Development of a Large-Scale Digital Twin Model for Predicting Crop Yield in Agrivoltaic Systems :

A Case Study in Lombardy, Italy

Integrated Photovoltaic Conference

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Jiawei Chen, Nicola Paciolla, Stefano Mariani, Chiara Corbari

Department of Civil and Environmental Engineering of Politecnico di Milano

Introduction

- Growing demand for food and renewable energy
- Agrivoltaics: dual use of land for solar energy and agriculture
- Challenge: Understanding shading effects on crop growth
- Need for comprehensive monitoring and modeling

Experimental Setup

- Advanced lysimeter system (1.5m × 1.5m × 1m)
- Comprehensive sensor network

Instrument	Measured variable	Units	Accuracy
Arduino Light Sensor	Brightness	lux	±5%
Anemometer	Wind speed Wind direction	m/s Azim. °	± (3% or 0.3 m/s) ±5°
Pluviometer	Deep percolation	mm	2%
Weighing Scale	Weight	kg	0.5 kg (0.22 mmH2O)
Soil Moisture sensors	Soil moisture and temperature	m3 m-3	± 0.03 m3 m-3
Soil Salinity sensors	Soil Electrical Conductivity (+ Temp + Soil Moisture)	µ S/cm	± (5% or 10 µS/cm)
Soil Heat Flux Plate	Soil Heat Flux	W m-2	± 3%
Radiometer	Net Radiation budget	W m-2	± 5%
Thermo-hygrometer	Air Relative Humidity Air Temperature	% °C	± 0.8%
Small Weighing scale	Weight	g	2g (0.02 mmH2O)
Thermal camera	Surface temperature	° C	0.1°C(1.20 mm spatial res.)
	RGB images	n/a	n/a (0.39 mm spatial res.)

Table.1 Measuring instruments and relevant accuracy.

Three Experimental Conditions

- Experiment 1: Baseline (No Shading)
- Experiment 2: Continuous Partial Shading
- Experiment 3: Intermittent Partial Shading

Figure 1. Agrivoltaic Experiment in Fantoli Laboratory

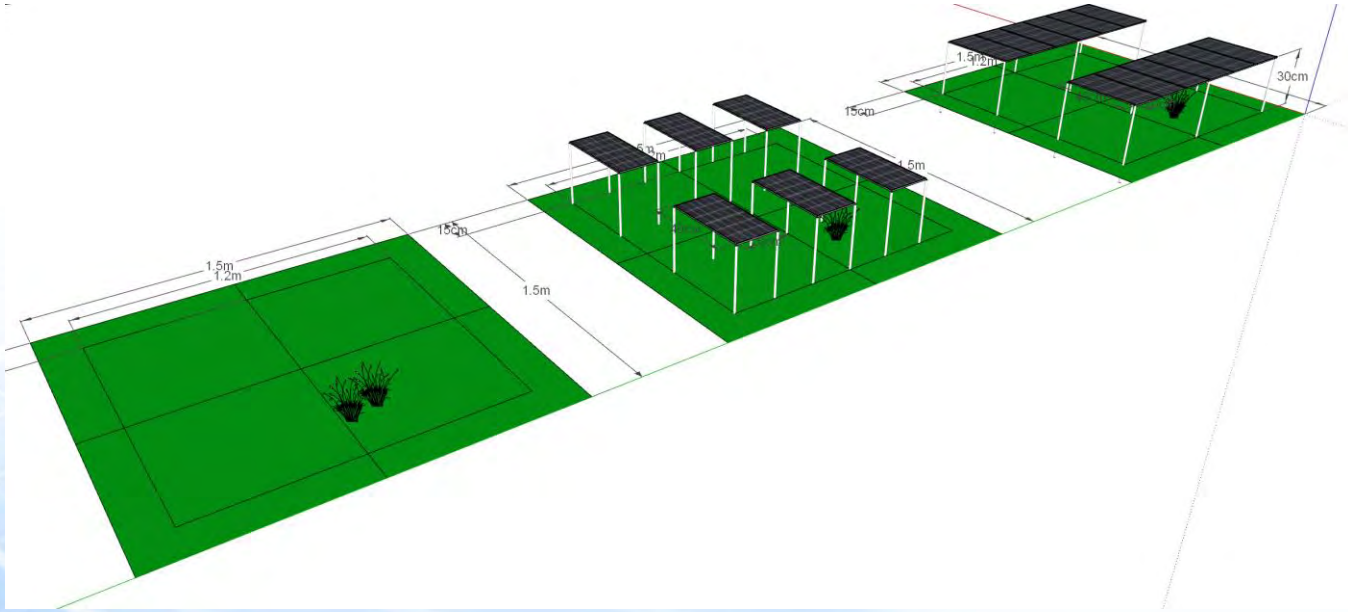

Figure 2. Three comparative experiments: baseline, continuous shading, intermittent shading

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Key Findings

- Soil Moisture Pattern :

-Higher retention under panels

-Most effective in continuous shading setup

- Light Distribution

-Clear zoning effect of panels

-More dynamic environment in intermittent setup

- Crop Response

-Yield affected by shading patterns

-Intermittent shading shows optimal balance

Soil Moisture Comparison

Location	Moisture Range (m^3/m^3)
Under Panels	0.25 - 0.31
Exposed Areas	0.15 - 0.25

Light Distribution Patterns

Shading Type	Light Level Range
Continuous Shading (Exp 2)	Peak: 50-60, Base: 0-3
Intermittent Shading (Exp 3)	High: 40-55, Medium: 20-35, Low: 0-3

Normalized Yield Results

Experiment Type	Relative Yield
No Shading	0.500 - 1.000
Continuous Shading	0.185 - 1.000
Intermittent Shading	0.320 - 1.000

Future Work

- Develop predictive models using collected experimental data
- Expand to different crops and seasonal variations
- Implement machine learning algorithms for yield prediction
- Validate digital twin model with actual photovoltaic installations
- Integration of satellite data for large-scale applications

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Thank you!

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