Does Renewable Energy increase Farmers' Well-being? Evidence from Solar Irrigation interventions in Bangladesh

Monzur Hossain, Ph.D.
Azreen Karim, Ph.D.
Bangladesh Institute of Development Studies (BIDS)

BIDS Research ALMANAC
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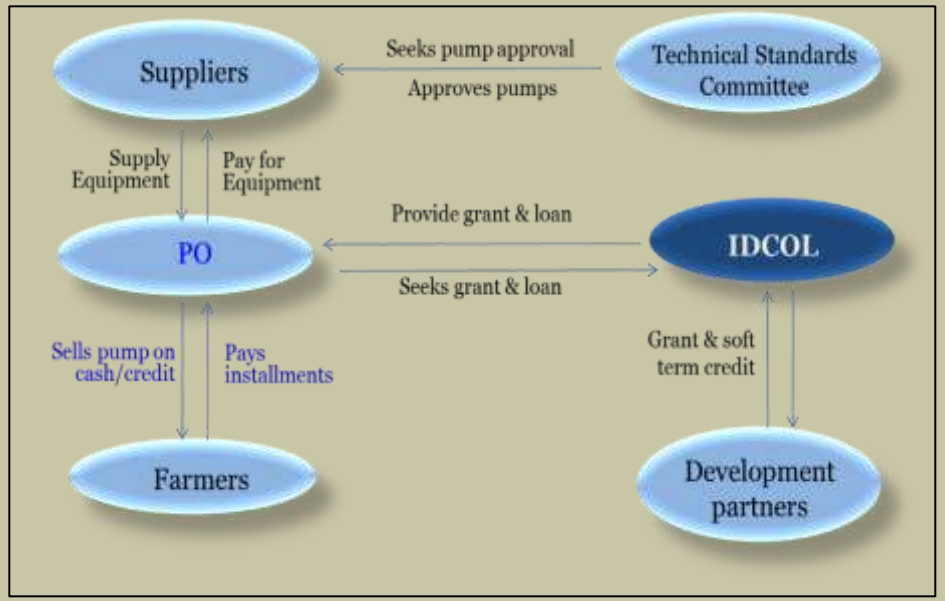
Outline

- Background
- SIPs: *What is it good for?*
- Literature Review
- Study Objective
- Data & Sample Distribution
- Methodology
- Descriptive Statistics
- Impact on rice production
- Farmers' Well-being: Contextualization
- Conclusive & Policy remarks

Background

Green Infrastructure for Irrigations: An Overview of Solar Irrigation Projects (SIP)



Solar power-based irrigation technology: *what is it good for?*

- **Access to Energy – SDG 7**
- **Clean Energy**
- **Green Productivity**
- **Farmers' Well-being**
- **Resilient Agriculture**

Literature Review

- **Suman (2018)**
  - Impacts of solar irrigation pumps program in Andhra Pradesh and Chhattisgarh states of India.
  - Implementation of solar-powered irrigation system has grossly increased the income of the farmers.
  - Reduced the cost of irrigation and wastage of water and has caused a change in cropping pattern in some areas.
  - Due to the usage of the solar-powered irrigation system, the pressure on general electrical grid has lowered, resulting export of surplus power to the grid.
  - Increased both the quality and quantity of the crops.

- **Burney et al. (2016, 2010)**

- **Garg (2018)**
  - Implementation of solar-power irrigation systems can lead to greater economic well-being by reducing costs incurred for use of coal and diesel for irrigation.

Study Objective

The purpose of this study is to estimate the impact of solar irrigation project on agricultural productivity in Bangladesh as well as to identify other beneficial roles of solar irrigation projects including energy consumption patterns in various irrigation modes, irrigation costs and reliability of irrigation.

Data & Sample Distribution

- A total of 1000 households have been systematically randomly selected and surveyed. Out of the total sample size, 500 households were solar irrigation adopted farmers (i.e. treatment) and the remaining 500 households were non-adopter (i.e. control) farmer households.

Table : Distribution of Samples across Administrative Divisions

Division	Treatment (%)	Control (%)
Dhaka	2	2
Chittagong	2	2
Rajshahi	6	6
Khulna	52	52
Rangpur	38	38
N	500	500

Methodology

- **Descriptive Analysis**

  - *Are there any systematic differences between the solar irrigation adopters and non-adopters with regards to the basic characteristics?*

- **Determinants of Access to Solar Irrigation**

Given the importance of household access to Solar irrigation (SI) program, we examine here what determines households access to IDCOL's SI program. We estimate the reduced form equation as follows:

$$S_i = \alpha + \beta X_i + \varepsilon_i$$

Where, S_i is household's SI adoption, X_i is a set of household and village level characteristics ε_i is unobserved random error term. β are unknown parameters to be estimated.

We consider the household's adoption of SI as the outcome variable. Since adoption of SI is a dummy variable, we apply *probit* model to determine the factors that explain SI access.

Methodology contd…

- **Instrumental Variable (IV) Regression**

$$Y_{ijs} = \alpha X_{ij} + \beta V_j + \gamma I_{ijs} + \delta P_{ijs} + \lambda O_{ijs} + \varepsilon_{ijs}$$

Here, Y is the outcome, X is household level controls, V is village level controls, I is the dummy for mode of irrigation (solar), P is total plot size or plot fertility, and O is other inputs. Then we run season-specific regression for above equation for aus, aman or boro season. More specifically, Y_{ij} represents seasonal (i.e. aus, amon and boro) total production for household i in village j; I indicates a dummy variable i.e. if the household use solar irrigation in different seasons = 1, 0 otherwise; X_{ij} denotes household-level characteristics (e.g. age, marital status, formal education, house ownership, land ownership, access to electricity, safe drinking water and sanitation); V_j indicates village-level characteristics which includes village population, households in village, total number of solar pump user, total number of diesel pump user, landless (below 0.5 acre), marginal land holder (0.5-1 acre), small land holder (1-2.5 acre), medium land holder (2.5-7.5 acre) etc.; α_1 represents the coefficients for seasonal solar irrigation use, household-level and village-level characteristics respectively and ε_{ij} captures the error term.

Cultivation-related Information

Table: Number of Plots, Area and Yield

Panel A: Aus season (*Boishakh- Srabon)*

Category	Treatment	Control	Difference	p-value
Number of plots harvested	1.62	1.65	-0.03	0.76
Area (acre)	.71	.70	.01	0.8
Total production of crop (mound)	63749	48989	14759	0.04

Panel B: Aman season (*Bhadro-Ogrohayon*)

Number of plots harvested	3.00	2.69	0.31	0.00
Area (acre)	1.35	1.26	0.09	0.16
Total production of crop (mound)	70129	66379	3749	0.34

Panel C: Boro Season (*Poush-Choitro*)

Number of plots harvested	3.17	2.80	0.36	0.00
Area (acre)	1.41	1.32	0.09	0.19
Total production of crop (mound)	261462	96410	165051	0.13

Crop Production-related Expenditure

(Costs and Returns of Crop Cultivation)

Panel A: Aus season

Category	Treatment	Control	Difference	p-value
Irrigation cost (Tk. per bigha)	1106.1	1138.89	-32.79	0.78
Total input cost (Tk)	13770.95	12354.70	1416.26	0.41
Net returns (Tk)	42446.19	36304.57	6141.62	0.23

Panel B: Aman season

Irrigation cost (Tk. per bigha)	1217.43	1410.56	-193.13	0.00
Total input cost (Tk)	22125.4	19445.96	2679.44	0.02
Net returns (Tk.)	47532.78	46543.58	989.20	0.74

Panel C: Boro season

Irrigation cost (Tk. per bigha)	2946.91	4129.73	-1182.82	0.00
Total input cost (Tk)	31785.05	28203.68	3581.37	0.03
Net returns (Tk)	225074.1	66660.47	158413.6	0.15

Irrigation-specific Information

Panel A: Aus season

Category	Treatment	Control	Difference	p-value
Area with irrigation available (%)				
Area with irrigation availed (%)	85.67	92.05	-6.38	0.01
Distance between irrigation plant and plot (ft.)	96.74	74.51	22.23	0.06
Number of days irrigated (days)	4.91	4.23	0.68	0.02
Number of hours irrigated per day (hours)	1.82	1.73	0.09	0.45
Received adequate water (Yes; %)	41.91	45.17	-3.26	0.25

Irrigation-specific Information

Panel B: Aman season

Area with irrigation availed (%)	83.05	86.02	-2.97	0.03
Distance between irrigation plant and plot (ft.)	131.70	82.83	48.87	0.00
Number of days irrigated (days)	8.65	7.49	1.17	0.00
Number of hours irrigated per day (hours)	1.74	1.90	-0.16	0.01
Received adequate water (yes; %)	76.13	71.90	4.24	0.01

Irrigation-specific Information

Panel C: Boro season

Area with irrigation availed (%)	95.89	96.89	-1.00	0.15
Distance between irrigation plant and plot (ft.)	138.03	75.34	62.69	0.00
Number of days irrigated (days)	32.91	27.89	5.02	0.00
Number of hours irrigated per day (hours)	1.94	2.00	-0.06	0.62
Received adequate water (yes; %)	87.61	77.89	9.72	0.00

Impact of solar irrigation on Aus production

VARIABLES	log(net rice return per decimal) Plot-1	log(net non-rice return per decimal) Plot-1	log(net return per decimal) Plot-1	log(net rice p return per decimal) Plot-2	log(net non-rice return per decimal) Plot-2	log(net return per decimal) Plot-2
Solar irrigation	0.110	-1.405	-3.014	-0.470***	-0.102	-0.118
	(0.187)	(1.427)	(1.909)	(0.164)	(0.151)	(0.149)
Adequacy of water*Solar irrigation	0.000	1.409	2.727	0.000	0.000	0.000
	(0.000)	(1.245)	(1.711)	(0.000)	(0.000)	(0.000)
Type of land (1=Elevated, 2=medium-high, 1=medium-low)	-0.105	-0.289***	-0.329***	-0.620***	-0.223***	-0.210**
	(0.133)	(0.063)	(0.079)	(0.135)	(0.077)	(0.089)
Received adequate water (1=yes, 2=no)	0.122	-0.854	-1.146			
	(0.453)	(0.594)	(0.769)			
Distance between source of irrigation and plot (ft)	-0.001	0.000		0.000	-0.000	-0.001
	(0.001)	(0.000)		(0.001)	(0.000)	(0.000)
No of irrigation days per season	0.001	0.067***		-0.073***	0.160***	0.001
	(0.031)	(0.013)		(0.020)	(0.031)	(0.022)
Hours of irrigation needed per day	-0.191***	-0.064**		-0.116***	-0.104	-0.098**
	(0.065)	(0.025)		(0.041)	(0.064)	(0.049)
Plot fertility	0.848***	0.319***	0.219**	-0.256	0.299**	0.129
	(0.258)	(0.083)	(0.106)	(0.191)	(0.123)	(0.135)
Age of Farmer	0.008	0.001	0.003	-0.009*	0.003	0.000
	(0.008)	(0.003)	(0.004)	(0.005)	(0.005)	(0.005)
Marital status		-0.102	-0.293		-0.465	-0.568
		(0.206)	(0.284)		(0.325)	(0.390)
Formal education	-0.162	-0.080	-0.079	0.469***	-0.177	-0.108
	(0.178)	(0.080)	(0.100)	(0.133)	(0.122)	(0.125)
House ownership		-0.977*	-1.186		-0.081	-1.361**
		(0.568)	(0.789)		(0.602)	(0.679)
Land ownership	0.001	-0.000**	-0.001*	-0.003***	-0.000	-0.000
	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Access to sanitation	-0.550	0.663**	0.491	-0.341	1.801***	0.761
	(0.402)	(0.295)	(0.336)	(0.265)	(0.594)	(0.478)
Total household in village	0.003	-0.000	0.000	0.011***	-0.000	0.000
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Total people in village	-0.000	-0.000	0.000	-0.002***	0.000	-0.000

Impact of solar irrigation on Aman production

VARIABLES	log(net return per decimal) All	log(net rice return per decimal) Plot-1	log(net non-rice return per decimal) Plot-1	log(net return per decimal) Plot-1	log(net return per decimal) Plot-2	log(net rice return per decimal) Plot-2	log(net non-rice return per decimal) Plot-2
Solar irrigation	0.211	-0.826*	12.643***	-0.450	-1.155*	-1.196**	4.142***
	(0.441)	(0.426)	(0.809)	(0.483)	(0.606)	(0.489)	(1.484)
Adequacy of water*Solar irrigation	-0.325	0.621*	-12.723***	0.236	0.913*	0.975**	--
	(0.417)	(0.367)	(0.698)	(0.415)	(0.527)	(0.425)	
Total hours of irrigation per season	0.004	-0.000		-0.001	-0.001	0.004	--
	(0.003)	(0.001)		(0.001)	(0.002)	(0.002)	
Type of land (1=high, 2=medium, 3=low)		-0.064**	0.451**	-0.130***	-0.043	-0.033	--
		(0.025)	(0.187)	(0.029)	(0.031)	(0.027)	
Received adequate water (1=yes, 2=no)	0.216	-0.174	9.980***	-0.093	-0.330**	-0.319***	--
	(0.184)	(0.146)	(0.664)	(0.158)	(0.149)	(0.120)	
Distance between source of irrigation and plot (ft)	-0.000	0.000	-0.001		0.000	0.000	--
	(0.000)	(0.000)	(0.001)		(0.000)	(0.000)	
No of irrigation days per season	-0.010**	-0.001	0.087**				--
	(0.005)	(0.002)	(0.043)				
Hours of irrigation per day	-0.021	0.002	0.111**				--
	(0.023)	(0.003)	(0.046)				
Plot fertility		0.080***	-0.915***	0.061*	0.096***	0.050	-1.383**
		(0.030)	(0.250)	(0.035)	(0.037)	(0.031)	(0.648)
Age of Farmer	-0.003*	-0.000	0.008	-0.001	-0.002	-0.000	0.054***
	(0.002)	(0.001)	(0.010)	(0.002)	(0.002)	(0.001)	(0.019)
Marital status	0.044	-0.058		-0.021	0.103	0.057	
	(0.109)	(0.086)		(0.104)	(0.113)	(0.093)	
Formal education	-0.089**	-0.089***	-1.245***	-0.093***	-0.103***	-0.091***	0.131
	(0.038)	(0.031)	(0.194)	(0.036)	(0.038)	(0.032)	(0.363)
House ownership	-0.155	-0.157	-0.379	-0.265*	-0.217	-0.140	-0.494
	(0.165)	(0.136)	(0.356)	(0.155)	(0.185)	(0.169)	(0.607)
Land ownership	0.000	-0.000	0.003***	-0.000	0.000	0.000	-0.002*
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Access to safe drinking water	0.037	0.062		0.108	-0.086	-0.137	
	(0.220)	(0.172)		(0.208)	(0.230)	(0.190)	

Impact of solar irrigation on Boro production

VARIABLES	log(net return per decimal) Plot-1	log(net rice return per decimal) Plot-1	log(net non-rice return per decimal) Plot-1	log(net return per decimal) Plot-2	log(net rice return per decimal) Plot-2	log(net non-rice return per decimal) Plot-2	log(net return per decimal) Plot-3	log(net rice return per decimal) Plot-3	log(net non-rice return per decimal) Plot-3
Solar irrigation	0.557 (0.392)	-0.504** (0.250)	9.571*** (3.384)	-1.067** (0.486)	-0.864*** (0.300)	0.859 (3.315)	-1.743** (0.763)	0.068 (0.370)	-0.217 (0.141)
Adequacy of water*Solar irrigation	-0.618 (0.384)	0.408* (0.245)	-9.420*** (3.324)	0.990** (0.474)	0.790*** (0.297)	-1.013 (3.294)	1.685** (0.754)	-0.083 (0.370)	0.000 (0.000)
Total hours of irrigation per season	-0.000 (0.001)			0.001* (0.001)			0.001 (0.001)		
Type of land (1=high, 2=medium, 3=low)	-0.017 (0.038)	0.017 (0.026)	-0.132 (0.280)	-0.020 (0.035)	-0.020 (0.024)	0.008 (0.131)	0.084* (0.044)	0.047 (0.029)	0.249** (0.104)
Received adequate water (1=yes, 2=no)	0.420*** (0.149)	0.010 (0.105)	1.012 (0.621)	-0.199 (0.151)	-0.203* (0.113)	-0.143 (0.276)	-0.285 (0.214)	0.157 (0.120)	-0.189 (0.256)
Distance between source of irrigation and plot (ft)	0.000 (0.000)	0.000 (0.000)	0.001 (0.001)	0.000 (0.000)	-0.000 (0.000)	0.001* (0.001)	-0.000* (0.000)	-0.000 (0.000)	-0.001 (0.000)
No of irrigation days per season	-0.008*** (0.002)	0.003* (0.002)	0.125*** (0.040)	-0.006*** (0.002)	0.003 (0.002)	0.141*** (0.025)	-0.003 (0.002)	0.005*** (0.002)	0.122*** (0.030)
Hours of irrigation per day	0.014 (0.028)	0.005 (0.003)	0.063 (0.081)	-0.053** (0.023)	-0.021** (0.010)	-0.044 (0.043)	-0.052 (0.033)	0.002 (0.014)	-0.055 (0.041)
Plot fertility	-0.042 (0.045)	-0.002 (0.032)	-0.189 (0.282)	-0.073* (0.043)	-0.083*** (0.029)	0.175 (0.150)	0.018 (0.052)	-0.030 (0.033)	0.233* (0.140)
Age of Farmer	-0.000 (0.002)	-0.000 (0.001)	-0.013 (0.012)	0.000 (0.002)	0.000 (0.001)	0.002 (0.006)	-0.001 (0.002)	0.001 (0.001)	-0.006 (0.005)
Marital status	0.023 (0.135)	-0.024 (0.094)	1.904* (1.062)	0.096 (0.121)	0.031 (0.075)	0.987* (0.599)	-0.008 (0.155)	0.033 (0.093)	0.343 (0.456)

Farmers' Well-being : Contextualization

- **Costs-effectiveness**
- **Productivity**
  - longer-term income potential
- **Time-use**
- **Carbon Emission**

Conclusive & Policy remarks

- **Costs** of solar irrigation is relatively lower compared to diesel irrigation.
- Solar irrigation **significantly increases** agricultural production when adequacy of water has been prevalent despite inconsistencies also prevail across seasons.
- **Reliability**, **accessibility** and **affordability** of solar irrigation prompted farmers to harvest in more areas and plots in relatively longer seasons like Aman and Boro that contributed to higher yield.
- Our findings suggest that **adoption of SIPs** are largely driven by sponsor initiatives, village meeting and peer effects respectively.

Conclusive & Policy remarks

- On the policy note, inconsistencies in our findings further indicate scope for further **cost-reduction** contributing to longer-term income potential of the farmers.
- More connectivity; particularly with the **Grid electricity**.
- Cautiousness should be there with regards to **arsenic** contamination.
- Enhancing scope for further improvement in irrigation options (including **gender sensitivity**) using renewable energy for farmers.

THANK YOU FOR YOUR KIND ATTENTION!

Contact email: azreenk@gmail.com