International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 03 | March - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Agrovoltaics Dual Use of Land for Solar Energy Production and Farming

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Abstract - Agrovoltaics is an innovative approach that combines agriculture and solar energy production on the same land. This project focuses on installing solar panels above crop fields to generate electricity while allowing crops to grow underneath. By sharing land resources, Agrovoltaics helps increase farmers' income and improves land-use efficiency. The partial shade from solar panels can reduce water evaporation and protect crops from extreme heat. At the same time, clean solar energy supports sustainable power generation and reduces dependence on fossil fuels. This system promotes environmental conservation while maintaining agricultural productivity. Overall, the Agrovoltaics project demonstrates a practical solution to meet growing energy demands without sacrificing food production

Key Words: Agriculture and solar energy production on the same land, Solar panels, LDR sensor, DHT22 sensor, ATmega32P microcontroller

1. INTRODUCTION

Introduction. Agriculture and energy production are two of the most essential pillars supporting modern society. With the rapid increase in population, the demand for food and electricity has grown significantly. At the same time, the availability of land and natural resources is steadily decreasing. Traditional farming methods alone are no longer sufficient to meet future food requirements, while conventional energy generation methods heavily depend on fossil fuels, leading to environmental pollution and climate change. These challenges highlight the urgent need for innovative and sustainable solutions that can address both food and energy demands simultaneously. Agrovoltaics is an emerging concept that offers a promising solution by combining agricultural activities with solar power generation on the same land. Instead of helping determine when irrigation is using separate areas for farming and solar power plants, Agrovoltaics systems install solar panels above or alongside crop fields. This dual-use approach allows crops to grow while solar panels generate clean electricity. By sharing land resources, Agrovoltaics improves land-use efficiency, reduces conflicts between agriculture and energy infrastructure, and supports sustainable rural development. Solar energy plays a crucial role in Agrovoltaics systems due to its renewable and eco-friendly nature. Solar panels convert sunlight into electrical energy, which can be used to power irrigation systems, sensors, lighting, and other agricultural equipment. In the proposed Agrovoltaics project, multiple solar panels are connected together to produce electrical power. The generated voltage is regulated using a voltage controller to ensure safe and stable operation of the entire system. The regulated power is then stored in a battery, enabling continuous operation even during low sunlight or nighttime conditions. The heart of the proposed system is the ATmega32P microcontroller, which acts as the central control unit. It continuously monitors environmental conditions using various sensors integrated into the system. A soil moisture sensor measures the water content in the soil, required. The DHT22 sensor provides accurate temperature and humidity readings, which are essential for crop health analysis. A rain sensor detects rainfall to prevent unnecessary watering, while an LDR sensor monitors light intensity to assess sunlight availability. An ultrasonic sensor can be used for obstacle detection or water level monitoring, enhancing system safety and automation. Based on real-time sensor data, the microcontroller makes intelligent decisions to control agricultural operations. When soil moisture levels fall below a defined threshold, the system automatically activates the water motor through the L293D motor driver, ensuring timely irrigation. Similarly, irrigation is stopped during rainfall or when sufficient moisture is detected, preventing water wastage. In addition to

irrigation control, the system also manages auxiliary loads such as LED lighting. The 12V LED units provide illumination for farm areas during low-light conditions, improving safety and operational visibility. All key system parameters, including sensor readings and power status, are displayed on an LCD screen, allowing farmers to easily monitor system performance in real time. Grid integration further supports the stability of the power network by contributing clean, renewable energy. The inclusion of the ESP8266-12E module enables wireless communication and future expansion into Internet of Things (Iota) applications. With this module, system data can be remotely monitored and analyzed, allowing farmers to track environmental conditions and energy generation from anywhere. This connectivity enhances decision-making, supports predictive farming techniques, and aligns with modern smart agriculture trends. Overall, the proposed Agrovoltaics system demonstrates a sustainable and intelligent approach to modern farming. By integrating solar energy generation, automated irrigation, environmental monitoring, and grid power export, the project addresses critical challenges related to energy scarcity, water conservation, and agricultural productivity. This system not only promotes renewable energy usage but also supports farmers in achieving higher efficiency, reduced operational costs, and improved environmental sustainability. The Agrovoltaics model presented in this project serves as a practical step toward a greener, smarter, and more resilient agricultural future.

ACKNOWLEDGEMENT

Agrovoltaics enables the dual use of land for both solar energy production and farming, addressing the growing competition for land between agriculture and renewable energy projects. This integrated approach allows solar panels to be installed above or between crops, on greenhouses, or on grazing land, enabling simultaneous food and clean energy production. By co-locating these systems, Agrovoltaics enhances land-use efficiency studies show potential increases of **60–70% in land productivity**—while offering benefits such as reduced water evaporation, improved crop resilience to heat stress, and higher solar panel efficiency due to cooling from vegetation.

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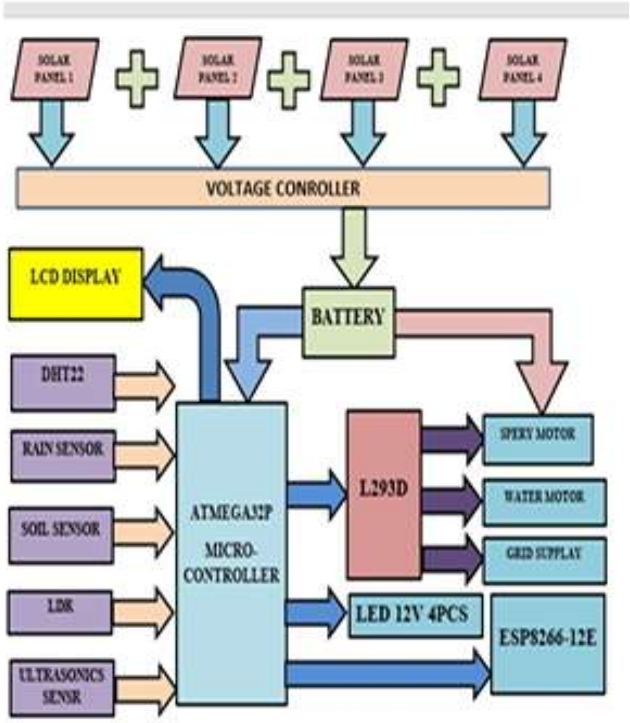

ADVANTAGES

1. Dual Use of Land

The biggest advantage of Agrovoltaics is that the same piece of land is used for both farming and electricity generation. Farmers can grow crops below solar panels while solar energy is produced above, which is very useful in areas where land availability is limited.0

2**. Additional Income for Farmer**

Agrovoltaics systems provide extra income to farmers. Apart from earning from crops, farmers can sell power Solar panels provide partial shade to crops, protecting them from extreme sunlight, heavy rainfall, and hailstorms. This controlled shading can reduce crop stress and improve crop quality in hot regions.

3. **Renewable and Clean Energy Generation**

Solar energy is a clean, renewable, and pollution-free source of power. Agrovoltaics helps reduce dependence on fossil fuels, lowers carbon emissions, and supports sustainable energy development.

4. Improved Crop Protection

Solar panels provide partial shade to crops, protecting them from extreme sunlight, heavy rainfall, and hailstorms. This controlled shading can reduce crop stress and improve crop quality in hot regions.

5. Reduced Water Requirement Due to shading from solar panels, water evaporation from soil is reduced. This helps retain moisture in the soil, leading to better water efficiency and reduced irrigation needs.

6. Increased Agricultural Productivity
Some crops such as vegetables, pulses, and leafy greens grow better under partial shade. Agrovoltaics creates a favorable micro 1. High Initial Investment climate, which can improve crop yield and overall farm productivity.
7. Reliable Power Supply for Rural Areas Electricity generated from Agrovoltaics can be used for irrigation pumps, cold storage, and farm equipment. Excess power can be supplied to the grid, improving electricity availability in rural areas.
8. Employment Generation Agrovoltaics creates job opportunities in installation, maintenance of solar panels, farming activities, and system monitoring. This supports rural employment and skill development.
9. Supports Sustainable Development
The project supports sustainable development goals by combining food security, clean energy production, and environmental protection in a single system.
10. Efficient Use of Natural Resources
Agrovoltaics promotes better utilization of sunlight, land, and water resources, making agriculture more resilient to climate change and

DISADVANTAGES

1. High initial Investment
The initial cost of installing solar panels, supporting structures, and electrical equipment is very high. Small farmers may find it difficult to afford this setup without government subsidies or financial support.
2. Complex System Design
Agrovoltaics systems require proper planning and technical design. Panel height, spacing, and tilt must be carefully decided so that crops receive enough sunlight. Poor design can reduce crop growth or solar output.
3. Limited Crop Selection
Not all crops grow well under shaded conditions. Sun-loving crops like wheat, rice, and sugarcane may show reduced yield under solar panels. This limits crop choices for farmers.
4. Maintenance Challenges
Solar panels require regular cleaning and maintenance to maintain efficiency. Dust, bird droppings, and agricultural activities can increase maintenance efforts and costs.
5. Difficulty in Using Farm Machinery
The presence of solar panel structures can 10. Grid Connectivity Issues restrict the movement of tractors and farming equipment. This can increase manual labor and reduce farming efficiency.
6. Dependence on Weather Conditions
Solar power generation depends on sunlight. During cloudy days, rainy seasons, or winters, electricity generation may decrease, affecting power availability and income.
7. Requirement of Skilled Labor
Installation, operation, and maintenance of Agrovoltaics systems require skilled technical workers, which may not be easily available in rural areas.
8. Land Use Restrictions
Once solar structures are installed, the land cannot be easily modified for other agricultural purposes. This flexibility in land use planning. Reduces
9. Possible Reduction in Crop Yield
If shading is not properly managed, crops may receive insufficient sunlight, leading to lower photosynthesis and reduced crop yield.
10. Grid connectively issues
In remote areas, grid connection and power evacuation infrastructure may be weak or unavailable. This can limit the ability to sell excess electricity to the grid.

CONCLUSION

Agrovoltaics is a smart and sustainable approach that combines agriculture and solar energy production on the same land. It helps farmers increase their income while producing clean and renewable electricity. By providing partial shade, the system can protect crops, reduce water loss, and improve land utilization. At the same time, excess electricity can be supplied to the grid, supporting energy demands and reducing dependence on fossil fuels. However, Agrovoltaics also faces challenges such as high initial cost, design complexity, and limited crop suitability. With proper planning, technical support, and government incentives, these limitations can be minimized. Overall, Agrovoltaics is a promising solution for future energy and food security, especially in countries like India where land and energy resources must be used efficiently The Agrovoltaics project successfully demonstrates that agricultural activities and solar power generation can be carried out together on the same land without disturbing farming operations. The system produces clean electricity while allowing crops to grow under controlled shading conditions. The results show better land utilization, reduced water evaporation, and additional income through solar energy generation. Farmers benefit from both crop yield and power supply, and excess electricity can be exported to the grid. Overall, the project proves that Agrovoltaics is a practical, sustainable, and future-oriented solution for meeting energy needs while supporting agriculture.

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