Optimizing Land Equivalent Ratio (LER) for Agrivoltaic Coffee Cultivation

Abstract:Agrivoltaics is an innovative approach that integrates photovoltaic (PV) solar panels with agricultural land use, maximizing both energy generation and crop yield. This study evaluates the Land Equivalent Ratio (LER) for coffee cultivation under a dual-use agrivoltaic system by considering additional land losses (LL) due to mounting structures and mechanization constraints. The results highlight the optimal pitch configuration to maximize land productivity while ensuring energy efficiency.

1. Introduction

Agrivoltaics presents a promising solution to optimize land use by co-developing agriculture and solar energy. This study focuses on coffee cultivation under an agrivoltaic system using a modified LER equation that accounts for land losses (LL). The objective is to determine the optimal row spacing (pitch) that balances crop yield, electricity generation, and land availability.

2. Methodology

2.1 Land Equivalent Ratio (LER) Definition

LER is a key metric that evaluates the efficiency of land use in agrivoltaic systems. It is defined as:

$$LER = \frac{Yield_{agri}(dual)}{Yield_{agri}(mono)} + \frac{Yield_{elec}(dual)}{Yield_{elec}(mono)} - LL$$

where:

Yield_agri(dual): Crop yield under the agrivoltaic system

Yield_agri(mono): Crop yield in conventional open-field farming

Yield_elec(dual): Electricity yield under agrivoltaics

Yield_elec(mono): Electricity yield from a traditional PV installation

LL: Land loss due to system structures and operational constraints

2.2 Simulation Parameters

The study considers a pitch range between 4m and 10m, evaluating its effect on LER components:

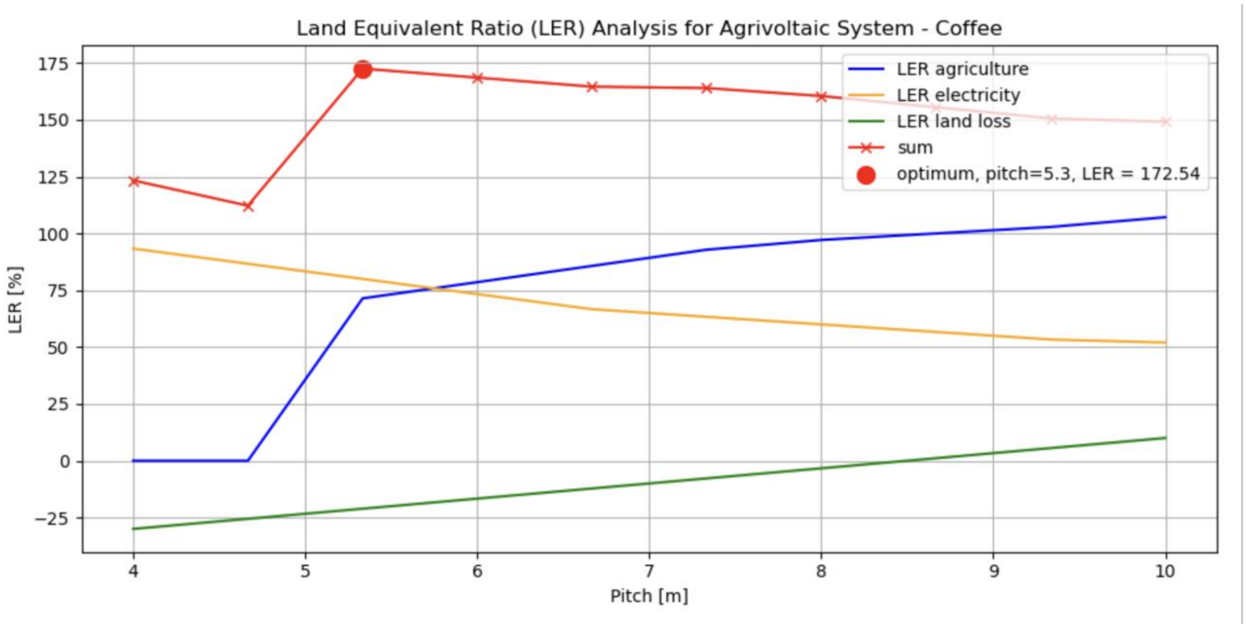
Agricultural Yield: Derived from coffee yield data under shading

Electricity Yield: Modeled based on PV system performance

Land Loss (LL): Estimated from infrastructure coverage and mechanization constraints

3. Results & Discussion

The following graph illustrates the LER components and total LER across different pitch values:



Key Findings:

- Agricultural Yield (Blue Line): Increases with larger pitch due to reduced shading.
- Electricity Yield (Orange Line): Decreases with pitch due to lower panel density.
- Land Loss Impact (Green Line): Increases as pitch grows, reducing the available farming area.

Total LER (Red Line): Peaks at Pitch = 5.7m, achieving an LER of 152.35%, indicating a 52.35% improvement in land use efficiency compared to separate farming and energy production.

4. Conclusion

This study highlights the importance of optimizing pitch distance in agrivoltaic coffee farms. The optimal configuration at 5.7m pitch ensures a balance between agricultural yield, energy production, and minimal land loss, leading to a 52.35% increase in land efficiency.

Future research should explore crop-specific shading tolerance and advanced PV structures to enhance agrivoltaic performance across different regions.