

AGRIVOLTAICS: WHERE FARMING MEETS SOLAR POWER

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ABSTRACT

Agrivoltaics (Agri-PV or solar sharing) is a dual land-use system that combines crop production with photovoltaic energy generation to optimize land productivity. Since crops utilize only a small fraction of incoming solar radiation, surplus sunlight can be converted into electricity with minimal impact on crop growth. Agrivoltaics enhances water-use efficiency, moderates microclimate, reduces soil erosion, and improves resilience to climate stress while supporting biodiversity and shade-tolerant crops. It also diversifies farm income and promotes rural energy access, offering a sustainable and climate-resilient approach despite challenges such as high installation costs.

KEYWORDS: Agrivoltaics, income diversification, solar energy, sustainability

INTRODUCTION

Agriculture today stands at a crossroads. On one hand, the demand for food is increasing due to rapid population growth; on the other, the availability of arable land is shrinking while climate change continues to threaten crop productivity. At the same time, the global push toward renewable energy has intensified the need for land to install solar power systems. This dual pressure on land resources has led to a fundamental question: Can we produce food and energy on the same land without compromising either?

The answer lies in an innovative approach known as agrivoltaics (AV), a system that integrates agriculture and solar energy generation on the same piece of land. Also referred to as Agri-PV, agro-PV, solar sharing, or agri-solar, agrivoltaics represents a transformative step toward sustainable land-use management.

WHAT IS AGRIVOLTAICS?

Agrivoltaics is a technology and land management strategy that allows simultaneous cultivation of crops (or livestock rearing) and generation of electricity through photovoltaic (PV) panels. Unlike conventional solar farms that occupy agricultural land exclusively, agrivoltaics ensures that farming activities continue alongside energy production. The concept was first introduced in 2004 in Japan by Akira Nagashima

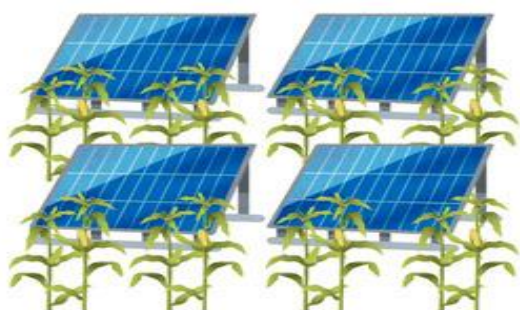
under the term “solar sharing.” His design was based on a key physiological principle of plants: crops utilize only about 3-6% of total incident solar radiation for photosynthesis. The remaining sunlight is either reflected, transmitted, or dissipated as heat. Agrivoltaics captures this unused portion of sunlight through solar panels, converting it into electricity while still allowing sufficient light for crop growth. This dual-use approach significantly enhances land-use efficiency, making it possible to generate both food and energy from the same area.

TYPES OF AGRIVOLTAIC SYSTEMS

1. Open Agrivoltaic System

Open systems are the most common form of agrivoltaics. In these systems, solar panels are installed above the crops or between crop rows, allowing sunlight to partially reach the plants. The panels are usually mounted on elevated structures so that farm machinery can operate underneath. These systems are particularly suitable for large scale farming and regions with high solar radiation. They offer flexibility in design and allow farmers to continue traditional agricultural practices with minimal disruption.

(A)



(B)



(C)



Fig. Different types of agrivoltaic systems. Classified into open systems (A) between crops (B) over crops and (C) closed systems (in a greenhouse structure) (Adopted from Soto-Gómez (2024)).

2. *Closed Agrivoltaic System*

Closed systems involve the integration of solar panels into greenhouse structures, either on the roof or walls. These systems require specialized technical design and management. Research indicates that crop production is generally not affected if the panel coverage remains below 20%. However, excessive coverage (50-100%) can significantly reduce light availability, leading to lower crop yields. Interestingly, certain crops such as peppers and leafy vegetables may benefit from partial shading, demonstrating that agrivoltaics can be tailored to specific crop requirements.

ENVIRONMENTAL, ECONOMIC AND SOCIAL ADVANTAGES

A. Environmental Benefits

- One of the most significant advantages of agrivoltaics lies in its ability to enhance environmental sustainability and climate resilience (Kumpanalaisatit et al., 2022).
- **Improved Water Use Efficiency:** The shading effect of solar panels reduces evaporation from soil and plant surfaces. Studies indicate that agrivoltaic systems can save up to 29% of irrigation water, making them highly valuable in water-scarce regions.
- **Microclimate Regulation:** Solar panels create a moderated microclimate beneath them by reducing temperature extremes. This helps protect crops from heat stress, which is becoming increasingly common under climate change scenarios.
- **Protection from Extreme Weather:** Agrivoltaic systems act as a physical barrier against extreme weather events such as hailstorms, heavy rainfall, and intense solar radiation.
- **Soil and Biodiversity Enhancement:** Reduced exposure to wind and water erosion helps maintain soil health. Additionally, the moderated environment under solar panels can support shade-tolerant crops and promote biodiversity by providing habitats for beneficial insects and pollinators.

B. Economic and Social Benefits

- Beyond environmental benefits, agrivoltaics offers substantial economic and social gains, especially for rural communities.
- **Income Diversification:** Farmers can generate additional income by selling electricity produced from solar panels. This reduces dependency on a single source of income and enhances financial stability.

- **Energy Access and Independence:** Agrivoltaic systems can provide clean energy for on-farm operations such as irrigation, storage, and processing. This reduces reliance on fossil fuels and lowers operational costs.
- **Enhanced Land Productivity:** By combining crop production with energy generation, agrivoltaics increases the overall productivity of land. Instead of choosing between food and energy, both outputs are achieved simultaneously.
- **Rural Development:** The adoption of agrivoltaics can create employment opportunities, improve infrastructure, and support rural electrification. It also encourages technological advancement in agricultural communities.
- **Environmental Sustainability:** By replacing fossil fuels with renewable energy, agrivoltaics contributes to reducing greenhouse gas emissions and supports climate change mitigation efforts.

AGRIVOLTAICS IN INDIAN CONTEXT

India, owing to its extensive agricultural sector and abundant solar energy resources, has significant potential for the adoption of agrivoltaic systems. The arid and semi-arid regions of the country, particularly Rajasthan, Gujarat, and Haryana, receive high solar radiation but face challenges such as water scarcity and heat stress, which adversely affect crop growth. In these areas, agrivoltaics offers a promising approach by integrating renewable energy generation with agricultural production (Yadav et al., 2024).

The Government of India aims to achieve 500,000 MW of renewable energy capacity by 2030, including around 300,000 MW from solar photovoltaics. Initiatives like the Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM) scheme support this target by promoting solar energy use in agriculture and improving farmers' energy security.

CHALLENGES AND TRADE-OFFS

Despite its numerous benefits, agrivoltaics is not without challenges. One of the primary concerns is the balance between crop yield and energy production. Excessive shading can reduce crop growth and yield, whereas insufficient panel coverage may limit energy generation. Therefore, designing agrivoltaic systems requires careful optimization of panel spacing, height, and orientation to ensure that both agriculture and energy production are maintained effectively. Another challenge is the initial investment cost, which can be high for farmers without financial support.

CONCLUSION

Integrating agriculture with photovoltaic technology can simultaneously address the growing requirements of food production and energy generation. India has considerable potential for harnessing renewable energy while ensuring food security for its population. Agrivoltaic systems can contribute to improving farmers' income by enabling dual land use and additional revenue generation. However, supportive policy frameworks and strategic modifications are essential for promoting wider adoption and effective implementation of agrivoltaic systems.

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