

Agrivoltaics- climate smart approach for the emerging world

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ABSTRACT

The Industrial Revolution brought technological advances that improved quality of life but at significant environmental costs, such as climate change and its impact on agriculture and energy needs. Agrivoltaic systems, which integrate agricultural cultivation with solar photovoltaic panels, offer a sustainable solution by combining food and energy production on the same land. Originating in the 1980s and popularized in recent decades, agrivoltaics enhances land use efficiency, protects crops, increases yields, and generates renewable energy while promoting rural electrification and reducing greenhouse gas emissions. Despite its benefits, the adoption of agrivoltaics faces challenges such as high costs, legal restrictions, and limited awareness. Overcoming these barriers requires policy support, financial incentives, and pilot projects. Agrivoltaics demonstrates significant potential to balance land demands for food and energy, improve farm resilience, and contribute to global sustainability goals, particularly in arid and developing regions.

Key word – Revolution, Agrivoltaic systems, electrification, sustainability

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INTRODUCTION

Since the Industrial Revolution, the world has experienced a dramatic transformation, driven largely by rapidly advancing technologies and the widespread use of fossil fuel-powered vehicles and machinery. These innovations have reduced human labor and greatly enhanced the quality of life. However, this progress has come with significant costs, increasingly evident in recent decades. Human activities have been a major contributor to climate change, resulting in severe climate events that have caused widespread damage to lives and property. Over time, these challenges have become more pressing, affecting agricultural systems and daily life. The rapid growth of the global population has intensified the demand for sufficient food supplies and clean, sustainable energy sources, further complicating the situation. The Green Revolution, while revolutionizing agriculture, made it heavily dependent on inputs, increasing the energy required for crop production. This has led to a heightened reliance on non-renewable, polluting energy sources, exacerbating atmospheric pollution. Additionally, land—a critical resource for agriculture—faces competing demands, particularly when shifting to renewable energy production to meet rising energy needs, potentially threatening food security for the growing population. To tackle these intertwined challenges, a promising innovation known as agrivoltaic systems has been introduced, offering a potential solution to balance food and energy production sustainably.

Agrivoltaic systems integrate soil-based agricultural cultivation with solar photovoltaic panels, resulting in a synergy of food production and energy generation while reducing competition for limited land resources. This novel technique not only stabilizes agricultural output but also protects crops that are vulnerable to climate change, benefiting rural economies and livelihoods. Adolf Goetzberger and Armin Zastrow established the notion of agrivoltaics in the early 1980s. However, widespread adoption occurred in the second decade of the twenty-first century. The term "agrivoltaics" was coined by a group of French scientists led by Christophe Dupraz to describe a system that combines solar panels and crops on the same piece of land to maximize land use efficiency. Later research in France indicated that this technology may enhance worldwide land productivity from 35% to 73%, making it an appealing choice for farmers and solar energy providers alike. Global agrivoltaics capacity increased from 5 MW in 2014 to 2.8 GW in 2020, with China leading the trend with 1.9 GW installed capacity, followed by developed nations such as Japan and Germany

(Trommsdorff, Gruber *et al.*, 2022). This method is especially attractive for developing tropical countries since it allows them to achieve development and climate goals while preserving agricultural land.

Agrivoltaic systems are classified into three types: elevated, inter-row, and a combination of both. In the elevated system, solar panels are installed directly above the crops, usually at a height of 6 feet. This structure protects crops from adverse weather conditions while also reducing light exposure, making it suitable for plants that like shade. The inter-row system grows crops between rows of solar panels rather than underneath them. While it does not provide the same level of extreme weather protection, it does allow for more sunlight exposure, which is beneficial to crops such as grasses, grains, and hardy vegetables.

POTENTIAL BENEFITS OF AGRIVOLTAICS:

1. **Enhanced Land Use Efficiency:** By allowing the simultaneous production of food and energy from the same area, agrivoltaics greatly increases the efficiency of land use and maximizes the potential output of the land.
2. **Food-Energy Synergy:** This system promotes a mutually beneficial interaction between the production of food and energy, providing a sustainable solution to the problems caused by climate change and ensuring a brighter future.
3. **Higher Crop Yields:** Agrivoltaics can increase crop yields for crops that like shade, increasing farming's profitability. This encourages economic growth in agricultural areas and helps to reduce poverty.
4. **Additional Income Source:** Farmers face difficulties due to the unpredictabilities of traditional farming, which include low returns, excessive expenses, poverty, debt, and unsecured loans. Because grid-connected solar panels enable farmers to sell extra electricity to utility companies, agrivoltaics offers an alternate source of revenue.
5. **Protection from Severe Weather:** Crops are better protected against severe weather conditions like hailstorms and excessive sunlight. In addition, the crops produce a microclimate that protects the solar panels, extending the agrivoltaic system's lifespan.
6. **Promotes Rural Electrification:** Combining solar energy systems with agricultural methods can promote rural electrification in underdeveloped areas with plenty of sunlight. There is a lot of potential for this kind of integration because solar energy is one of the most readily available renewable resources in the world. For example, agrivoltaic systems in Japan have produced an astounding 284 million MWh of electricity year (Gonocruz *et al.*, 2021). Remote locations around the world can be electrified with this technology in a sustainable and dependable manner.
7. **Reduces Greenhouse Gas Emissions:** Electricity generation from non-renewable sources contributes heavily to greenhouse gas emissions. Agrivoltaics reduces reliance on these sources by promoting renewable energy production. For example, the European Commission aimed for 32% of energy to be sourced from renewables by 2020 (Renewable Energy Target, European Commission), a goal that agrivoltaic systems can help achieve through their integration of sustainable energy and agriculture.

Challenges of adopting agrivoltaics

1. **Cultivation Challenges:** Farmers may find it challenging to adopt agrivoltaic technology due to the unpredictability of crop reactions to this technology. Extensive testing is frequently necessary to identify the best crop-system combination, which can be costly and time-consuming.
2. **Expensive:** Compared to conventional solar panels, agrivoltaic system installation is more expensive and requires a large amount of maintenance. These expenses can be prohibitive for small-scale producers. To properly handle and maintain the panels, farmers also require training. Long-term advantages, however, may outweigh these expenditures.
3. **Land Use Restrictions:** Legal and regulatory limitations prevent large-scale commercial solar developments from being established in many developing nations, which restricts the broad use of agrivoltaic systems.
4. **Impact on Soil Quality:** Installing solar panels may lead to soil compaction, negatively affecting soil health. Farmers must implement soil remediation measures, which can increase their workload and financial burden.
5. **Limited Awareness and Fear of Failure:** A lack of awareness about the potential benefits of agrivoltaics among the farming community hampers its adoption. Furthermore, apprehension about the risks and uncertainties associated with this technology creates additional challenges for its acceptance and implementation.

Way forward

- **Policy and Regulatory Support:** Challenges in adopting agrivoltaic systems can be addressed through well-designed government policies and regulations. For example, tropical countries have introduced

various initiatives to promote agrivoltaic adoption. In India, the government launched the PM-KUSUM scheme to help farmers implement agrivoltaic systems on a small scale.

- **Financial Incentives for Farmers:** Providing price support, such as subsidies, can encourage farmers to adopt new technologies like agrivoltaics. These incentives will extend the system's benefits to remote rural areas, fostering widespread adoption and increasing agricultural and energy efficiency.
- **Centres of Excellence:** Creating specialized centres of excellence at technical colleges and universities can be extremely important for agrivoltaic technology training and capacity building. These facilities can help developers reach more potential users and educate rural communities about the advantages of agrivoltaics.
- **Pilot Projects and Business Model Testing:** Pilot projects should test new designs and technologies and experiment with various crop selections to assess the commercial viability of agrivoltaic systems. These initiatives will increase the versatility and profitability of agrivoltaic systems and enable them to be refined for a variety of situations.

CONCLUSION

Agrivoltaics offers a promising solution to the competition between food and energy production for land. It has the potential to reduce greenhouse gas emissions, generate renewable energy, and improve the climate resilience of farms. The technology also provides additional benefits, such as increased land use efficiency, income generation, poverty alleviation, and enhanced crop yields, making it a highly attractive option for farmers, particularly in developing countries. Despite its advantages, agrivoltaics is still in its early stages of development, requiring further research to unlock its full potential on a larger scale. Additionally, overcoming legal, cultural, and political obstacles necessitates comprehensive studies and policy interventions. Pilot projects conducted to date have shown particular promise in arid and semi-arid regions, where the adoption of agrivoltaic systems has proven highly beneficial. As a result, agrivoltaics not only provides a stable environmental framework for farmers but also aligns with global efforts to curb greenhouse gas emissions and promote sustainable development.

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