



AGRI MAGAZINE

(International E-Magazine for Agricultural Articles)

Volume: 03, Issue: 10 (October, 2026)

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

©Agri Magazine, ISSN: 3048-8656

Agrivoltaic System: Harnessing the Sun for Food and Energy Security

* Vivek Kumar Singh, Sanchitpal Singh, Umashankar Rawat and Vineet Kumar Pandey
PhD Scholars, ICAR-Indian Veterinary Research Institute (IVRI), Izatnagar,
Bareilly, Uttar Pradesh, India

*Corresponding Author's email: vivekvet02@gmail.com

Agriculture and energy are two essential pillars of economic development. Agriculture provides food, employment and livelihoods, while energy supports irrigation, farm machinery, food processing and storage. However, both sectors face growing challenges. Farmers are experiencing rising input costs, water scarcity and unpredictable weather, while the expansion of renewable energy is increasing the demand for land suitable for solar power generation. The agrivoltaic system offers a promising answer. Also known as agri-photovoltaics or solar sharing, agrivoltaics combines agricultural production with solar photovoltaic (PV) electricity generation on the same land. Solar panels are installed above or between cultivated areas, allowing farming activities to continue beneath or around them. Instead of choosing between food production and solar energy, agrivoltaics seeks to make both activities compatible. Depending on the design, crops may benefit from partial shade, livestock may graze beneath elevated panels, and the electricity generated can support farm operations or be supplied to the power grid. For India, where agriculture supports millions of households and solar energy has considerable potential, this approach deserves particular attention. Research by the Indian Council of Agricultural Research (ICAR) has highlighted Agrivoltaic as a promising option for arid regions, where high temperatures and limited water availability create serious agricultural constraints [1]. Agrivoltaics is not simply the installation of solar panels on farmland. It is a carefully designed farming system in which agricultural productivity, electricity generation, water use and farmers' economic interests must be considered together.

What is an Agrivoltaic system?

An Agrivoltaic system is an arrangement in which solar photovoltaic panels and agricultural activities coexist on the same land. The panels convert sunlight into electricity, while crops, livestock or other agricultural enterprises continue to utilize the land. In conventional ground-mounted solar parks, land is primarily used for electricity generation, and agricultural activities may be restricted. In Agrivoltaics, the height, spacing, orientation and layout of solar panels are designed to accommodate agricultural operations. The central principle is dual land use: a single area contributes to both agricultural production and renewable energy generation. For example, a farmer may cultivate suitable vegetables beneath elevated solar panels. The panels generate electricity while the cultivated land continues to produce agricultural commodities. In hot and dry regions, partial shade may reduce excessive solar exposure and soil water loss for certain crops. However, excessive shading can reduce plant growth, making appropriate system design essential. Agrivoltaics therefore aims to balance two requirements: providing sufficient sunlight for crops and capturing enough solar energy to make electricity generation economically viable.

Types of Agrivoltaic systems

1. Elevated solar panel systems

In this arrangement, solar panels are installed on elevated structures that allow crops to grow underneath. The height and spacing are planned to accommodate sunlight requirements, agricultural machinery and other farming activities. This design can be suitable for selected vegetables, horticultural crops and other plants that tolerate partial shade. It allows farmers to continue cultivation rather than convert the entire area into a solar installation. However, elevated structures generally require stronger supports and greater investment than conventional ground-mounted panels.

2. Inter-row solar panel systems

In this system, solar panels are installed in rows with sufficient space between them for cultivation. Crops grow in the open areas, receiving direct sunlight for part of the day and shade when the panels obstruct incoming radiation. This arrangement may be less expensive than high-elevation systems, but the available cultivation area depends on panel spacing and the movement of farm machinery.

3. Solar grazing systems

Solar grazing combines livestock production with electricity generation. Sheep and other suitable livestock can graze beneath or between solar panels, provided the installation is designed for safe animal movement. The vegetation can provide grazing opportunities, while panels may offer shelter from excessive sunlight. However, stocking density, pasture management, animal welfare and protection of electrical equipment must be considered carefully.

4. Greenhouse Agrivoltaics

In greenhouse Agrivoltaics, photovoltaic panels are incorporated into greenhouse roofs or installed above protected cultivation structures. Depending on their design, the panels may partially replace conventional roofing materials or provide additional shade. Electricity can support irrigation, ventilation, cooling and other greenhouse operations. However, panel transparency, light transmission, temperature management and installation costs must be evaluated before adoption. These examples demonstrate that agrivoltaics is not a single technology. Each system must be adapted to local agricultural conditions, crop requirements and economic objectives.

How does an Agrivoltaic system work?

Sunlight is the common resource shared by crops and solar panels. Plants use sunlight for photosynthesis, while photovoltaic cells convert solar radiation into electricity. When panels are installed over agricultural land, they alter the distribution of sunlight, temperature, wind and moisture beneath them. These changes can influence crop growth, irrigation requirements and the local microclimate. The outcome depends on several factors, including panel height, spacing, orientation, crop selection and local weather conditions. Some crops may benefit from partial shade during hot and dry periods, whereas crops requiring intensive sunlight may experience reduced yields. Water management is equally important. Shade can reduce direct solar radiation and potentially lower soil evaporation, but panels can also concentrate rainfall along their edges and create uneven soil moisture. Therefore, the success of agrivoltaics depends on designing the solar installation around the needs of the agricultural enterprise rather than maximizing electricity production alone.

Advantages of Agrivoltaic systems

1. Dual use of agricultural land

The most important advantage of Agrivoltaics is the potential to produce food and electricity from the same area. This can reduce competition between agricultural production and renewable energy development. Instead of replacing cultivation with a solar park, farmers can continue suitable agricultural activities beneath or between panels. The overall benefit depends on maintaining meaningful agricultural production alongside electricity generation.

2. Additional income for farmers

Agrivoltaics may create additional revenue through electricity sales, land-leasing arrangements or savings on electricity used for farm operations. For example, a farmer may continue cultivating crops while receiving income under an agreement with a solar developer. Alternatively, electricity generated on the farm can support irrigation pumps, machinery and other equipment. However, additional income is not guaranteed. The financial outcome depends on installation costs, financing, electricity tariffs, crop returns, maintenance expenses and contractual arrangements.

3. Protection against excessive heat

High temperatures can reduce crop growth, damage reproductive structures and increase water requirements. In hot regions, partial shade from solar panels can reduce excessive solar exposure and moderate the microclimate. This may benefit selected vegetables, horticultural crops and other plants sensitive to heat stress. Livestock may also benefit from shade when grazing systems are appropriately designed. However, excessive shade can restrict photosynthesis and reduce yields. The crop, panel coverage and seasonal conditions must therefore be carefully matched.

4. Improved water-use efficiency

Water scarcity is a major constraint in many Indian agricultural regions. By reducing direct sunlight and wind exposure in shaded areas, solar panels may lower soil evaporation and crop water demand. Rainwater falling on panels can also be collected or directed towards designated areas through suitable drainage arrangements. Nevertheless, water savings vary with soil type, crop, rainfall, irrigation practices and panel design. These benefits should be established through field measurements rather than assumed for every installation.

5. Renewable energy for agricultural operations

Electricity generated through Agrivoltaics can support irrigation, pumping, cooling, storage, processing and other farm activities. This can improve access to energy, particularly where electricity supply is unreliable or expensive. Solar power may also support decentralized agricultural infrastructure, including cold storage, food-processing units and milk-chilling facilities. The practical benefits depend on electricity demand, grid access, storage requirements and the capacity of the installation.

6. Environmental benefits

Solar electricity can reduce dependence on fossil-fuel-based energy. At the same time, continued cultivation can help maintain agricultural use of the land. Where agrivoltaics reduces the need to clear additional land for solar installations, it may also help limit land-use conflicts. However, environmental benefits depend on responsible construction, soil management, water use and the disposal or recycling of photovoltaic equipment at the end of its useful life.

Disadvantages and challenges of Agrivoltaic systems

Despite its potential, Agrivoltaics has several limitations that must be addressed before widespread adoption.

1. **High initial investment:** Elevated structures, specialized mounting systems and electrical equipment can increase installation costs compared with conventional solar farms.
2. **Possible reduction in crop yield:** Excessive shading can limit photosynthesis and reduce crop growth, particularly in crops requiring high levels of sunlight.
3. **Difficult farm operations:** Panel supports may obstruct tractors, harvesters, irrigation equipment and other machinery. Adequate clearance and well-planned layouts are essential.
4. **Technical and maintenance requirements:** Farmers may require specialist support for electrical maintenance, structural safety and monitoring.
5. **Unequal distribution of benefits:** If farmers lease their land without suitable contractual safeguards, they may lose agricultural access or receive limited economic benefits. Agreements should clearly establish rent, ownership, responsibilities, access rights and restoration obligations.

6. Uncertain long-term profitability: Electricity prices, crop prices, financing costs and maintenance expenses may change over time. Each project requires an economic assessment based on realistic assumptions.

Agrivoltaics should therefore be introduced through careful planning and site-specific evaluation rather than treated as a universally suitable solution.

Agrivoltaics in India: Opportunities and progress

India has substantial solar energy potential and a large agricultural sector, making Agrivoltaics relevant to the country's efforts to strengthen energy security and farmers' livelihoods. The approach is particularly promising in hot and dry regions where heat stress and water scarcity limit agricultural productivity. Rajasthan and other semi-arid regions offer opportunities to investigate systems combining solar power with suitable crops, horticulture and livestock activities. ICAR's Central Arid Zone Research Institute (CAZRI), Jodhpur, has contributed to research on Agrivoltaics for western India's arid conditions. Its work highlights the potential of integrating renewable energy with agricultural production under environmental constraints [1]. An important development occurred on 18 December 2025, when ICAR inaugurated a 100 kWp Agrivoltaic pilot project at the Indian Agricultural Research Institute (IARI), New Delhi. The project features single-axis solar tracking and ground-screw foundations and was implemented by GIZ India in collaboration with the Ministry of New and Renewable Energy (MNRE), ICAR-IARI and the National Institute of Solar Energy [4]. The project provides a platform for evaluating Agrivoltaic technologies under Indian conditions. Continued monitoring of crop performance, energy generation, water use and economic returns will be important for guiding future deployment. India's PM-KUSUM scheme also supports decentralized solar power plants and solarization of agricultural pumps. Although not every installation under this scheme is an Agrivoltaic system, its provisions for stilt-mounted solar plants create a relevant policy connection with agricultural land use. Current scheme provisions and state-level arrangements should be checked before planning a project [5].

Which crops are suitable for Agrivoltaics?

Crop suitability depends on sunlight requirements, temperature, water availability, growing season and the amount of shade created by the panels. Selected leafy vegetables, certain horticultural crops and shade-tolerant plants may perform well under partial shading. Other crops may also be suitable if panel coverage is limited and light distribution is carefully managed. In India, crops such as spinach, coriander and other leafy vegetables could be investigated alongside selected fodder crops, medicinal plants and horticultural species. These are potential candidates for local trials, not crops guaranteed to perform better beneath panels. Field studies should compare crop yields, quality, water consumption and profitability under solar panels with those under comparable open-field conditions. Such research can help identify suitable crop-solar combinations for different agro-climatic regions.

Strategies for successful adoption

Successful Agrivoltaic development requires collaboration among farmers, agricultural scientists, solar engineers, energy companies and government agencies. First, the suitability of the land should be assessed, including soil conditions, sunlight, water availability, existing crops and machinery requirements. Second, solar panels should be arranged to accommodate agricultural operations. Panel height, spacing and orientation must provide sufficient light and access for planting, irrigation and harvesting. Third, farmers should receive clear information about installation costs, financing, electricity revenue, maintenance responsibilities and contractual obligations. Fourth, demonstration projects and multi-season field trials should establish which crops and designs perform well under local conditions. The combined economic return from agricultural production and electricity generation should be evaluated. Finally, policies and financial mechanisms should protect farmers' interests and encourage installations that maintain meaningful agricultural production.

Conclusion

Agrivoltaics offers a promising approach to addressing the interconnected challenges of food production, renewable energy generation, land availability and climate resilience. By combining solar electricity generation with crop cultivation or livestock activities, it creates opportunities to use agricultural land more efficiently while potentially providing additional income and reducing heat or water stress. However, its success depends on careful system design, suitable crop selection, reliable technical support and fair economic arrangements. Excessive shading, high installation costs and poor planning can undermine its benefits. For India, the next step is to expand scientifically monitored pilot projects, identify locally suitable crops and develop practical models that farmers can adopt without compromising agricultural production. The ultimate objective is to make solar energy a partner in agriculture rather than a replacement for it. With appropriate research, investment and farmer participation, Agrivoltaics could become an important component of India's transition towards sustainable and climate-resilient farming.

References

1. Jat, N. K., Poonia, S., & Santra, P. (2025). Agrivoltaics: A promising farming system for the western arid regions of India. *Indian Farming*, 75(3), 14-18.
2. Widmer, J., Christ, B., Grenz, J., & Norgrove, L. (2024). Agrivoltaics, a promising new tool for electricity and food production: A systematic review. *Renewable and Sustainable Energy Reviews*, 192, 114277.
3. Chopdar, R. K., Sengar, N., Giri, N. C., & Halliday, D. (2024). Comprehensive review on agrivoltaics with technical, environmental and societal insights. *Renewable and Sustainable Energy Reviews*, 197, 114416.
4. ICAR. (2025). *DG ICAR inaugurates Agri Voltaic Facility (Agri-PV) at ICAR-IARI*.
5. Ministry of New and Renewable Energy, Government of India. *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM)*.