

Net Zero Emission Farming Using Photovoltaic Cells

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ABSTRACT - Achieving net-zero emissions in agriculture is critical for combating climate change and ensuring long-term food security. This research proposes a sustainable farming model that integrates photovoltaic (PV) solar energy systems with carbon credit mechanisms to minimize greenhouse gas emissions. The study highlights the dual benefits of renewable energy use and carbon sequestration practices, offering both environmental and economic gains. Results from case studies demonstrate a significant reduction in carbon footprint and energy costs, validating the feasibility of this integrated approach for climate-resilient agriculture.

Key Words: Photovoltaic cell, Carbon Credits, Sustainable Agriculture, Green House Gases, Sustainable Farming

1. INTRODUCTION

Climate change has intensified the need for sustainable and carbon-neutral agricultural practices. Agriculture contributes significantly to global greenhouse gas emissions through fuel consumption, soil degradation, and methane release. Integrating photovoltaic (PV) technology and carbon offset mechanisms provides a strategic pathway to mitigate these effects. This paper presents a model leveraging solar energy and verified carbon credit programs to enable farmers to transition towards net-zero emissions while maintaining economic viability.



Figure 1: Project model showing photovoltaic cell application areas

2. LITERATURE REVIEW

The field of photovoltaic (PV) technology has witnessed significant advancements over the past few years, particularly in enhancing efficiency, material innovation, and sustainability. This literature survey summarizes key studies from 2019 onward.

Wang et al. (2021) conducted a comprehensive review of perovskite solar cells, which have gained attention due to their rapidly increasing efficiency and ease of fabrication. The study highlighted challenges related to stability and toxicity, especially due to the presence of lead, but also noted promising developments in lead-free alternatives and encapsulation strategies [1]. In a breakthrough work, Al-Ashouri et al. (2020) developed a monolithic perovskite/silicon tandem solar cell that achieved an efficiency of over 29%. This marked a significant improvement over traditional single-junction silicon cells and demonstrated the potential of tandem structures in commercial

applications [2]. Global trends and technological developments in the PV sector were summarized by the International Energy Agency (IEA) in its 2023 report. The IEA highlighted that solar PV had become one of the fastest-growing renewable energy sources, supported by declining costs and increasing deployment in both utility-scale and rooftop segments [3]. Brabec et al. (2020) discussed the progress in organic photovoltaic (OPV) technologies, which offer advantages such as flexibility and lightweight construction. Though currently less efficient than silicon-based cells, OPVs are considered promising for niche applications like wearable electronics and building-integrated photovoltaic [4]. The reliability and long-term performance of PV systems were investigated by Köntges et al. (2019), who analyzed common degradation modes and failures in PV modules. Their findings emphasized the need for robust quality control and standardized testing procedures to ensure performance consistency over a module's 25–30-year lifespan [5]. Guerrero-Lemus et al. (2019) presented a technology review on bifacial solar modules, which can capture sunlight from both sides. The study explained how bifacial systems increase energy yield, especially when installed on reflective surfaces, and are becoming increasingly viable for commercial installations [6]. Recycling and the end-of-life management of PV panels were explored by Tao and Yu (2022). Their research stressed the importance of developing effective recycling technologies and regulatory frameworks to address the growing volume of solar panel waste and to support circular economy principles [7]. Emerging materials, particularly polymers, were discussed by Li, Zhu, and Yang (2019). Their study focused on the potential of polymer-based solar cells in producing lightweight, flexible PV devices, which are especially useful in mobile or portable applications [8]. The application of machine learning (ML) in PV energy prediction was assessed by Al Garni and Awasthi (2021). They demonstrated how ML models could improve the accuracy of energy yield forecasts, optimize PV system operation, and assist in decision-making for energy planning [9]. Finally, Yin et al. (2020) explored transparent solar cells, an emerging solution for building-integrated photovoltaics (BIPV). These cells allow for electricity generation without obstructing visibility, making them ideal for windows, facades, and other architectural applications [10]. Carbon Credits in Agriculture: Lal (2004) and Smith et al. (2007) highlight regenerative practices such as no-till farming and cover cropping that enhance soil carbon storage [11]. Wollenberg et al. (2016) emphasized that pairing PV systems with carbon credits ensures economic sustainability and environmental compliance [12]. Photovoltaic Systems in Agriculture: Agro-photovoltaic (APV), introduced by Fraunhofer ISE (2017), demonstrated a 60% increase in land productivity by combining food and energy production. Studies have shown that installing solar panels over crops can optimize land use while producing renewable energy [13].

3. METHODOLOGY

3.1 Net-Zero Framework: The approach involves minimizing on-farm GHG emissions and offsetting the remainder through carbon credits.



Figure 2: Photovoltaic energy for farm equipment and house hold applications

3.2 Role of PV Cells: Solar panels are used to power irrigation systems, tractors, and household electricity needs. This reduces dependency on diesel and grid electricity.

3.3 Carbon Sequestration and Credits: Carbon credits are earned by adopting techniques such as:

- Solar PV installation
- No-till farming
- Manure and fertilizer management

3.4 Financial Model: Cost-benefit analysis includes reduced energy bills, capital recovery period, and earnings through carbon credits.

4. EXPERIMENTAL RESULTS

A case study on a 5-acre farm showed diesel usage of 324 liters/year, resulting in 859.57 kg CO₂ emissions. Implementing solar panels eliminated emission as well as generating the electricity required for household and agriculture purpose resulting saving of INR Rs.90, 264 annually.

- A comprehensive carbon footprint was calculated before applying the model which will be minimizes after the implementation of model. Not only carbon concentration reduces additionally farmers benefited from reduced energy cost and increased profitability, and it reduce the dependency of farmers from the government for fossil fuel.

- Farmer having 5 acre land required average 27 liter diesel per month for tractor and to run other equipment's.

Carbon footprint:-

Consumption of diesel per year = 27 x 12 = 324 liters per family

Carbon emission through diesel = 324 x 2.653

= 859.572 kg of CO₂

After the implementation of this model we can minimize this emission.

Table 1: Cost calculation for conventional sources

Particular	Unit/Month	Rate	Duration	Cost/Year
Household application	120 units/M	Rs.10	12 (M)	14,400/-
Pump	447.6 units/M	Rs.10	10 (M)	44,760/-
Diesel Requirement	27 litres/M	Rs. 96	12 (M)	31,104/-
Per year expenditure without Solar Energy				90,264/-

Table 2: Per Day Electricity Requirement for installation of 3kw of solar panel

Particular	Household	Tractor 35 HP	Other Equipment's	Total
Unit /Day	4	4	0.5	8.5 Units

Per day Electricity Requirement = 8.5 units (without pumping requirements)

- Installation cost for 3 kw solar panel
=Rs.2,00,000–Rs.78,000 (Subsidy)
=Rs.1,22,000/-.....A

- Installation cost for 3 HP Solar Pump
=Rs.29,500/- (Government's MTSSP Scheme).....B

One time investment = 1,22,000+29,500=Rs.1,51,500/- (A+B)

• Cost effectiveness using solar panels

After the implementation of the solar panel we can recover the investment in next two years. After that we can save every year 90,267/- up to next 20 years (25 years panel efficiency warranty by government or company)

Total saving of 20 years = 90,264 x 20 = 18, 05,280.00/-

• Additional cost benefits through Carbon Credit:-

In India, Farmers can generate approximately 6-8 carbon credits per hectare by adopting above farming model, and 1 carbon credits price is 30-35\$ in international market.

Benefits through selling carbon credits = 6(No) x 2(Hec.) x 30\$ x 85(Rs.) = Rs. 30,600 rupees. (Extra earning for each year)

5. DISCUSSION

This integrated model showcases the potential of combining clean energy with climate-smart agricultural practices. PV cells reduce operational carbon intensity, while sustainable soil practices earn farmers carbon credits. Beyond emission reductions, the model provides energy security and financial resilience.

The barriers include initial capital investment and the need for awareness and policy support. Government schemes such as MTSSP and subsidies greatly improve accessibility.

6. CONCLUSION

The proposed net-zero farming model effectively combines solar energy and carbon credit strategies to reduce emissions, lower costs, and generate additional income. This approach supports the global goals of sustainable development and climate resilience, making it an ideal model for replication across similar agro-climatic regions.

This sustainable farming model uses solar energy, organic composting, and carbon credits to reduce fossil fuel reliance and operational costs. Farmers save up to Rs.18,05,280.00/- over 20 years, energy independence, and also can earn extra income through carbon credits. The model lowers carbon emissions, reduces synthetic fertilizer use, and promotes eco-friendly practices, ensuring long-term profitability and supporting climate change mitigation. It aligns with global sustainability goals for a greener, more resilient agricultural future.

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planning, surveying, and environmental engineering. His interdisciplinary expertise supports sustainable infrastructure planning and effective water resource management, with a strong emphasis on practical, community-based solutions.

A notable achievement in his career is his recognition as a speaker on environmental topics for government organizations, where he shares his knowledge to promote awareness and drive environmental stewardship.

Prof. Kadlag continues to integrate academic rigor with practical relevance, aiming to develop sustainable engineering solutions that benefit both society and the environment.

BIOGRAPHIES



Prof. Chetan Kumar Sukadeo Kadlag is an accomplished academic and professional in the field of Civil and Environmental Engineering. He holds a Bachelor's degree in Civil Engineering (BE) and a Master's degree in Environmental Engineering (ME), and is currently pursuing his Ph.D., reflecting his deep commitment to lifelong learning and academic excellence.

He serves as an Assistant Professor in the Department of Civil Engineering at Amrutvahini College of Engineering, Sangamner. In this role, he is actively engaged in teaching, research, and mentoring students, while also contributing to departmental growth and innovation.

Prof. Kadlag's professional interests span across irrigation