Agrivoltaic system

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On Line Training and Capacity Building
Program on Knowledge Management of Agro PV Plants and RE Grid Integration
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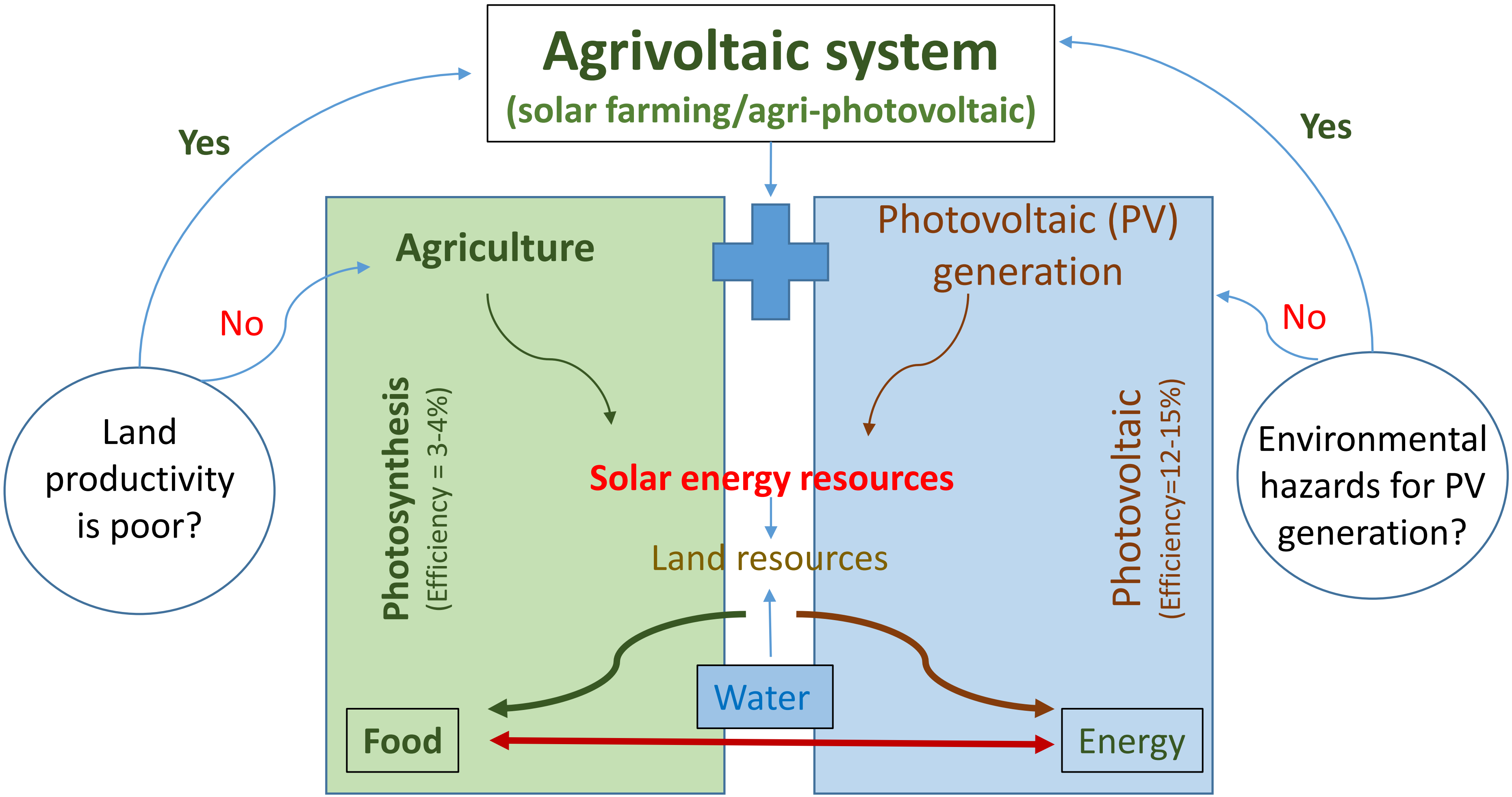
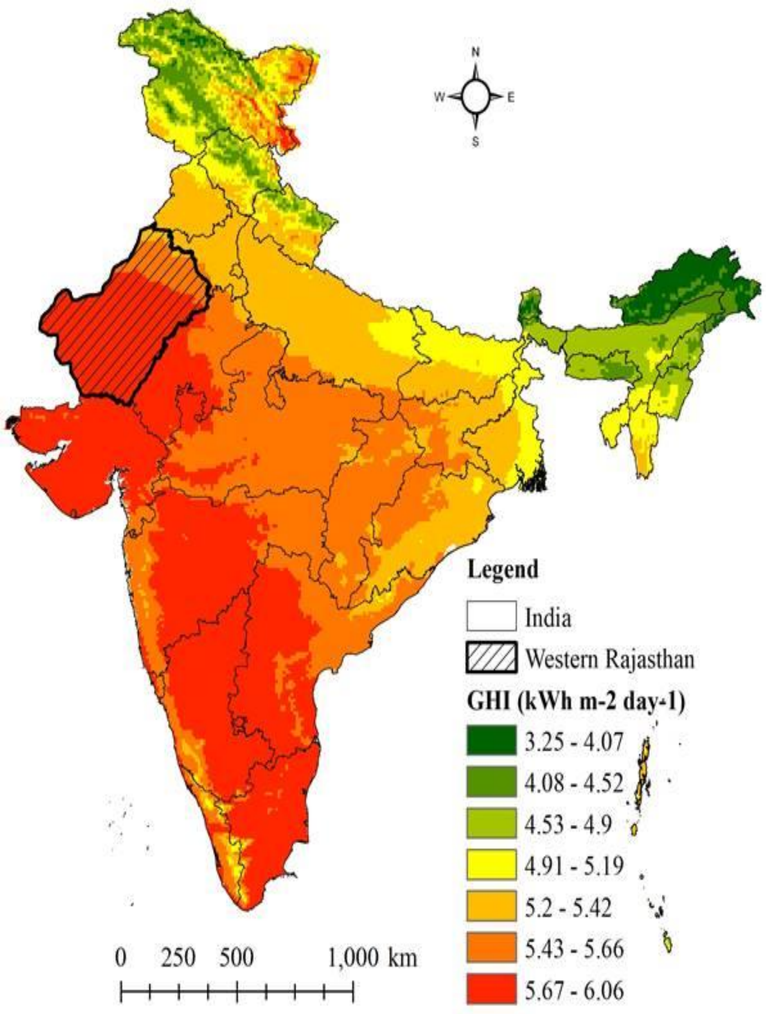
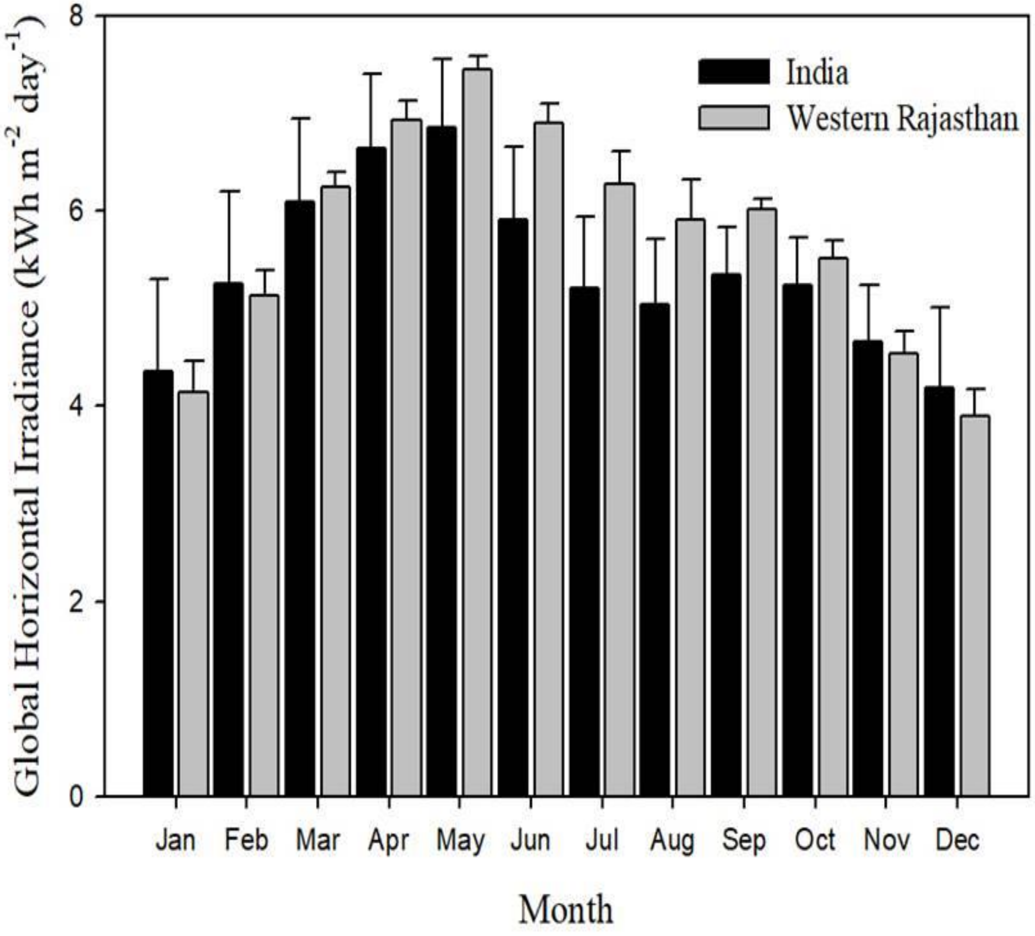

Agrivoltaic system
(solar farming/agri-photovoltaic)
Yes
Yes
Agriculture
Photovoltaic (PV) generation
No
No
Land productivity is poor?
Environmental hazards for PV generation?
Photosynthesis
(Efficiency = 3-4%)
Photovoltaic
(Efficiency=12-15%)
Solar energy resources
Land resources
Water
Food
Energy

Availability of solar irradiation in India vis-a-vis western Rajasthan





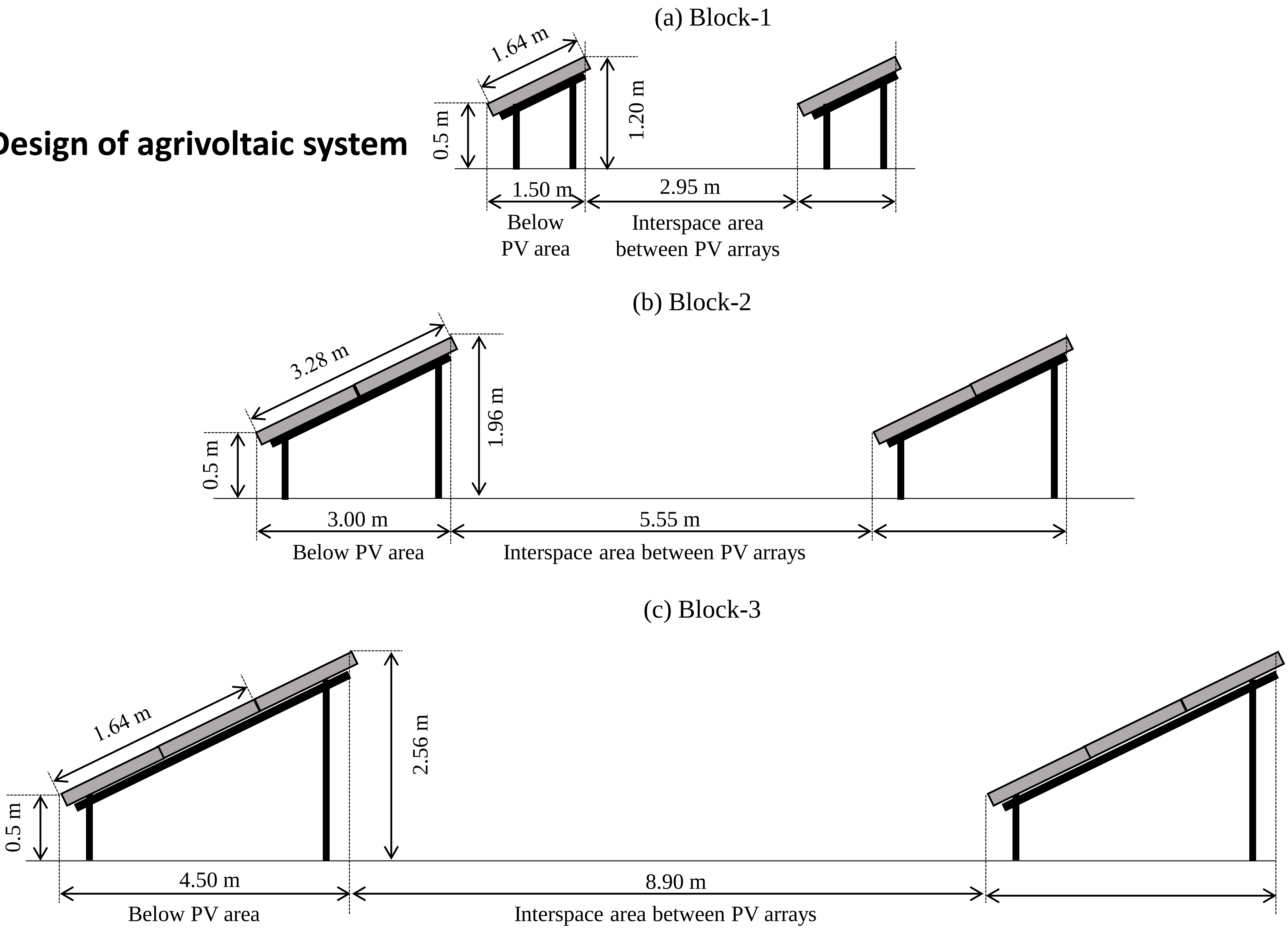
Experiences of agrivoltaic system from Europe

Dupraz et al., 2011
Marrou et al., 2013
Marrou et al., 2019
(Montpellier, France)

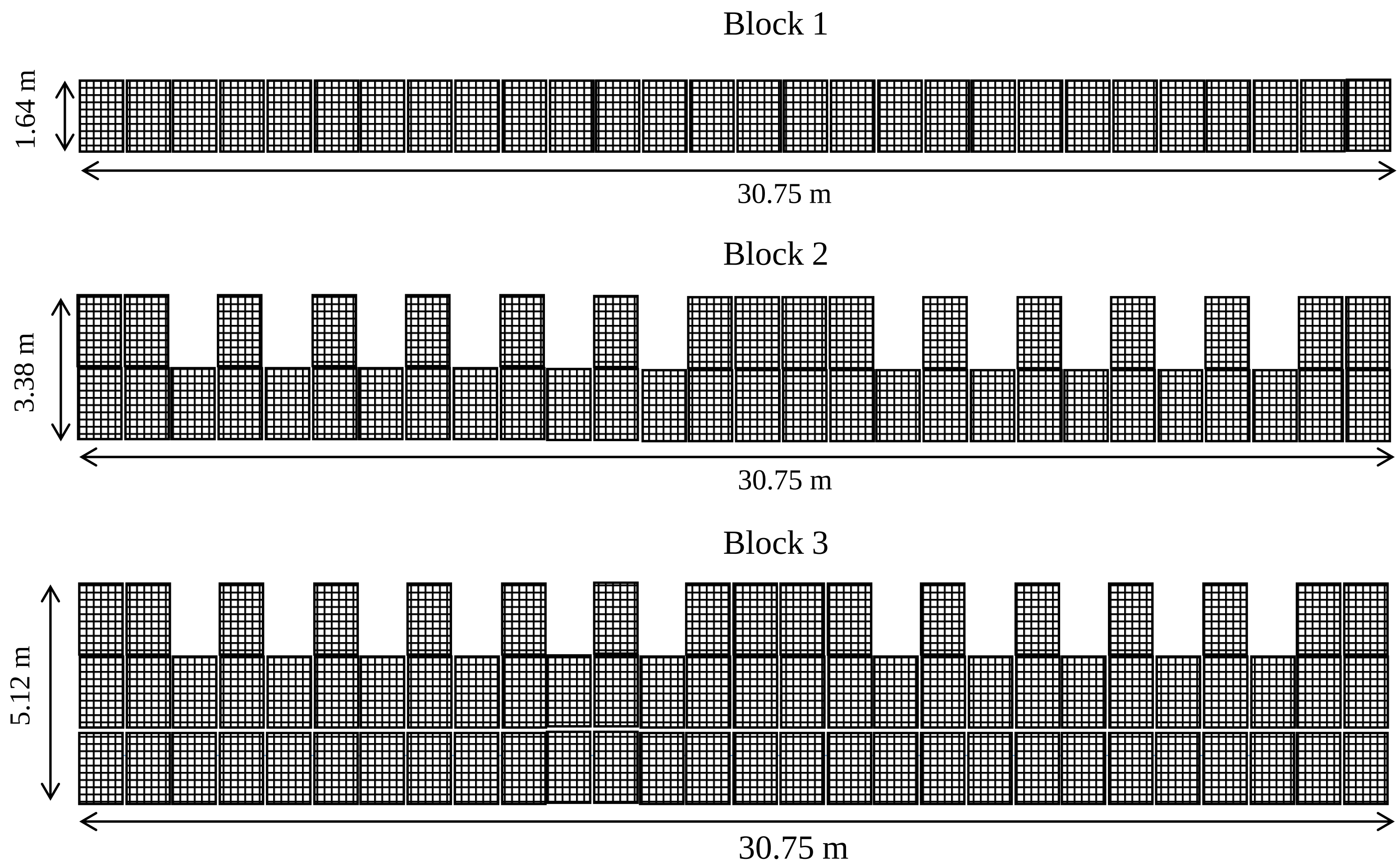
High mounting structure, Low PV density

Schindele et al 2020
(Heggelbach, Germany)

Design of agrivoltaic system

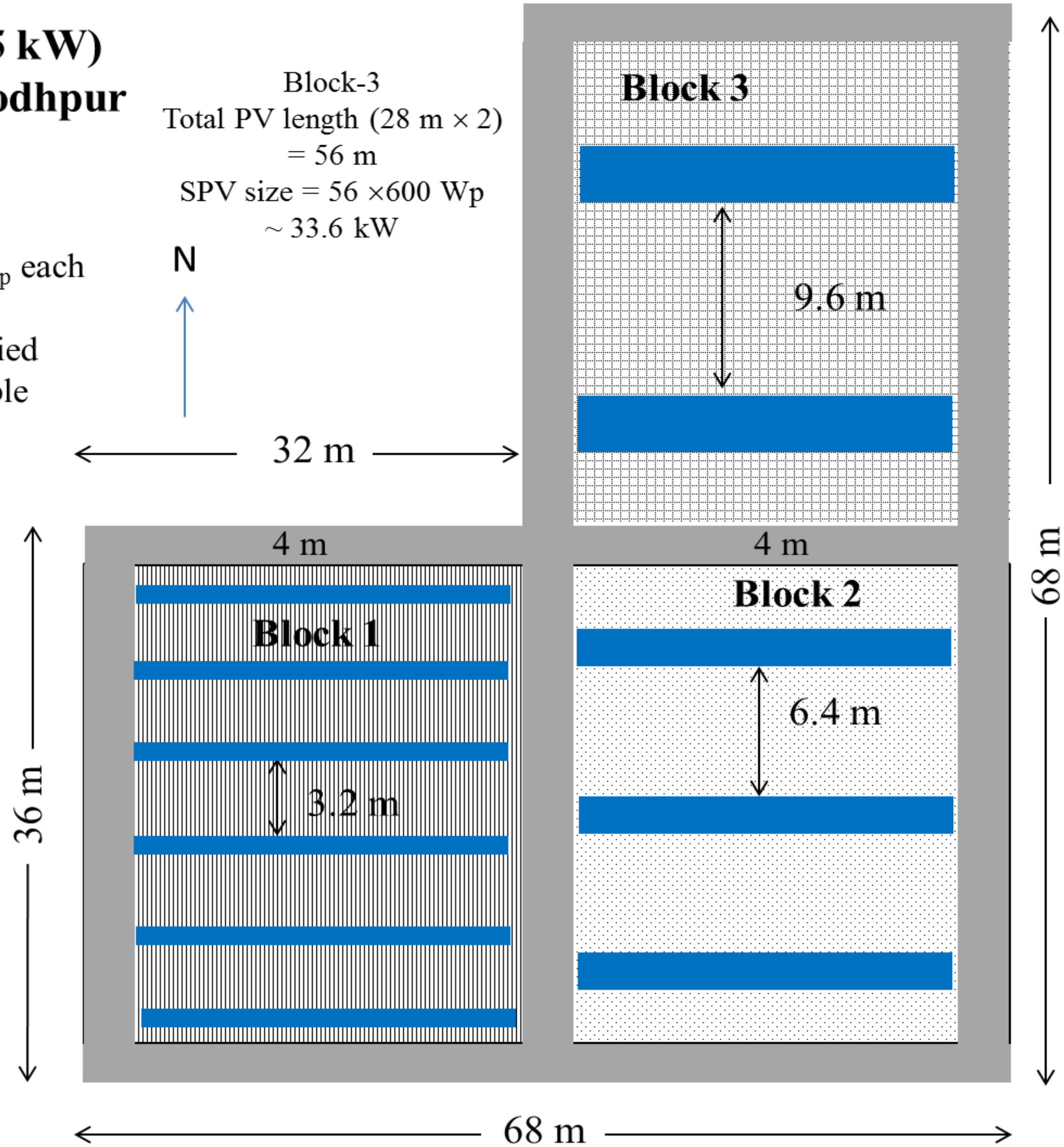


PV array design in agrivoltaic system



SPV layout design (105 kW)
Place: ICAR-CAZRI, Jodhpur

- Field size = 68 m × 68 m
- Block size = 28 m × 28 m
- PV module capacity = 200 W_p each
- Total capacity = 105 kW
- The system needs to be grid tied
- Distance from field to available transformer: ~750-1000 m



Performance of crops in agrivoltaic system at Jodhpur

Kharif crops: Growth and yield of *Vigna radiata* was not affected by the shade of PV module, whereas rest two are affected

Rabi crops: Growth and yield of *Plantago ovata* and *Cuminum cyminum* are significantly affected by shade of PV module

Medicinal crops: Performance of medicinal crops were superior in the interspace area than over control

Vegetable crops: Growth and yield of Solanum melongena was significantly affected by shade of PV module

Rainwater harvesting in agrivoltaic system

Rainfall — Annual rainfall in Jodhpur 350 mm

↓

Top of PV module — 260 W_p PV module 1.64 m × 0.992 m

↓

Water conveying MS sheet channel — Rectangular shape 2° slope

↓

Underground PVC pipe network — 6 inch dia 2 ft below depth

↓

Water storage tank — 1 lakh litre capacity

↓

Solar PV pump — Efficiency of the system is 69.2%.

↓

- Cleaning of PV module
- Supplemental irrigation

Field photographs of rainwater harvesting system

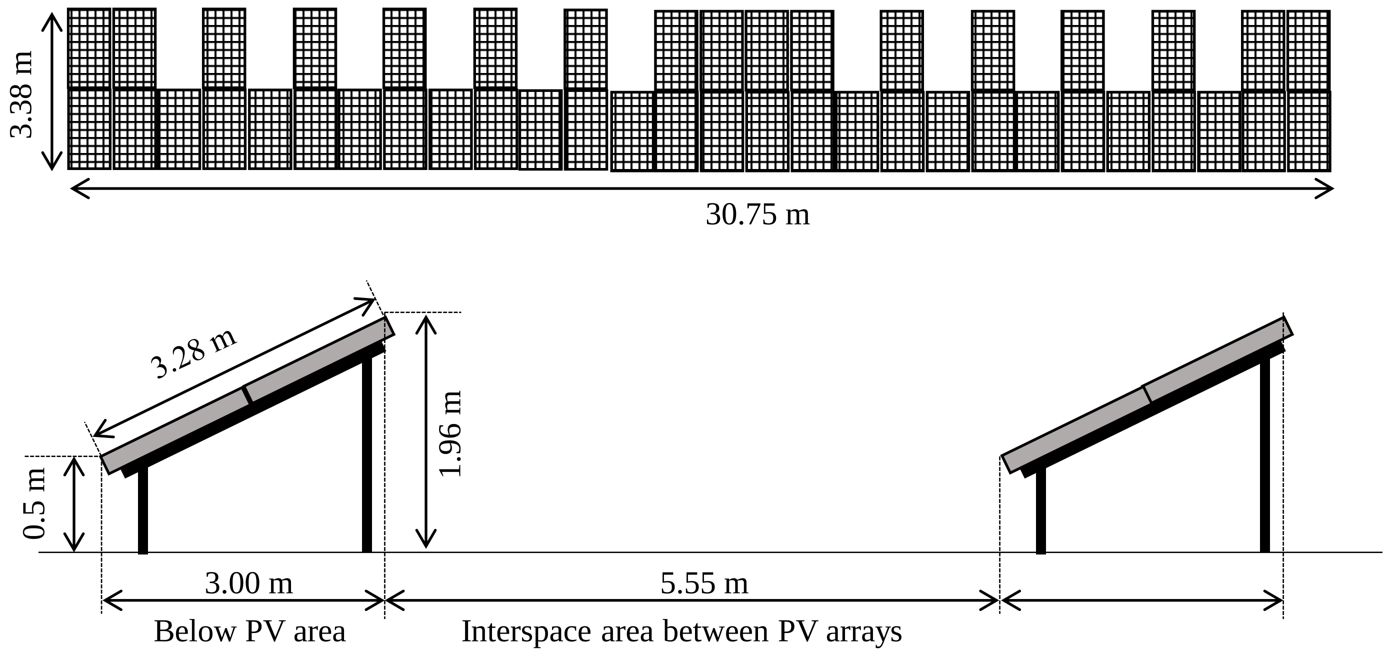
Field photographs of agri-voltaic system at ICAR-CAZRI, Jodhpur

Field photographs of agri-voltaic system at ICAR-CAZRI, Jodhpur

Field photographs of agri-voltaic system at ICAR-CAZRI, Jodhpur

Agrivoltaic system: Best Model

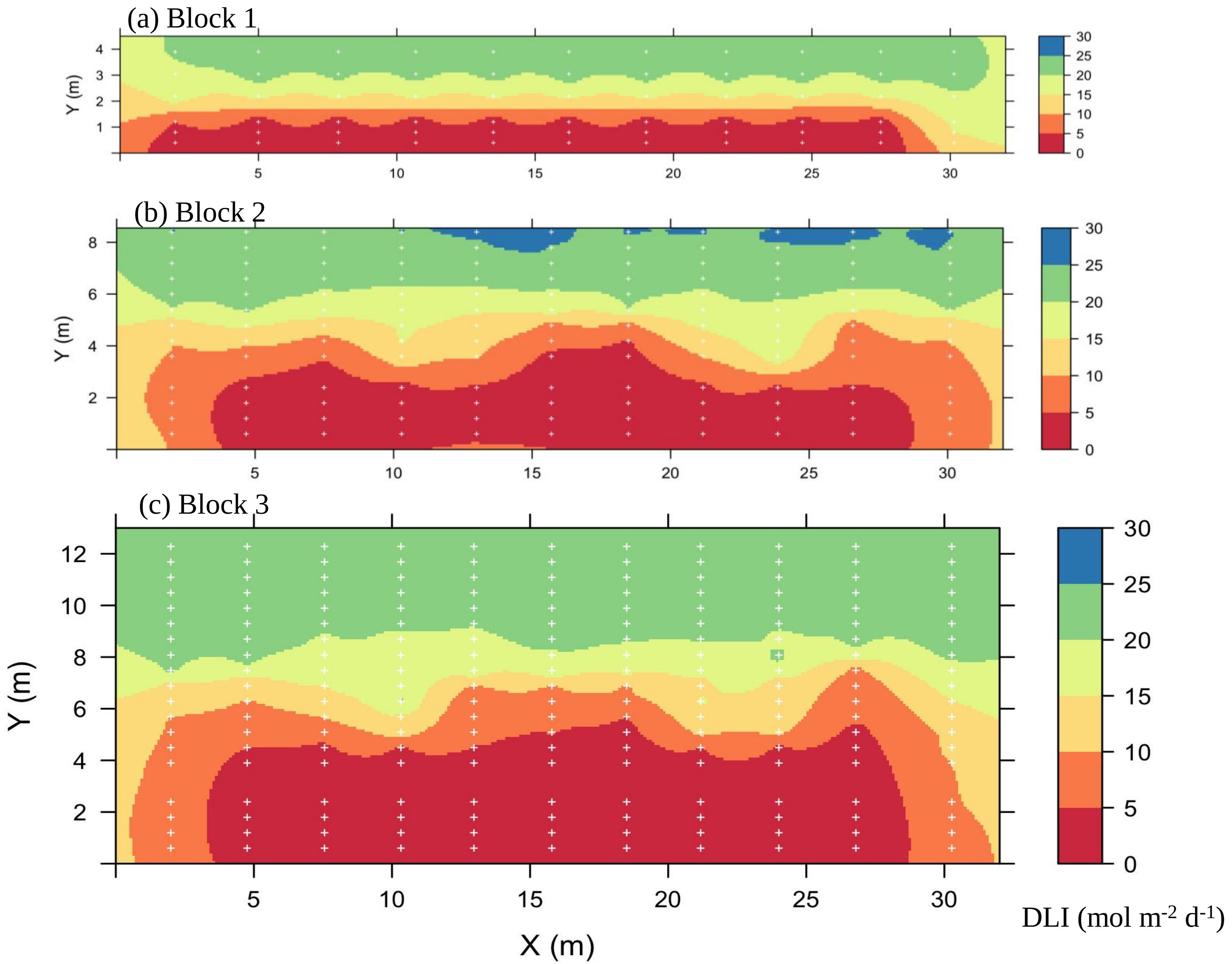
Best model (Double row model)
1st row with full density and 2nd row with 60% PV density



Best performing crops in agrivoltaic system

Interspace area	Kharif season:	Moong bean (*Vigna radiata*)	Yield 438 kg/ha
	Rabi season:	Isabgool (*Plantago ovata*)	Yield 582 kg/ha
Below PV area	Rabi season	Spinach, Amaranthus	-

DLI in agrivoltaic system



Economics of agrivoltaic system (double row model)

Sr. No.	Item	Value
1.	Area	1 ha
2.	Capacity (Double row model)	400 kW_p
3.	Life cycle	25 years
4.	Cash outflow for ground mounted PV system (Rs 42,000/kWp)	Rs 1,68,00,000/-
5.	Cash outflow for replacement cost of inverter (once in life cycle) (Rs 6/Watt of inverter)	Rs 30,00,000/-
6.	Cash outflow for repair and maintenance cost @0.1% of initial investment	Rs 16,800/-
7.	Cash outflow for crop cultivation (Moong bean during kharif and isabgol during rabi)	
8.	Annual generation (@4 kWh/day/kWp with 1% decrease per year)	5,84,000 kWh
9.	Electricity sale price (Rs/kWh)	Rs 5.00/-
10.	Cash inflow from PV component (Rs/ha/y)	Rs 29,20,000/-
11.	Cash inflow from crop component (Moong bean and isabgool) (Rs/ha/y)	Rs 80,349/-
12.	Simple payback period	5.87 years
13.	Discounted payback period	10.40 years
14.	Internal rate of return	16%
15	Net present value at a discount rate of 10%	Rs 70,15,128

Green energy generation
Doble row model of agrivoltaic system

Agrivoltaic system

Area: 1 ha

Capacity: 400 kW_p

Generation rate:
4 $kWh/day/kW_p$

Annual generation:
$4 \times 400 \times 365$ kWh
=**5,84,400 kWh**
(unit)

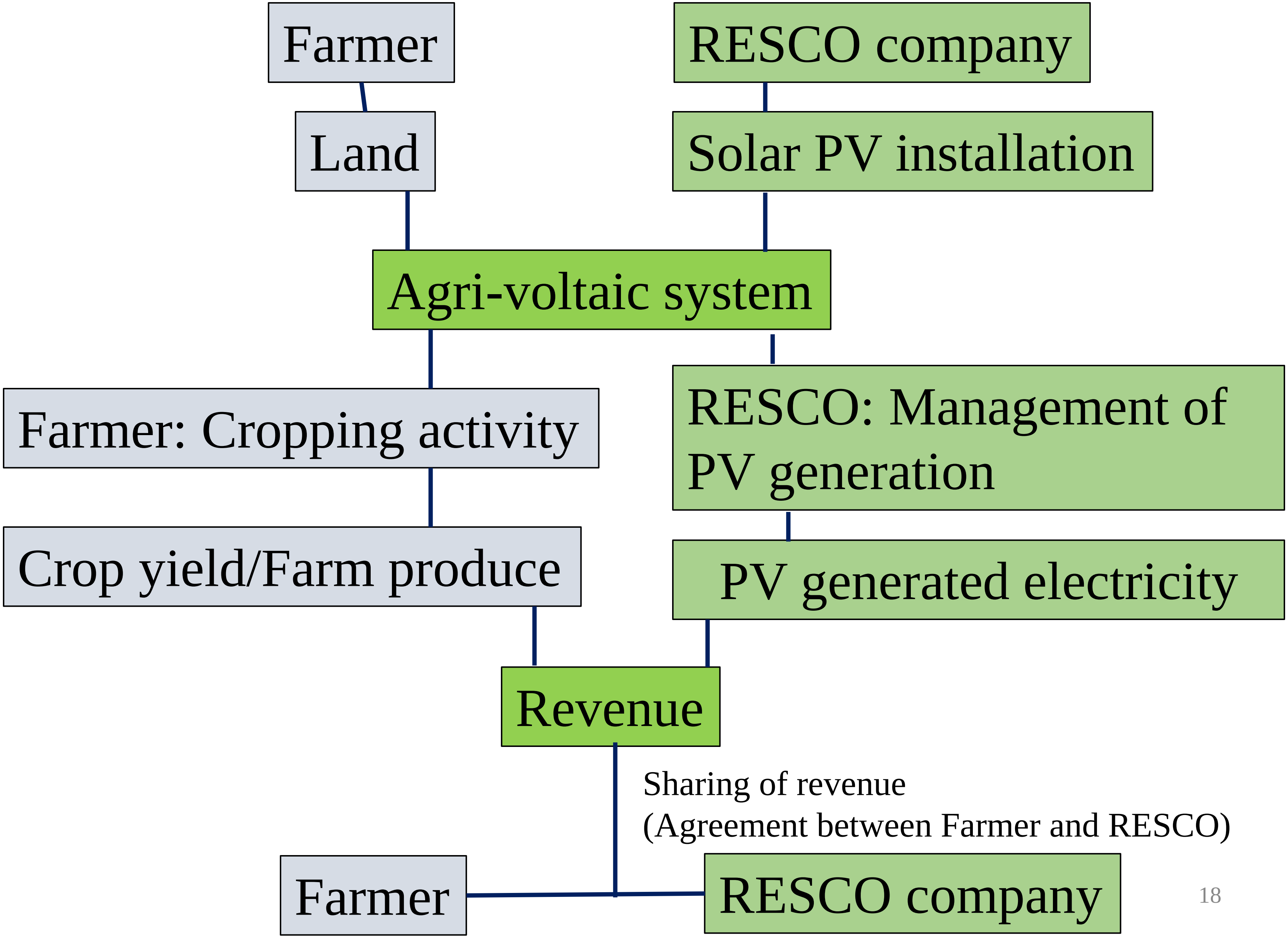
Coal based power plant

Equivalent Energy
5,84,400 kWh

Emission factor
= 0.82 kg CO_2e/ kWh

Annual emission
=479 ton CO_2e

Agrivoltaic system in Farmer's field-KUSUM scheme



Benefits of Agri-voltaic system

- Increased income from farm land
- Recycling of harvested rainwater for cleaning PV modules and irrigating crops (1.5 lakh litre per acre and can provide 40 mm irrigation in 1 acre land)
- Improvement in microclimate for crop cultivation and optimum PV generation
- Reduction in soil erosion by wind
- Reduction in dust load on PV panel
- Improvement in land equivalent ratio (LER ~1.41)
- Soil moisture conservation by reducing the wind speed on ground surface
- Reduction in GHG emission (598.6 tons of CO_2 savings/year/ha)

Few perceived drawbacks

- Safety of field workers engaged in agricultural activity
- Managerial complexity: additional load on plant manager for agricultural activity
- Ownership issue: Farmer and solar power plant functionary
- Sharing of benefits in case of joint venture
- High capital investment during initial establishment

STRATEGY PAPER

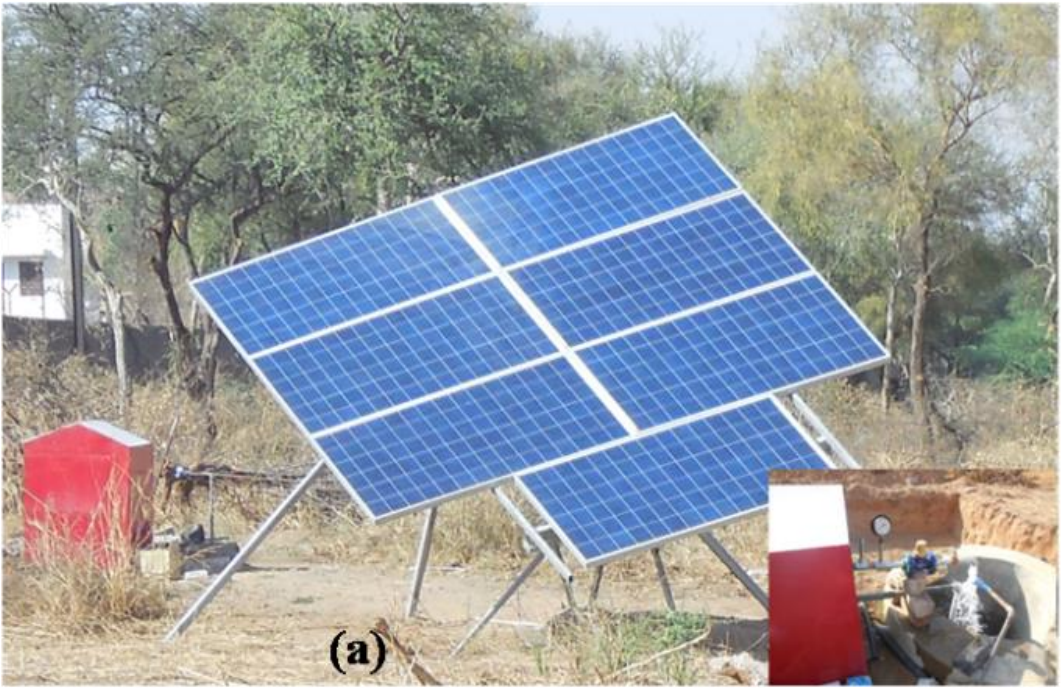
10

Renewable Energy: A New Paradigm for Growth in Agriculture

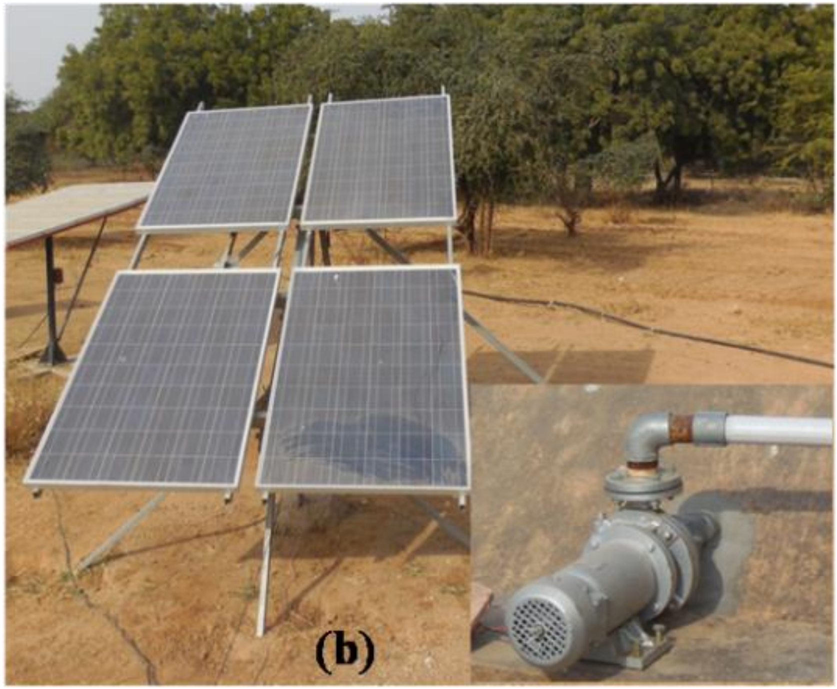
NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI

December 2018

Small sized (1 HP) solar PV pumping system for marginal farmers in India

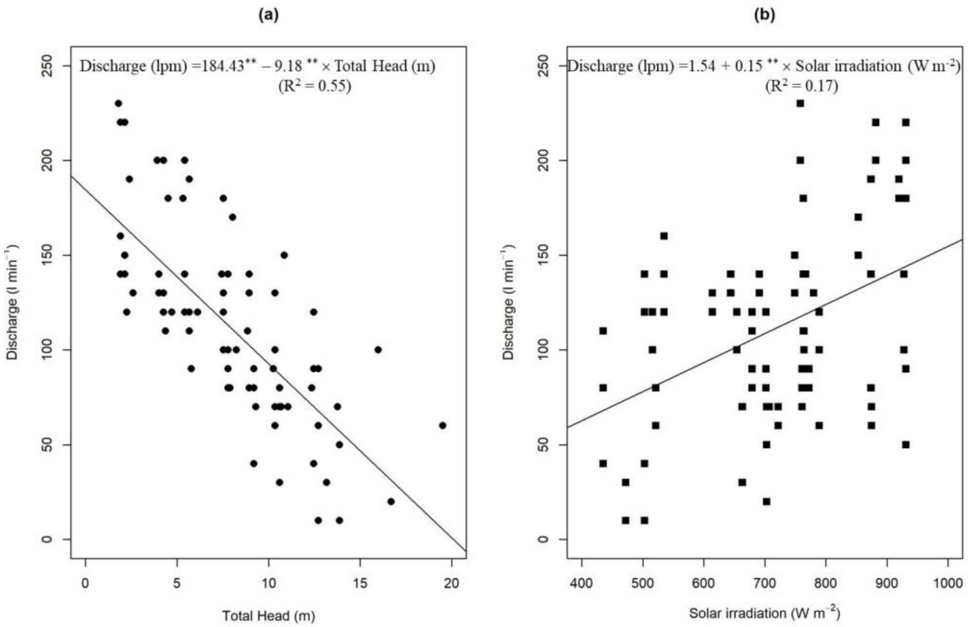


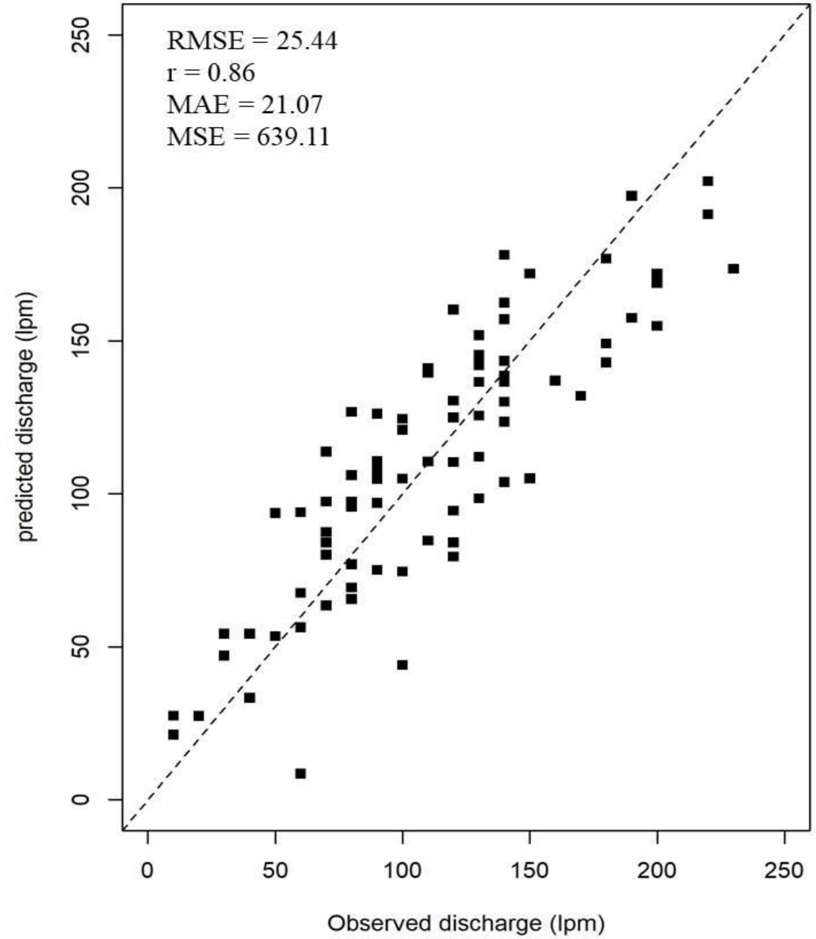
1 HP AC solar Pump



1 HP DC solar Pump

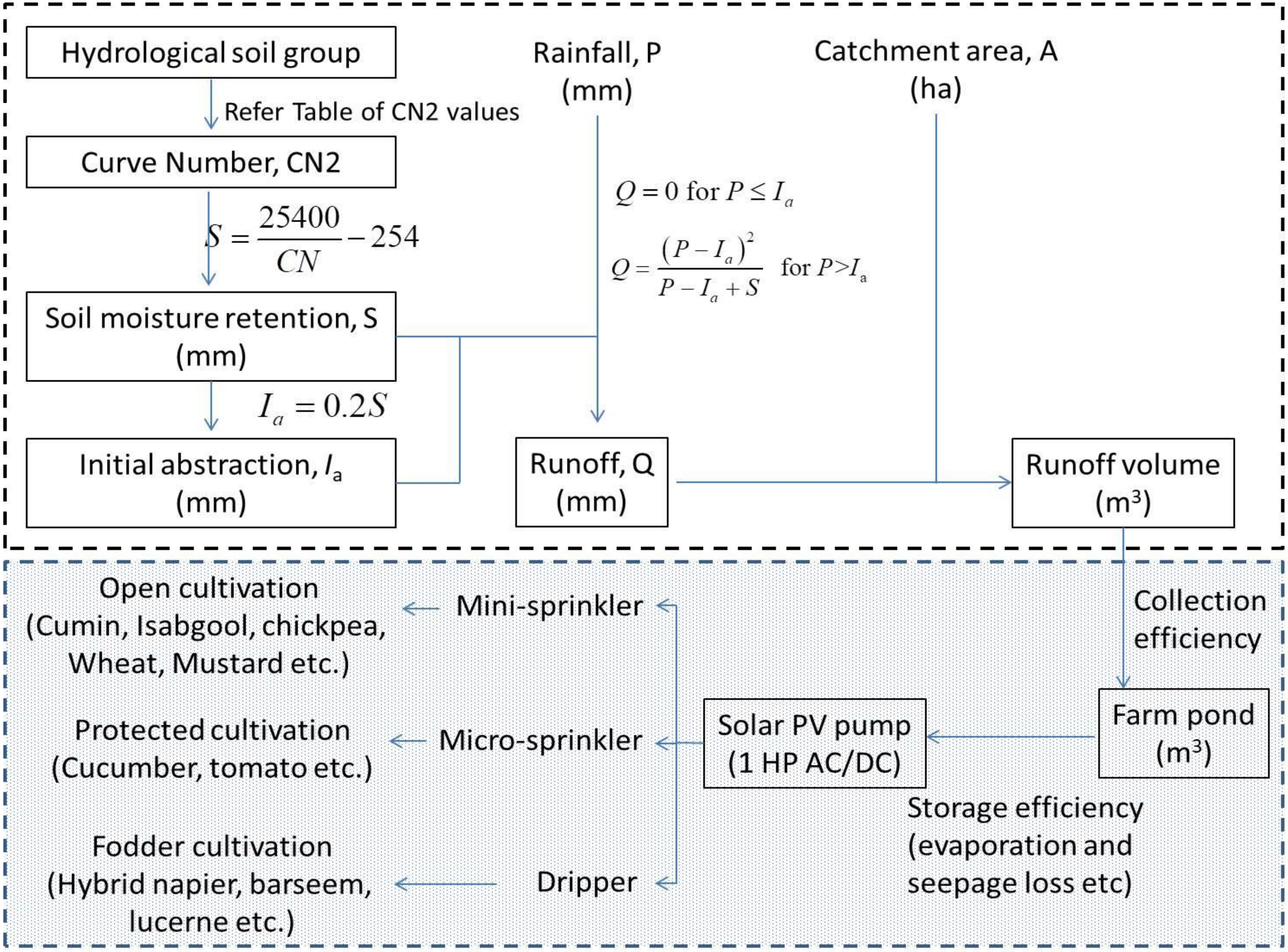
Influence of head and solar irradiation on 1 HP solar PV pumping system





$$Q \text{ (lpm)} = 68.23^{**} + 0.16^{**} \times J \text{ (W m}^{-2}\text{)} - 9.41^{**} \times H \text{ (m) (R}^2\text{=0.75)}$$

Solar PV pumping opportunity with runoff water harvesting system



Further reading on solar PV pumping system

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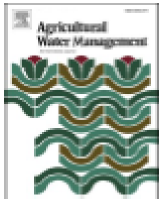

Performance evaluation of solar PV pumping system for providing irrigation through micro-irrigation techniques using surface water resources in hot arid region of India

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Greenhouse gas emission
Irrigation uniformity

ABSTRACT

Solar PV pumping system for irrigation purpose has been gained importance in recent times considering its environmental friendly characteristics and to reduce the dependency on fossil fuel based energy sources for pumping. In general, 3 HP and 5 HP capacity solar PV pumping systems are used for irrigation purpose in India. However, large capacity pumps are often also used to lift groundwater resources, which may lead to further depletion of ground water table. Keeping in mind these constraints, performance of small sized solar PV pumps of 1 HP capacity was evaluated to lift and irrigate shallow water resources using pressurized irrigation systems. Experimental observations revealed that 1 HP solar PV pumping system either AC or DC type could successfully be used to operate mini-sprinklers, micro-sprinklers and drippers with good irrigation uniformity. Further, a self-sustainable module for sustainable use of water and energy was designed in which both water and energy are harvested and recycled. Life cycle cost analysis showed that 1 HP (DC) solar PV pumping system was slightly cheaper than corresponding AC pumping system. Even, the carbon footprint of 1 HP solar PV pumping systems is quite lower (0.009 kg CO_2-eq ha-mm^{-1}) than grid-connected electric pumps (1.214 kg CO_2-eq ha-mm^{-1}) and diesel operated pumps (0.382 kg CO_2-eq ha-mm^{-1}). Therefore, 1 HP solar PV pumping systems could be a feasible solution for small and marginal farmers in the context of water scarcity situation in near future and to mitigate the climate change effects in agricultural farms.


Thank you
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