

# Agri-Photovoltaic Systems and Farmer Empowerment An Agricultural Extension Perspective

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## Summary

Agri-Photovoltaic (AgPV) systems represent a transformative agricultural innovation that enables simultaneous electricity generation and crop production on the same land. As of 2024, global AgPV capacity reached approximately 14 GW with rapid growth in Asia-Pacific leading adoption. Recent pilot studies demonstrate that AgPV can increase farmer incomes by 200-400% while

maintaining or even improving crop yields for shade-tolerant crops. Agricultural extension services play a critical role in accelerating equitable adoption through demonstration plots, training programs, and financing facilitation, particularly for smallholder farmers who constitute 80% of sub-Saharan Africa's agricultural production.

## What is AgPV?

Agri-photovoltaics, also known as agrivoltaics or solar farming, refers to the simultaneous use of land for both agriculture and photovoltaic power generation. The system involves mounting solar panels either as elevated structures above crops (overhead PV) or with ground-mounted panels spaced to allow cultivation between rows (interspace PV).



## Key system types include:

- **Overhead PV:** Panels mounted 2-4 meters above crops on elevated structures, allowing full agricultural operations beneath.
- **Interspace PV:** Ground-mounted panels with wide spacing between rows for crop cultivation.
- **Vertical bifacial systems:** Vertical panel arrangements that provide wind protection while maximizing sunlight exposure for crops.

## Why AgPV Matters for Smallholder Farmers

### Income Diversification and Enhancement

AgPV offers smallholder farmers multiple revenue streams that can significantly boost household incomes. In Delhi's Najafgarh plant, farmers increased income four-fold from INR 30,000 to INR 1.2 lakh per acre annually through lease arrangements. **Key income sources include:**

- Land lease rentals to solar developers
- Direct electricity sales under feed-in tariff schemes
- Value-added processing using on-site renewable energy
- Premium pricing for shade-grown specialty crops

### Microclimate Benefits and Water Efficiency

Solar panels create beneficial microclimates that reduce crop evapotranspiration rates by up to 20-60% while decreasing water consumption by 15-20%. This **"shading effect"** proves

particularly valuable in arid regions where farmers at CAZRI Jodhpur harvested up to 150,000 liters of rainwater annually using integrated collection systems.

### Crop Protection and Year-Round Production

AgPV systems provide natural protection against hailstorms, excessive heat, and frost damage. In Netherlands trials, specialty crops including berries showed improved yield and

quality under semi-transparent panels that filtered direct sunlight while maintaining optimal growing conditions.

### Current Status & Key Statistics

#### Global Adoption Trends (2024-2025)

| Metric                 | Value                          |
|------------------------|--------------------------------|
| Global AgPV Capacity   | 14 GW (2024)                   |
| Market Growth Rate     | 12.4% CAGR                     |
| Leading Region         | Asia-Pacific (70% of projects) |
| Typical Payback Period | 3-6 years                      |
| Average System Height  | 2-4 meters                     |
| Water Use Reduction    | 15-20%                         |

#### Regional adoption highlights:

- **China:** Leading with 12 GW installed capacity as of 2024.
- **Europe:** 15 MW operational with 403 MW allocated through German tenders in 2022.
- **India:** 15+ pilot projects totaling ~15 MW across multiple states, with Maharashtra
- **PAANI Foundation** programs showing promising results.
- **Sub-Saharan Africa:** 11 million economically feasible sites identified with potential profits of \$5.2 billion annually.

### Economic Performance

Recent studies indicate impressive economic returns. In Senegal, potato farmers replacing diesel pumps with solar irrigation achieved 55% internal rate of return with payback

periods under two years. Sub-Saharan Africa analysis suggests average discounted investment requirements of \$3 billion annually could generate over \$5 billion in farmer profits.

### How Agricultural Extension Can Accelerate Equitable Adoption

#### Demonstration and Training Programs

Extension services must establish **AgPV demonstration plots** showcasing technology benefits and optimal crop-panel configurations. CAZRI's pilot program successfully demonstrated yield improvements for beans, vegetables, and medicinal crops under controlled shading conditions.

#### Recommended extension activities:

- On-farm trials testing locally-adapted crop varieties
- Seasonal training workshops on AgPV management

- Peer-to-peer learning networks connecting early adopters
- Technical skill development for system maintenance

#### Financing Facilitation

Extension agents can bridge the gap between farmers and financial institutions by:

- Facilitating access to blended finance instruments and soft loans
- Supporting applications for government subsidies under schemes like PM-KUSUM

- Connecting farmers with pay-as-you-go (PAYG) financing models

### Gender-Sensitive Approaches

Women farmers require targeted support given their limited access to land ownership and credit. Extension programs should prioritize

- Developing farmer cooperatives for collective bargaining power.

training women's groups, provide childcare during workshops, and ensure women's participation in AgPV cooperative structures.

### Barriers, Risks & Trade offs

#### Technical and Economic Challenges

**Capital costs** remain 30-100% higher than conventional solar installations due to elevated mounting structures and specialized designs. Land use policies often fail to recognize dual-use systems, creating regulatory uncertainty for developers and farmers.

**Operational constraints** include:

- Limited mobility for large agricultural machinery.
- Safety concerns regarding high-voltage equipment proximity.
- Structural maintenance costs in humid agricultural environments.
- Coordination challenges between energy and agricultural operations.

#### Yield Impacts

While some crops benefit from partial shading, others show significant yield reductions. Rice and wheat typically exhibit decreased productivity under AgPV systems, while leafy vegetables, legumes, and berries often show improved yields. Meta-analysis suggests corn yields decrease roughly linearly with shading intensity.

#### Equity Concerns

Without proper safeguards, AgPV adoption may exacerbate rural inequalities by benefiting only landowners while displacing agricultural workers. Extension programs must ensure inclusive participation and monitor social impacts.

### Policy & Financing Instruments That Work

#### Financial Mechanisms

**Effective financing approaches** include:

- Feed-in tariffs with AgPV premium rates
- Blended finance combining grants, concessional loans, and private investment

- Value chain financing linking energy revenues to agricultural credit
- Public-private partnerships reducing farmer risk exposure

### Practical Recommendations for Extension Agents

#### Immediate Action Steps

1. **Establish demonstration sites** in diverse agro-climatic zones testing optimal panel heights, spacing, and crop combinations.
2. **Develop training curricula** covering AgPV system design, crop management under shade, and financial planning.
3. **Create monitoring protocols** tracking crop yields, energy production, and farmer income impacts.
4. **Build partnerships** with solar developers, financial institutions, and research organizations.

5. **Design inclusive programs** ensuring women and youth participation in AgPV initiatives.
6. **Facilitate farmer cooperatives** for collective procurement and management of AgPV systems.
7. **Establish maintenance networks** providing technical support and spare parts access.
8. **Monitor social impacts** to prevent displacement of agricultural workers.

### Case Studies

#### Success Story: ICAR-CAZRI Jodhpur Integration

The Central Arid Zone Research Institute's pioneering 105 kW AgPV system in Rajasthan demonstrates successful integration in India's

challenging arid conditions. The project combines elevated solar panels with rainwater harvesting, supporting cultivation of beans, vegetables, and medicinal plants while generating clean electricity. Farmers reported improved crop resilience during heat waves and consistent water availability through the integrated collection system.

#### **Scaling Example: GIZ-NISE Partnership**

#### **Conclusion & Call to Action**

Agri-Photovoltaic systems offer immense potential for empowering farmers through diversified income streams, improved crop resilience, and enhanced resource efficiency. Agricultural extension services must lead this transformation by establishing demonstration sites, building farmer capacity, and facilitating

The December 2024 MoU between National Institute of Solar Energy, SunSeed APV, and GIZ India launched a 16.5 kW rooftop agrivoltaics pilot evaluating crop impacts and commercial feasibility in urban settings. This partnership model demonstrates how international cooperation can accelerate technology transfer and knowledge generation for wider adoption.

access to appropriate financing. The window for equitable AgPV adoption is narrowing as rapid solar deployment continues-extension agents must act decisively to ensure smallholder farmers benefit from this agricultural revolution.