीच्या खतांचा जादा वापर

3.75



भारतीय कृषि अनुसंधान परिषद, नवी दिल्ली पुरस्कृत आणि जीवन ज्योत चॅरिटेबल ट्रस्ट, परभणी संचालित

कृषि विज्ञान केंद्र

जिंतुर रोड, परभणी ४३१४०१ फोन : (०२४५२) २२३०४५



मृदा परिक्षण अहवाल

पावती क्र: १११९

दिनांक : ०२/१२/२०२२

शेतकऱ्यांचे नांव : श्रीशिकुल मधुकर शिंदे सर्व्हे नं / गट क्र.: ५५१/२

गांव : भोगवत तालुका : भोगवत जिल्हा : परभणी

अ. क्र.	गुणधर्म	निरीक्षण	स्पष्टीकरण
१	सामु (पी.एच.)	७.९१	चांगले
२	क्षारता (इसी) डेसी सायमन/मी	०.१७०	चांगले
३	सैद्रीय कार्ब (टक्के) (ऑर्गॅनिक कार्बन)	०.१२	शेथील अथिड
४	उपलब्ध नत्र (कि./हे.) (N)	३०५.५	मध्यम
५	उपलब्ध स्फुरद (कि./हे.) (P)	१८.१	मध्यम
६	उपलब्ध पालाश (कि./हे.) (K)	२८६.५	मध्यम
७	मुक्त चुना (टक्के) (CaCo ₃)	९.०५	चुकीय अतिरिक्त
८	उपलब्ध गंधक (S) (पीपीएम)	१२.७	मध्यम
९	उपलब्ध जस्त (Zn) (पीपीएम)	०.८९९	कमी
१०	उपलब्ध बोरॉन (B) (पीपीएम)	०.९११	उत्तरे
११	उपलब्ध लोह (Fe) (पीपीएम)	२.०९	कमी
१२	उपलब्ध मंगल (Mn) (पीपीएम)	११.५०	उत्तरे
१३	उपलब्ध तांबे (Cu) (पीपीएम)	—	—

अ. क्र.	पीक	हंगाम	शेणखत (गाडया / हे.)	शिफारस केलेली मात्रा कि. / हेक्टर		
				नत्र	स्फुरद	पालाश

अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा	अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा
१	गंधक (S)		४	लोह (Fe)	
२	जस्त (Zn)		५	मंगल (Mn)	
३	बोरॉन (B)		६	तांबे (Cu)	

Krushvi Vigyan Kendra
Jintur Road, Parbhani

प्रमुख

माती आणि पाणी परिक्षण प्रयोगशाळा,

वरिष्ठ शास्त्रज्ञ व प्रमुख
कृषि विज्ञान केंद्र, परभणी

विशेष शिफारस : सेंद्रिय व हिरवळीच्या खतांचा जादा वापर

monopical 1.75



भारतीय कृषि अनुसंधान परिषद, नवी दिल्ली पुरस्कृत आणि जीवन ज्योत चॅरिटेबल ट्रस्ट, परभणी संचालित

कृषि विज्ञान केंद्र

जिंतुर रोड, परभणी ४३१४०१ फोन : (०२४५२) २२३०४५



मृदा परिक्षण अहवाल

पावती क्र: १११४

दिनांक: ०३/१२/२०२२

शेतकऱ्यांचे नाव: अशोक मोरामाजी अदो सर्वे नं / गट क्र.: ५०

गांव: भांगवत तालुका: भांगवत जिल्हा: पुणे

अ. क्र.	गुणधर्म	निरीक्षण	स्पष्टीकरण
१	सामु (पी.एच.)	५.९५	चांगले
२	क्षारता (इसी) डेसी सायमन /मी	०.१९२	चांगले
३	सेंद्रीय कार्ब (टक्के) (ऑर्गॅनिक कार्बन)	०.५२	मध्यम
४	उपलब्ध नत्र (कि./हे.) (N)	२६५.९	कमी
५	उपलब्ध स्फुरद (कि./हे.) (P)	१६.८	मध्यम
६	उपलब्ध पालाश (कि./हे.) (K)	६२५.५	अत्यंत अधिक
७	मुक्त चुना (टक्के) (CaCO ₃)	८.५०	उपलब्धता
८	उपलब्ध गंधक (S) (पीपीएम)	११.७	मध्यम
९	उपलब्ध जस्त (Zn) (पीपीएम)	०.३७५	कमी
१०	उपलब्ध बोरॉन (B) (पीपीएम)	०.८०२	मध्यम
११	उपलब्ध लोह (Fe) (पीपीएम)	५.५०	पुढे
१२	उपलब्ध मंगल (Mn) (पीपीएम)	१२.६०	पुढे
१३	उपलब्ध तांबे (Cu) (पीपीएम)	—	—

अ. क्र.	पीक	हंगाम	शेणखत (गाडया /हे.)	शिफारस केलेली मात्रा कि. / हेक्टर		
				नत्र	स्फुरद	पालाश

अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा	अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा
१	गंधक (S)		४	लोह (Fe)	
२	जस्त (Zn)		५	मंगल (Mn)	
३	बोरॉन (B)		६	तांबे (Cu)	

प्रमुख

Krushi Vigyan Kendra
Jintur Road, Parbhani

माती आणि पाणी परिक्षण प्रयोगशाळा,

वरिष्ठ शास्त्रज्ञ व प्रमुख
कृषि विज्ञान केंद्र, परभणी

विशेष शिफारस : सेंद्रीय व हिरवळीच्या खतांचा जादा वापर

watercane 1.7541.25



भारतीय कृषि अनुसंधान परिषद, नवी दिल्ली पुरस्कृत आणि जीवन ज्योत चॅरिटेबल ट्रस्ट, परभणी संचलित

कृषि विज्ञान केंद्र

जिंतुर रोड, परभणी ४३१४०१ फोन : (०२४५२) २२३०४५



मृदा परिक्षण अहवाल

पावती क्र: ११२०

दिनांक : २३/१२/२०२२

शेतकऱ्यांचे नाव : किशोर गजराज कदम सर्व्हे नं / गट क्र.: ५०

गांव : भांगवत तालुका : भांगवत जिल्हा : परभणी

अ. क्र.	गुणधर्म	निरीक्षण	स्पष्टीकरण
१	सामु (पी.एच.)	७.६५	चौगुळी
२	क्षारता (इसी) डेसी सायमन /मी	०.३६६	चौगुळी
३	सेंद्रीय कार्ब (टक्के) (ऑर्गॅनिक कार्बन)	०.५६	मध्यम
४	उपलब्ध नत्र (कि./हे.) (N)	२०८.९	कमी
५	उपलब्ध स्फुरद (कि./हे.) (P)	१०.२	कमी
६	उपलब्ध पालाश (कि./हे.) (K)	३४४.५	अत्यंत अधिक
७	मुक्त चुना (टक्के) (CaCo ₃)	१०.०	मुक्तचुनामुक्त
८	उपलब्ध गंधक (S) (पीपीएम)	८.५	कमी
९	उपलब्ध जस्त (Zn) (पीपीएम)	०.२२५	मध्यम
१०	उपलब्ध बोरॉन (B) (पीपीएम)	०.०३६	कमी
११	उपलब्ध लोह (Fe) (पीपीएम)	६.३९	पुरेसे
१२	उपलब्ध मंगल (Mn) (पीपीएम)	१३.२०	पुरेसे
१३	उपलब्ध तांबे (Cu) (पीपीएम)	—	—

अ. क्र.	पीक	हंगाम	शेणखत (गाडया /हे.)	शिफारस केलेली मात्रा कि. / हेक्टर		
				नत्र	स्फुरद	पालाश

अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा	अ. क्र.	घटक	जमिनीतून दयावयाची खताची मात्रा
१	गंधक (S)		४	लोह (Fe)	
२	जस्त (Zn)		५	मंगल (Mn)	
३	बोरॉन (B)		६	तांबे (Cu)	

प्रमुख

माती आणि पाणी परिक्षण प्रयोगशाळा,

Krushi Vigyan Kendra
Jintur Road, Parbhani

वरिष्ठ शास्त्रज्ञ व प्रमुख
कृषि विज्ञान केंद्र, परभणी

विशेष शिफारस : सेंद्रिय व हिरवळीच्या खतांचा जादा वापर

Sahyadri Farmers Producer Company Ltd - FFC LAB

Gat No-314/1,314/2/1, Mohadi - Dindori Road,
At Post-Mohadi, Tal-Dindori, Nashik, - 422207,
Maharashtra, India Email- ffclab@sahyadrifarms.com
Toll Free No.: 1800 212 00 2020 / 7066045937



Seeding goodness

WATER TEST REPORT

Date of Sample Receipt :	12/08/2022	Test Report No :	FFCLAB/22/TR-01642
Customer Name :	Sunseed Agro		
Address :	AP Zari Tal Pathari Dist Parbhani		
Sample Description/Type :	Kave	Contact No. :	8308998084
Sample ID :	WT/08/22/01	Sample Drawn By:	Nilesh Magar
Date of start Analysis :	12/08/2022	Date of Reporting :	15/08/2022
Sample Quantity/Packing :	500 ml	Invoice No. :	99030579
Batch Code :	NA	Gat No./ Plot No. :	NA

Sr. No.	Parameter	Result	Unit	LOQ	Limits	Test Method	Equipment used for Analysis
1	pH (पी. एच.)	7.43	NA	NA	6.5-7.5	SF/FFCLAB/TM/WT-01	pH METER
2	Electrical Conductivity (ई.सी.)	0.85	ds/m	NA	<1.6	SF/FFCLAB/TM/WT-02	EC METER
3	Total Dissolved Solids	415	%	NA	<500	SF/FFCLAB/TM/WT-05	WET ANALYSIS
4	K - Potassium (पोटेशियम)	4.40	PPM	NA	NA	SF/FFCLAB/TM/WT-08	ICP-OES
5	Ca - Calcium (कैल्शियम)	101.00	PPM	NA	<100	SF/FFCLAB/TM/WT-08	ICP-OES
6	Mg - Magnesium (मैग्नेशियम)	32.20	PPM	NA	<30	SF/FFCLAB/TM/WT-08	ICP-OES
7	S - Sulphur (सल्फर)	14.00	PPM	NA	NA	SF/FFCLAB/TM/WT-08	ICP-OES
8	Fe - Ferrous (फेरस)	0.11	PPM	NA	NA	SF/FFCLAB/TM/WT-08	ICP-OES
9	Mn - Manganese (मैंगनीज)	0.01	PPM	NA	NA	SF/FFCLAB/TM/WT-08	ICP-OES
10	Zn - Zinc (ज़िंक)	0.01	PPM	NA	NA	SF/FFCLAB/TM/WT-08	ICP-OES
11	Cu - Copper (कॉपर)	0.01	PPM	NA	NA	SF/FFCLAB/TM/WT-08	ICP-OES
12	B - Boron (बोरॉन)	0.15	PPM	NA	<0.7	SF/FFCLAB/TM/WT-08	ICP-OES
13	Mo - Molybdenum (मॉलिब्डेनम)	0.04	PPM	NA	NA	SF/FFCLAB/TM/WT-08	ICP-OES
14	Na - Sodium (सोडियम)	98.50	PPM	NA	<35	SF/FFCLAB/TM/WT-08	ICP-OES
15	NO ₃ - Nitrate-N (नाइट्रेट नाइट्रोजन)	2.42	PPM	NA	<5	SF/FFCLAB/TM/WT-09	Spectrophotometer
16	Carbonate (कार्बोनेट)	9.60	PPM	NA	NA	SF/FFCLAB/TM/WT-06	WET ANALYSIS
17	Bi-carbonate (बायकार्बोनेट)	425	PPM	NA	<305	SF/FFCLAB/TM/WT-06	WET ANALYSIS
18	Sodium Adsorption Ratio	2.18	meq/kg	NA	<10	SF/FFCLAB/TM/WT-10	WET ANALYSIS
19	Residual Sodium Carbonate	0.73	meq/kg	NA	<1.25	SF/FFCLAB/TM/WT-04	WET ANALYSIS
20	Cl - Chlorides (क्लोराइड)	51.40	PPM	NA	<178	SF/FFCLAB/TM/WT-03	WET ANALYSIS

This test report purely aims for understanding nutrient status of the submitted sample on the basis of our technical expertise. In true manner it is very subjective to the certain set of variable factors, hence interpretation of the same shall be correlated to the actual conditions. We won't own any liability for inappropriate use resulting whatsoever tangible or intangible damage/ loss. This can't be produced for any kind of legal purpose.

HIGH
OPTIMUM
LOW

BLQ-Below Limit of Quantification.

NA-Not Applied.

Authorised Signatory

Note:

- The result listed refer only to the tested samples & applicable parameters.
- This report is not to be reproduced except in full, without written approval of the laboratory.
- In case sampling is not done by laboratory, the results apply to the sample as received.
- There are no additions to, deviation or exclusion from the method.

