



AGRI MAGAZINE

(International E-Magazine for Agricultural Articles)

Volume: 03, Issue: 06 (June, 2026)

Available online at <http://www.agrimagazine.in>

© Agri Magazine, ISSN: 3048-8656

Crops Beneath Panels: India's Dual-Use Solar Revolution

*Abinash Kumar Patel¹, Pradeep Kumar² and Ramesh Kharwar²

¹Research Scholar, Department of Horticulture, Post Graduate College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa Samastipur, Bihar, India

²Research Scholar (Horticulture), School of Agricultural Sciences and Technology, Babsaheb Bhimrao Ambedkar University (A Central University), Lucknow (UP), India

*Corresponding Author's email: abinashpatel56@gmail.com

The growing global population and increasing pressure on natural resources have created an urgent need for sustainable solutions that can simultaneously support food production and energy generation. Agrivoltaics, a system that combines agriculture with solar power production on the same piece of land, has emerged as a promising approach to address these challenges. In this system, crops are cultivated beneath or around solar panels, allowing farmers to produce food while generating clean, renewable energy. Agrivoltaic systems offer several advantages, including improved land-use efficiency, reduced water loss through evaporation, and protection of crops from excessive heat and harsh weather conditions. The partial shade provided by solar panels can create a favorable microclimate for many vegetable crops, helping to improve water-use efficiency and enhance resilience to climate change. In addition to supporting agricultural productivity, agrivoltaics provides farmers with an additional source of income through electricity generation and reduced energy costs. Different agrivoltaic models, such as elevated solar panels, photovoltaic greenhouses, floating solar systems, and solar grazing systems, are being implemented in various parts of the world. In India, where agricultural land and energy demand are both significant concerns, agrivoltaics has considerable potential to contribute to sustainable development goals. Government initiatives and pilot projects have demonstrated its ability to improve farm profitability, increase renewable energy production, and strengthen rural livelihoods. Despite its benefits, the adoption of agrivoltaics faces challenges such as high installation costs, technical and design limitations, policy barriers, and limited awareness among farmers. Addressing these constraints through research, supportive policies, financial incentives, and capacity-building programs will be essential for large-scale implementation. Overall, agrivoltaics represents a climate-smart and resource-efficient farming strategy that can play a vital role in ensuring food security, promoting renewable energy, and supporting sustainable vegetable production in the future.

Keywords: Agrivoltaics, Renewable Energy, Sustainable Agriculture, Solar Energy, Climate-Smart Farming, Water-Use Efficiency.

Introduction

According to the United Nations, the world population is expected to reach 8.5 billion in 2030 and 9.8 billion in 2050. This growth, together with urbanisation and industrialisation, will lead to a significant increase in demand for food, water, and energy. To overcome these issues, farmers and researchers are adopting innovative ideas that improve both farm productivity and sustainability. One such promising approach is agrivoltaics a system where crops are cultivated beneath solar panels, allowing for the combined use of land for both food production and clean energy generation. This technology not only helps farmers increase

their income but also contributes to reducing carbon emissions, saving water, and making farming more climate-resilient.

What is agrivoltaics?

Agrivoltaics, also known as agrisolar or dual-use solar, is the practice of utilizing the same land for both farming and solar power generation. The agrivoltaic definition refers to combining agricultural activity with solar for agriculture technology by installing solar panels for agriculture above or between crops, or on grazing land. This allows food production and clean energy to happen side by side. This approach maximizes land use, helps protect crops by providing shade, and supports farmers by creating new income sources. First introduced in the 1980s, agrivoltaics is gaining popularity worldwide as a smart way to grow food and generate renewable energy together, especially important for countries like India with limited land and high energy needs.

Advantages of agrivoltaics farming

- **Maximizes land productivity**

Farmers can increase land-use efficiency by up to 186% by using agrivoltaics to generate renewable energy while carrying on with their agricultural operations. By reducing conflicts between farming and energy development, this dual use helps achieve solar capacity targets without compromising priceless farmland.

- **Improves crop resilience and yields**

Partial shade from solar panels keeps soil moisture levels stable, lowers water evaporation, and moderates temperature extremes. According to research from Arizona and Kenya, this microclimate promotes the growth of some crops, particularly in hot or arid areas, resulting in increase in yields and less need for irrigation.

- **Diversifies income for farmers**

Farmers generate extra income by combining crop or livestock production with solar for agriculture. They can lower electricity costs, supply clean energy to farm operations, and occasionally resell excess power to the grid, boosting the stability of farm income. Solar for agriculture thus works on multiple levels of sustainability.

- **Enhances ecosystem services and biodiversity**

By preserving native vegetation and establishing habitats for pollinators like bees, agrivoltaics sites can enhance the health of ecosystems. By controlling stormwater runoff and reducing the need for herbicides, these green areas lessen their negative effects on the environment and maintenance expenses.

- **Provides grazing opportunities**

Sheep and chickens are examples of livestock that can graze beneath solar agriculture panels, naturally controlling vegetation while enjoying the shade and protection they provide. This promotes animal welfare and lowers maintenance.

- **Improves working conditions for farm laborers**

By providing shade, solar agriculture installations improve comfort and safety for farm workers spending extended periods of time outside by shielding them from intense heat and damaging UV rays.

- **Helps combat climate change**

Agrivoltaics in India helps achieve regional and national objectives to reduce greenhouse gas emissions and increase climate resilience in agriculture by producing clean, renewable energy and lowering dependency on fossil fuels.

- **Reduces water consumption**

In regions that are prone to drought, the shade from agrivoltaics farming reduces the amount of water lost by transpiration and evaporation from plants and soil, thereby promoting more sustainable farming practices.

Overall, agrivoltaics is a futuristic approach that transforms how we use land, supporting food production, clean energy, and ecosystem health simultaneously while strengthening rural economies.

How does agrivoltaics farming work?

Agrivoltaics is all about making the most out of the same piece of land by combining farming and solar power. Solar panels capture sunlight to produce electricity, while the space beneath is used to grow plants or raise livestock.

- **Elevated solar panels:**

Instead of placing solar panels directly on the ground, they are mounted on structures high enough to let sunlight and rain reach the crops below. These elevated solar panels for agriculture also allow farmers to move their equipment underneath without any trouble.

- **Partial shading:**

The panels provide shade, which helps protect crops from extreme heat and reduces water evaporation from the soil. This creates a cooler, more stable environment for plants to grow, especially in hot or dry regions.

- **Dual use of land:**

With solar panels generating electricity and crops or animals thriving below, farmers get two benefits from the same land, food and clean energy.

- **Electricity for the farm and beyond:**

The solar energy produced on an agrivoltaic farm can power farm operations, reducing electricity costs. If there's extra power, it can be fed back into the grid, providing additional income.

Uses and applications of agrivoltaics farming

1. Solar panels above crops

The most common agrivoltaics application involves installing solar panels above crop fields. This setup provides partial shade to crops, which can improve water retention and reduce heat stress, especially beneficial for dry farming, where irrigation is limited. By integrating solar panel for agriculture systems, farmers can grow crops and generate electricity simultaneously, making land use more efficient.

2. Photovoltaic greenhouses

Another exciting use of agrivoltaics is photovoltaic greenhouses, where solar panels are placed on the greenhouse roof or exterior. These panels act as a canopy, regulating the temperature and humidity inside the greenhouse, which reduces energy consumption for climate control. The electricity produced powers greenhouse operations, cutting costs and boosting sustainability.

3. Grazing and livestock farming

Agrivoltaics isn't limited to crops. Solar installations can be designed over grazing land, allowing livestock such as sheep or goats to shelter under panels. This dual use of land supports animal welfare by providing shade and reduces vegetation maintenance costs.

4. Powering agricultural operations

The solar energy for agriculture can be used directly on farms for powering irrigation pumps, lighting, fencing, and other equipment vital to farming operations. Using solar for agriculture reduces dependency on fossil fuels and cuts energy costs, helping farmers save money and reduce their carbon footprint.

5. Water extraction and irrigation

In many rural areas, access to water is a major challenge. Agrivoltaic solar power can run pumps that extract water from wells, enabling more efficient irrigation systems and supporting crop growth in arid regions. This coupling of solar energy with water management is a game-changer for sustainable farming.

6. Supporting biodiversity and ecosystem services

Some agrivoltaic farms incorporate pollinator-friendly habitats under and around solar panels, enhancing biodiversity and promoting ecosystem health. This approach benefits crops that rely on pollination and supports environmental sustainability.

What are the different types of agrivoltaic systems?

Agrivoltaic systems come in several designs, each adapted to different crops, landscapes, and farming needs. The main types of agrivoltaics in India include:

- 1. Elevated solar panels:** Solar panels for agriculture are mounted on tall structures above crops, allowing enough space for farming machinery and sunlight to reach plants below.
- 2. Solar panels between crop rows:** Panels are installed at ground level between rows of crops, providing partial shade while maximizing land use.
- 3. Photovoltaic greenhouses:** Solar panels are integrated into greenhouse roofs or walls, generating electricity while controlling temperature and humidity for plants inside.
- 4. Floating solar panels:** Panels float on water bodies near farms, such as irrigation ponds, helping generate power without using additional land.
- 5. Solar grazing systems:** Panels are installed over grazing land where livestock can roam freely, combining animal farming with solar energy.

Current trends and future of agrivoltaics in India

Agrivoltaics in India presents a convincing answer to the twin problems of energy production and land scarcity as the nation works toward its ambitious target of 500 GW of renewable energy capacity by 2030. Integrating solar infrastructure into farmland could help meet energy targets without displacing food production, as 60% of India's land is under cultivation. The MNRE estimates that an extra 630 GWp of solar power could be produced by putting solar panels on just 1% of India's agricultural land. However, progress has been slow; there are currently 20 agrivoltaic farm projects, primarily in Gujarat. These include government-backed pilot programs, R&D systems, and a few business endeavors for agrivoltaics farming.

What are the challenges to agrivoltaics farming?

Although agrivoltaic (APV) systems offer significant opportunities for improving land-use efficiency and promoting sustainable agriculture, several technical, economic, agronomic, and policy-related challenges continue to hinder their large-scale adoption in India.

1. High capital costs

Because of their higher structures, higher material requirements, and more complicated installations, agrivoltaic systems are substantially more expensive than ground-mounted solar. Prices per kw can increase by 1.3-2 times. Costs are further increased by lower panel density, wind resistance specifications, and higher panel heights. For small and marginal farmers, this makes APV financially difficult unless financing options or subsidies are implemented.

2. Uncertain impact on crop yields

The way that crops react to solar panel shading varies greatly. While some crops, like leafy greens, benefit yields of staple crops like wheat and rice are frequently lower. Although Land Equivalent Ratio (LER) values can conceal decreases in food production, they may indicate overall gains. Yield results are highly dependent on the panel. Crop type, spacing, orientation, and local agroclimatic conditions, all of which call for site-specific data and trials prior to scaling.

3. Design and compatibility issues

Energy production and agricultural requirements must be balanced when designing agrivoltaic systems. For crop health, proper row spacing and enough room for farm equipment, particularly harvesters, are essential. Advanced technologies (like movable or transport panels) are still costly and uncommon in India, and many of the panels and mounting systems that are currently in use are not designed with agriculture in mind.

4. Operation, maintenance, and safety

Most farmers lack the technical know-how and routine maintenance needed for APV systems. Risks include exposed wiring or electrical infrastructure raising safety concerns and unintentional damage to solar equipment while farming. Reliance on outside technicians may result in higher operating expenses and downtime over time.

5. Soil and water impacts

Compaction and erosion of the soil may result from the installation of solar structures, particularly if heavy equipment is used or topsoil is removed. The microclimate is changed by shading, which may lower evapotranspiration but also has an impact on water requirements and rainfall distribution. More research is required to determine how different crops will react to these changes.

6. Grid integration and storage constraints

Although off-grid systems are less practical than grid-connected ones, many rural areas lack nearby substations or sufficient evacuation infrastructure. Without adequate planning, intermittent solar generation could put strain on the grid. In Indian APV setups, battery storage is still costly and unproven.

7. Regulatory and policy barriers

Clear national regulations pertaining to agrivoltaics are lacking. In some states, dual-use applications may be restricted by land use classifications and farmland protection laws. Solar installation approval procedures on agricultural land are intricate and dispersed among several agencies.

8. Farmer awareness and adoption

The potential advantages of APV are unknown to the majority of farmers. The perceived threats to crop yields and disturbances to farming practices are the reasons for skepticism. Adoption is likely to stay low in the absence of robust outreach, training, and demonstration initiatives, particularly through Farmer Producer Organizations (FPOs).

Schemes and initiatives for agrivoltaics in India

Several national initiatives in India support the adoption of agrivoltaics by encouraging the integration of solar energy into agricultural systems and fostering cooperation among key stakeholders. These programs are designed to promote the use of renewable energy in farming while creating additional income opportunities for farmers. By providing financial assistance, policy support, and platforms for collaboration among government agencies, farmers, researchers, and private organizations, these schemes help accelerate the deployment of agrivoltaic technologies. Their broader objective is to strengthen rural livelihoods, improve energy security, and contribute to the country's sustainable development and clean energy goals.

1. India Agrivoltaics Alliance (IAA)

The Indian Agrivoltaics Alliance (IAA), founded by the National Solar Energy Federation of India (NSEFI), was created to encourage the integration of agriculture and solar energy production. The alliance serves as a collaborative platform that connects key stakeholders, including government agencies, farmers, solar energy companies, researchers, and financial institutions. Its primary objective is to support the growth of agrivoltaic systems by developing sustainable business models, assessing their social and economic benefits, and promoting policies that facilitate wider adoption. Through research, awareness programs, and stakeholder engagement, the IAA plays an important role in advancing agrivoltaics as a viable solution for sustainable farming and renewable energy development in India.

2. PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan)

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM), introduced in 2019, is a flagship government initiative designed to promote the use of solar energy in the agricultural sector. The scheme aims to enhance farmers' income, reduce dependence on conventional energy sources, and encourage sustainable farming practices through the adoption of renewable energy technologies.

PM-KUSUM consists of three key components. Component A supports the establishment of decentralized, grid-connected solar power plants with capacities ranging from 500 kW to 2 MW. Component B focuses on providing standalone solar-powered irrigation pumps of up to 7.5 HP in off-grid and remote agricultural areas. Component C enables the solarization of existing grid-connected agricultural pumps, allowing farmers to generate solar power for their own use and supply surplus electricity to the grid.

To encourage participation, the scheme offers financial assistance in the form of capital subsidies and facilitates access to bank credit, making solar energy technologies more affordable and accessible for farmers. By promoting clean energy adoption in agriculture, PM-KUSUM contributes to improved energy security, reduced irrigation costs, and enhanced environmental sustainability.

Agrivoltaics projects in India

Agrivoltaics is emerging as a promising solution in India by integrating agricultural production with solar energy generation on the same land. One notable example is the large-scale agrivoltaic farm established by Anand Jain, an alumnus of IIT Roorkee, in Sagar, Madhya Pradesh. Spread across 16 acres, the farm cultivates crops such as strawberries and lettuce beneath elevated solar panels while generating approximately 25,000 units of renewable electricity every day. This innovative system enables farmers to earn additional income from solar power without sacrificing crop production. The solar panels also help reduce water loss, provide shade to crops, and protect them from harsh weather conditions.

Similar initiatives are being implemented across the country. In Nashik, Maharashtra, Sahyadri Farms, India's largest Farmer Producer Organization, has introduced a pilot agrivoltaic project that combines grape cultivation with solar energy production, creating opportunities for higher farmer income and sustainable farming practices. In Rajasthan, the Central Arid Zone Research Institute (CAZRI), Jodhpur, demonstrated the benefits of a 105 kWp agrivoltaic system, which improved land-use efficiency and water productivity in arid environments. Another successful example is the Muradpur lift irrigation project in Nagpur, where floating solar panels have been integrated with irrigation infrastructure. This system supports irrigation across nearly 465 acres of farmland, reduces energy expenses, and enables farmers to grow up to three crops annually. Together, these initiatives highlight the significant potential of agrivoltaics to enhance agricultural productivity, optimize land and water resources, and promote clean energy adoption in rural India.

Conclusion

Agrivoltaics is a sustainable approach that allows farmers to use the same piece of land for both agriculture and solar energy production. This integrated system helps maximize land productivity while providing several economic and environmental advantages. In addition to generating clean electricity, agrivoltaics can increase farmers' income, reduce energy costs, and protect crops from extreme weather conditions such as excessive heat and drought. As concerns about food security, energy demand, and climate change continue to grow, agrivoltaics presents a practical solution for building a more resilient agricultural sector. With supportive policies, financial incentives, farmer training programs, and greater public awareness, this innovative technology has the potential to play a key role in advancing sustainable agriculture and rural development in India.

References

1. Renno, C., & Di Marino, O. (2026). Agrivoltaics Across Crops and Technologies: A Systematic Review of Experimental Tests on Yield, Microclimate, and Energy Performance. *Energies*, 19(2), 539.
2. Santhosh, R., Baskaran, R., Harisudan, C., Prabhakaran, J., & Kumar, K. B. (2025). Agrivoltaic farming: A sustainable approach for climate-smart agriculture. *Plant Science Today*, 12(sp1).
3. Mohammad, G., Ghosh, H., Mitra, K., & Saha, N. (2024). Sun, soil, and sustainability: opportunities and challenges of agri-voltaic systems in India. *Current Agriculture Research Journal*, 12(1), 49-62.