Harvesting Sun and Soil: Agri-voltaic Prospects in Northeast India

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ABSTRACT

Agri-voltaic system integrates crop cultivation and solar energy generation on shared land, offering a sustainable solution to Northeast India's land and climate challenges. Elevated solar panels permit sunlight and create microclimates, enhancing soil moisture and protecting crops from extreme weather. Recent pilot projects across India including Northeast initiatives with vertical bifacial panels and solar-powered tea blending units demonstrate improved farm productivity, reduced irrigation needs, and diversified farmer incomes. Policy efforts and technological advances, including IoT-based monitoring, support adaptation for local conditions while overcoming barriers related to awareness, design complexity, and revenue-sharing. Collaborative action among governments, researchers, and farmers is crucial to maximizing the dual benefits of agri-voltaic system and securing food and energy futures in the region.

INTRODUCTION

Agri-voltaic systems help farmers use their land better by growing crops and making solar power at the same time. This method works well in places where land scarcity and climate challenges threaten the prevalent traditional methods of farming for livelihood. Basically, northeast India has limited fertile farmland and growing environmental stresses so putting solar panels above crops on the same land can produce both food and clean energy together. This system helps farmers grow crops and generate electricity from the same piece of land, creating better income opportunities. Farmers get extra money by using solar power for their farms or selling extra electricity to the grid. The crops benefit because water evaporation reduces and they get protection from extreme weather. In region like northeastern India, combining agriculture with solar installations is essential for proper utilization of available land. With this innovative agri-voltaic systems, it prevents competition between energy production and food production by using the same land for both purposes. By adopting agri-voltaic systems, northeast India may achieve the country's net-zero targets while keeping food production safe. These systems will only create new income chances for farmers and local people in the area.

What is Agri-voltaic?

Basically, agri-voltaic means using the same land for growing crops and making solar power at the same time. Solar panels are mounted on high structures so crops can grow underneath itself. This method further allows both energy production and farming on the same land. Modern systems use bifacial panels that capture sunlight from both sides and smart tracking mechanisms to optimize light distribution throughout the day. Shadows from panels create a beneficial "microclimate" by lowering temperatures and reducing water evaporation, which favours crop growth during periods of intense heat. (Scarano *et al*., 2025; Ukwu *et al*., 2025).

Researchers have found that shade from solar modules reduces irrigation requirements by up to 30%, increases soil moisture retention, and protects crops from hail and harsh weather conditions, consequently enhancing crop yields in various agricultural settings (Roxani *et al*., 2023). This dual-use approach is particularly pertinent in regions facing land constraints, where traditional solar farms would otherwise displace agricultural land, exacerbating food security concerns (Soto-Gómez, 2024). Agrivoltaic systems can surely reduce land-use conflicts between farming and solar energy production. Moreover, these systems allow farmers to grow crops and generate electricity on the same land area. This approach further reduces conflicts in areas with strong farming traditions by allowing food and energy production to happen at the same time (Victoria *et al*., 2024). The method itself helps farmers grow crops while also generating power.

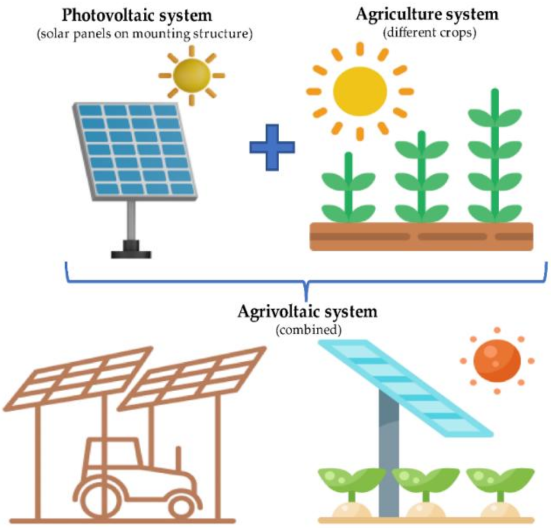

Figure 1. Agrivoltaic system and PV systems on the same agricultural land (*Source*: Chalgynbayeva *et al.*, 2023)

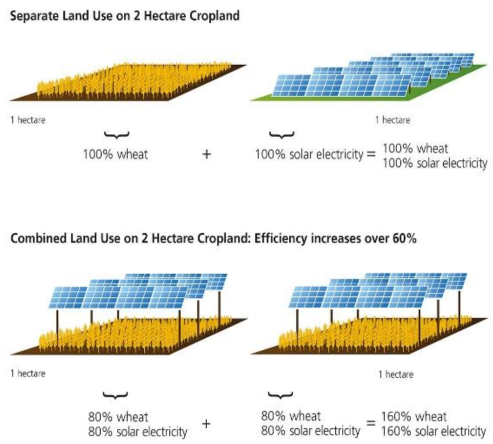

Figure 2: Separate land use on same crop area (Anon, 2025a) (*Source:* https://metsolar. eu/blog/what-is-agrivoltaics-how-can-solar-energy-and-agriculture-work-together/)

Advantages for Northeast India

Northeast India receives high solar radiation throughout the year and has different crop growing patterns. This region is well-suited for solar energy development in agriculture. India is surely well-placed for agri-voltaic adoption due to its abundant solar resources and large agricultural land base. Moreover, the country's growing energy demands and need for sustainable farming practices make this technology highly suitable. The region's undulating terrain and smallholder farms face land constraints, making dual land use especially valuable.

Climate Resilience: Solar panels provide protective cover for crops and act as barriers against heavy rain, hail, and excessive sunlight. This protection reduces crop losses when extreme weather happens and helps farmers get consistent yields throughout the growing season. Further, the partial shading from the panels itself reduces the overall system efficiency. Basically, this approach can improve how plants use light by reducing light damage and keeping the same proper light levels, especially for crops that grow in shade, which increases overall plant productivity (Victoria *et al*., 2024).

Water Conservation and Reduced Irrigation: With partial shading, solar panels decrease soil evaporation rates and enhance moisture retention. Fields underneath the solar panels typically require less supplementary irrigation, thereby conserves water resources and improve cost effectiveness in crop production among the farmers. This result is reported mostly in arid and semi-arid regions where there is water scarcity for agricultural productivity (Victoria *et al.,* 2024) (Cinderby *et al*., 2024).

Opportunities for Additional Income: Framers income from electricity generated from agrivoltaic system provides farmers with financial stability in addition to agricultural yield. Electricity generation and selling to the grid, lowering household energy bills, leasing land to energy developers, or being eligible for subsidies and renewable energy incentives are some examples of revenue streams.

Enhanced Land Productivity: Research reveals that using the same land for both farming and energy production can increase significantly greater returns for the farmers. In some cases, the combined income of power generated, and food yield has been estimated at > 1.5 times the productivity achieved by conventional farming or stand-alone solar installations (Dinesh & Pearce, 2015). In contrast to traditional agriculture, some agrivoltaic systems have shown an economic value gain of more than 30% when solar-generated power is combined with crop cultivation that can withstand shade.

Expanding Pilot Projects Across India

By mid-2024, India had made significant strides in experimenting with agrivoltaics, with the National Solar Energy Federation reporting at least 22 pilot projects operating across different states (Anon, 2025b). These initiatives mark a crucial step in testing whether food cultivation and solar energy generation can be jointly optimized in the country's diverse agro-climatic zones. These pilot projects contribute valuable data to refine design parameters, such as optimal panel height and spacing, and identify crop varieties best suited for co-habitation with solar infrastructure.

One of the leading examples is found in Parbhani district, Maharashtra, where a 1.4 MW agrivoltaics farm has been integrated into a much larger 50 MW solar park (Anon, 2025c). Here, staple and high-value crops such as ginger, turmeric, green gram, and okra are cultivated beneath elevated solar arrays. The layout allows sufficient sunlight penetration while providing partial shade that protects delicate crops from heat stress.

Figure 3. Interspace cropping at APV site (cabbage cultivation between PV rows) (*Source*: https://india.mongabay.com/2024/08/agrivoltaics-in-india-get-a-fresh-boost-from-tech-and-design-innovations/)

Another notable innovation is the introduction of vertical bifacial solar modules in Maharashtra. Unlike traditional horizontal arrays, these panels are mounted vertically, which minimizes the extent of land covered by infrastructure. Early pilot results indicate that more than 90 percent of agricultural land remains cultivable while still generating solar electricity at competitive efficiency levels. This finding is significant because land competition between farming and energy projects has often been cited as a limitation for renewable expansion in rural areas. By adopting bifacial technology, which captures sunlight from both sides of the panel, the system ensures continuous energy production while leaving fields open for crop cycles. These early demonstrations are reshaping policy conversations about land use in India.

Advancements and Initiatives in Northeast India

Although the northeast has significant renewable potential, about 129 GW mostly from hydropower, the solar segment remains underdeveloped. Recent initiatives are therefore focused on expanding solar energy solutions that complement agriculture, improving rural livelihoods and energy access (Singh *et al*., 2025).

One pioneering milestone is the inauguration of the Northeast's first agrivoltaics and solar-powered tea blending unit at Srikishan Sarda College (SS College) (Anon, 2025d). This project leverages solar power to support local agricultural processing, demonstrating the potential for dual-use energy-agriculture infrastructure in the region’s tea industry, a major economic sector.

The government has steadily increased efforts to install solar microgrids and solar-powered irrigation systems in remote tribal and rural areas of northeastern states such as Tripura. For example, financial support amounting to over Rs. 810 billion has been sanctioned to set up 274 solar microgrids in districts where grid connectivity remains unreliable or absent (Anon, 2025 e). This initiative addresses the chronic energy access gap while supporting agricultural activities through reliable power supply for irrigation and farm mechanization, which are critical in hilly and flood-prone terrains. Further, state governments in the northeast are updating their renewable energy policies to better match technological advances and local needs. This policy evolution is crucial for fostering investments in agrivoltaics startups and initiatives.

Decentralized solar solutions such as vertical bifacial panels, which minimize shading impact on crops, are increasingly considered particularly suitable for the diverse agro-climatic zones of the northeast. These efforts reflect a broader national push under government schemes like PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan), scaled up recently to enhance solar adoption in agricultural sectors across India, including the northeast (Anon, 2025f).

Farmers' Experience and Social Impact

Farmers managing agro-photovoltaic (APV) setups have reported stable incomes with reduced reliance on diesel and expensive electricity, thereby enhancing resilience against unpredictable weather conditions. Many projects enable farmers to supply surplus power to the local grid at affordable rates, providing communities with access to cheaper energy. Specifically, initiatives like the SPICE project demonstrate how solar cooperatives empower small farmers by lowering diesel dependency and generating additional income through energy sales. Additionally, pilot projects often engage local labour for activities such as maintenance, crop monitoring, and harvesting, which helps expand rural employment opportunities. The engagement of local labour in the upkeep and monitoring of these systems not only creates jobs but also strengthens community involvement and sustainability (Anon, 2025g & 2025h).

Policy Innovation – PM-KUSUM Scheme

The **PM-KUSUM scheme** was scaled up in January 2024 to support decentralized solar installations on farmlands nationwide, including the northeast India (Anon, 2025f).

- Small solar plants (500 kW–2 MW) are incentivized for installation on cultivable and barren land, with power purchases assured by DISCOMs at set feed-in tariffs.
- Farmers receive capital subsidies (up to 50% in Northeast states) to install solar irrigation pumps, reducing irrigation costs and allowing excess power sale to the grid.
- Local farmer cooperatives, FPOs, and panchayats are encouraged to form project partnerships for dual food-energy benefits.

Emerging Technology and Research Collaborations

Recent years have witnessed significant technological innovations that enhance the feasibility and efficiency of agri-voltaic (AgriPV) systems. For example, farmers can better manage soil health under solar canopies and optimise irrigation schedules by integrating IoT-based soil moisture sensors, which allow for real-time field condition monitoring (Alharbey *et al*., 2024; Zito *et al*., 2024). Moreover, using bifacial solar panels which absorb sunlight from both sides increases energy output without sacrificing crop growth since they can be positioned strategically to improve light distribution (Badran and Dhimish, 2024).

These technical advancements resulted from collaborative efforts across different sectors. The collective efforts from government agencies, academic institutions, and private firms are crucial to improving developments on AgriPV technology, advancement and knowledge dissemination. For instance, the global partnerships like SunSeed APV and the Indo-German cooperation under GIZ concentrate on technology transfer, bringing state-of-the-art research to real-world uses in Indian agriculture. Moreover, these programs have given strong initiatives on capacity building like farmer training/workshops, hands-on demonstrations, and development of crop planning techniques suited to local climatic conditions and agricultural situations.

Challenges and Roadmap to Wider Adoption

Agrivoltaics in India holds significant promise, but its expansion faces five major hurdles: limited farmer awareness and training opportunities, the design complexity of site-specific systems, disputes over land tenure and revenue-sharing models, gaps in clear policy support beyond existing schemes, and inadequate rural infrastructure for large-scale integration. Overcoming these obstacles calls for coordinated action. Government programs must evolve with targeted subsidies, transparent frameworks, and technical guidelines; research institutions should test and validate crop-panel compatibilities; and community engagement must ensure farmer participation in shaping solutions. With stronger policies, collaborative business models, and capacity-building initiatives, agrivoltaics can align renewable energy growth with resilient food production.

CONCLUSION

Agrivoltaic systems offer a viable way to enhance both food and energy security in Northeast India by merging solar generation with crop cultivation on the same land. This dual-use approach improves farmer resilience to climate stresses, diversifies incomes, conserves resources, and supports soil health. Realizing its potential will require region-specific policies with clear incentives, technical support, and crop insurance, alongside strong community participation and farmer training. With coordinated efforts from government, research institutions, and private players, the Northeast can pioneer agro-voltaic models tailored to its agro-climatic diversity, driving sustainable rural growth while contributing to India's renewable energy and climate goals.

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