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Solar or electric: A comparison of farm profitability for groundwater-fed irrigation under different water development regimes in western zone of Tamil Nadu

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Abstract

This study evaluated the economic feasibility of adopting solar-powered irrigation systems (SPIS) coupled with drip irrigation for coconut cultivation across different water development regimes in Coimbatore district. Results revealed that SPIS adoption led to significantly higher average coconut yields of 18,650 nuts/ha in over-exploited regions, 19,942 nuts/ha in critical + semi-critical regions, and 20,943 nuts/ha in safe regions. Moreover, SPIS demonstrates lower operational costs, with an average annual operational cost of ₹44,714/ha compared to ₹65840/ha for conventional methods. The total cost was lower for SPIS users across all regimes, with average total costs of ₹1,09,607/ha in over-exploited regions, ₹1,05,493/ha in critical + semi-critical regions and ₹1,07,396/ha in safe regions. These findings enhanced the economic benefits of SPIS with drip irrigation adoption and highlighted the need for targeted policies to overcome initial investment barriers, promoting sustainable agriculture in water-scarce regions of Tamil Nadu.

Keywords: Solar powered irrigation system, Drip irrigation, Electric pump, Cost and returns, Coconut

Introduction

Increased consumption of water in agriculture causing rapid depletion of groundwater sources; hence groundwater level is decreasing (Kumar *et al.*, 2011) [4]. Pumping of groundwater for irrigation from water-scarce region requires a lot of energy due to the declined groundwater table level (Shah *et al.*, 2018, Sarkar 2020) [8, 7]. As a result, the need for energy in agriculture is growing, which is adding to the electricity grid (Sarkar 2020) [7] So, the governments have started to shift their focus from conventional energy to renewable energy sources like solar power in response to increasing concerns about the environmental impact of agriculture. Solar powered irrigation system (SPIS) minimises the dependence on diesel or coal-based electricity. The combination of falling solar panel costs worldwide, fluctuating diesel prices, and the introduction of the 'Tatkal scheme' by TANGEDCO for facilitating electricity connections for farmers has significantly boosted the popularity of solar energy adoption, particularly in rural areas. Farmers' adoption of solar pumps is still slow and relatively limited, despite the government concentrated efforts to encourage this practice. This sluggish adoption can be attributed to various factors such as high initial investment costs, limited access to financing options, inadequate awareness about the benefits of solar irrigation, technical complexities, and infrastructural constraints (Oosthuizen *et al.*, 2005) [6]. These challenges collectively hinder the widespread adoption of solar pumps in agricultural practices, highlighting the need for further interventions and support mechanisms to accelerate their uptake.

SPIS with drip irrigation in Tamil Nadu

Tamil Nadu government is actively promoting the use of solar energy in agriculture through its 'Green Energy in Agriculture' initiative, offering subsidy assistance to farmers for installing Solar Powered Irrigation Systems (SPIS). Since 2012-13, the government has been advocating for off-grid SPIS, with significant support provided during 2021-22, where approximately 5000 solar pump sets up to a capacity of 10 HP received 70 per cent subsidy to benefit farmers. However, to mitigate groundwater over-extraction, the government mandates that solar pumps must be coupled with drip irrigation systems (Majeed *et al.*, 2023) [5]. Honrao (2015) [2] discovered that replacing diesel pumps with Solar-Powered Irrigation Systems (SPIS) led to a substantial reduction in input costs and a notable improvement in productivity and profitability in rural villages of Maharashtra. Jalajakshi & Jagadish (2009) [9]. Found that hat the adoption of drip irrigation technology led to enhanced crop productivity and savings in irrigation labour costs. Selection of irrigation technology has a significant impact on agricultural profitability, resource sustainability, and economic resilience with escalating concerns over water scarcity and energy costs ((Kumar 2007) [3]. The main objective of the study is to examine the cost and returns of coconut cultivation under solar pump irrigation across various water development regimes, comparing them with electric pump systems and also assessed the impact of irrigation system i.e. with drip and without drip irrigation. In Coimbatore district, nearly 70 per cent of the farmers cultivate coconut crop. Coconut crop cultivation in overexploited conditions was found to be less energy efficient than less-exploited region (Gurunathan and Palanisami 2008) [1]. Coimbatore district, with over 300 sunny days annually, stands as an ideal region for solar pump adoption, promising both water and energy conservation in agriculture.

Methodology
Sampling framework
The study employed multi-stage stratified random sampling, focusing on regions with significant groundwater depletion, especially in Coimbatore, Dindigul, and Namakkal. Coimbatore district was chosen due to its pronounced groundwater depletion and higher adoption rates of water management technologies like drip irrigation and solar pumps. A cross-sectional descriptive sampling approach was utilized to select farmers using various irrigation methods, including solar pumps with micro irrigation (G_1), electric pumps with micro irrigation (G_2) and conventional methods (G_3) as control. A total of 270 farmers were randomly selected across different water development regimes to represent the study sample.

Data
The primary data was collected from the sample respondents during June to September 2023. Primary data was collected using a well-structured and pre-tested questionnaires through personal interviews with the sample respondents. The interview schedule covered the general aspects of the sample farmers such as age, educational status, occupation, family size, land holding, cropping pattern, crop yield, cost of production (input cost and realised cost on output) for various crops. The data collected were processed, tabulated, and then statistical analysis was performed.

Cost concepts
Cost concept method for perennial crop was used to calculate the cost and returns of sample farmers. Cost of Cultivation for Perennial crops:

Establishment cost
The establishment cost for starting a plantation were compiled item by item.
1. Digging pits,
2. Planting material,
3. Gap filling,
4. Manures and fertilizers,
5. Human labour,
6. Machine power,
7. Plant protection chemical,
8. Rental value of land,
9. Land tax

Amortization of fixed cost
Process of spreading the initial expenses incurred in establishing a coconut plantation over a period of time. It calculates the annual fixed component involved in establishment and maintenance. Capital investment made in first five years for establishment was divided into equal annual instalments for the economic life of coconut plantation starting fifth year, and spread over amortization cost, throughout its economic life. The average life of coconut plantation was taken as 50 years.

$$A = \frac{P\left(\frac{r}{100}\right)\left(1+\frac{r}{100}\right)^{n}}{\left(1+\frac{r}{100}\right)^{n-1}}$$

Where,
A = Amortization cost
P = Total establishment cost
r = Rate of interest @ 7.5 per cent
n = Number of years

Operation and Maintenance cost
1. Value of human labour
2. Value of machine power
3. Value of insecticide and pesticide
4. Value of manure (owned and purchased)
5. Value of fertilizer
6. Irrigation charges
7. Land revenue
8. Miscellaneous expenses

Total cost of cultivation of perennial crop per ha
Total cost of cultivation = Annual share of establishment cost (amortized cost) + Interest on fixed capital excluding land + rental value of owned land + Interest on working capital + Operation and maintenance cost

Results and discussion
Profitability of coconut cultivation under different water management technology across water development regimes
Coconut cultivation in the study area is widespread among farmers. Being a perennial crop, cost of cultivation encompasses both establishment and maintenance costs. The table 1-3 illustrates the cultivation expenses involved in coconut farming under different water management technology across water development regimes.

Over-exploited region
The cost of cultivation and income details for coconut farmers in overexploited region under different water management technology are presented in Table 1. The total cost of cultivation per hectare of coconut crop under G_1 with ₹1.10 lakhs/ha is marginally lower than that of G_2 and G_3 are ₹1.15 lakhs/ha and ₹1.11 lakhs/ha respectively. The difference between G_1 and other category farmers in annual establishment cost shows a positive difference of ₹3591/ha over G_2 and ₹13508/ha over G_3. Unlike other crops, human labour occupies major share of about 18.16 per cent, 18.03 per cent and 25.21 per cent in G_1, G_2 and G_3 respectively. The average yield of coconut in G_1 is 18650 nuts/ha, which is higher than G_2 and G_3 category farmers yield by 72 nuts/ha and 3062 nuts/ha respectively. The Average net income of G_1 is ₹1.08 lakhs/ha is higher than G_2 with ₹1.01 lakhs/ha and G_3 with ₹65707/ha, the difference in net income of G_1 irrigation of coconut in overexploited region over G_2 and G_3 are ₹6510/ha and ₹42253/ha.

Table 1: Cost of cultivation of coconut under different water management technology in overexploited region (Rs/ha)

Particulars	Over-exploited				
	G_1 (1)	G_2 (2)	G_3 (3)	Difference between solar over G_2 and G_3	
				(1-2)	(1-3)
Human labour	19500 (18.16)	19500 (18.03)	27969 (25.21)	0	-8469
Machine power	2900 (2.70)	2900 (2.68)	2900 (2.61)	0	0
Fertilizers and manures	6854 (6.38)	6854 (6.34)	8100 (7.30)	0	-1246
Plant protection chemicals	500 (0.47)	500 (0.46)	500 (0.45)	0	0
Weeding	7289 (6.79)	7289 (6.74)	10125 (9.13)	0	-2836
Irrigation	3500 (3.26)	12580 (5.44)	6350 (5.72)	-9080	-2850
Miscellaneous	1500 (1.40)	1500 (1.39)	1500 (1.35)	0	0
Interest on working capital	2943 (2.74)	3579 (2.88)	4021 (3.62)	-636	-1078
Operation cost (I)	44986 (41.90)	54702 (43.96)	61465 (55.40)	-9716	-16479
Rental value of land	24500 (22.82)	24500 (22.66)	24500 (22.08)	0	0
Land revenue	45 (0.04)	45 (0.04)	45 (0.04)	0	0
Depreciation	1227 (1.14)	1227 (1.13)	1227 (1.11)	0	0
Annual establishment cost	31925(27.87)	28334 (26.20)	18417(16.60)	3591	13508
Interest on fixed capital	6924 (6.23)	6493 (6.00)	5303 (4.78)	431	1621
Fixed cost (II)	64621 (58.10)	60599 (56.04)	49492 (44.60)	4022	15129
Total cost (I+II)	109607 (100.00)	115301(100.00)	110957 (100.00)	-5694	-1350
Average yield (nuts/ha)	18650	18578	15588	72	3062
Main product value	211367	210551	176664	816	34703
By-product value	6200	6200	5600	0	600
Gross income	217567	216751	182264	816	35303
Net income	107960	101450	65707	6510	42253

Source: Primary data collection (2023)
Note: Figures in the parentheses indicate the percentage of the total cost

Critical + Semi-critical region

The cost of cultivation and income details for coconut farmers in critical + semi-critical region under different water management technology is presented in Table 2. The total cost of cultivation per hectare of coconut crop under G_1 with ₹1.05 lakhs/ha is marginally lower than that of G_2 and G_3 are ₹1.11 lakhs/ha and ₹1.08 lakhs/ha respectively. The average yield of coconut in G_1 is 19942 nuts/ha, which is higher than G_2 and G_3 category farmers yield by 43 nuts/ha and 4062 nuts/ha respectively. The Average net income of G_1 is ₹1.27 lakhs/ha is higher than G_2 with ₹1.20 lakhs/ha and G_3 with ₹71759/ha, the difference in net income of G_1 irrigation of coconut in critical + semi-critical region over G_2 and G_3 are ₹6295/ha and ₹54975/ha.

Table 2: Cost of cultivation of coconut under different water management technology in critical + semi-critical region (Rs/ha)

Particulars	Critical + Semi-critical				
	G_1 (1)	G_2 (2)	G_3 (3)	Difference between solar over G_2 and G_3	
				(1-2)	(1-3)
Human labour	19500 (18.48)	19500 (17.52)	27969 (26.37)	0	-8469
Machine power	2900 (2.75)	2900 (2.61)	2900 (2.73)	0	0
Fertilizers and manures	6750 (6.40)	6750 (6.07)	8000 (7.54)	0	-1250
Plant protection chemicals	500 (0.47)	500 (0.45)	500 (0.47)	0	0
Weeding	7289 (6.91)	7289 (6.55)	10125 (9.55)	0	-2836
Irrigation	3000 (2.84)	12000 (10.78)	6350 (5.99)	-9000	-3350
Miscellaneous	1500 (1.42)	1500 (1.35)	1500 (1.41)	0	0
Interest on working capital	2901 (2.75)	3531 (3.17)	4014 (3.78)	-630	-1113
Operation cost (I)	44340 (42.03)	53970 (48.50)	61358 (57.84)	-9630	-17018
Rental value of land	23500 (22.28)	23500 (21.12)	24000 (22.63)	0	-500
Land revenue	45 (0.04)	45 (0.04)	45 (0.04)	0	0
Depreciation	1177 (1.12)	1177 (1.06)	1202 (1.13)	0	-25
Annual establishment cost	29879 (28.32)	26451 (23.77)	16589 (15.64)	3428	13290
Interest on fixed capital	6552 (6.21)	6141 (5.52)	5020 (2.72)	411	1532
Fixed cost (II)	61153 (57.97)	57314 (51.50)	46857 (42.16)	3839	14297
Total cost (I+II)	105493 (100.00)	111284 (100.00)	108215 (100.00)	-5791	-2722
Average yield (nuts/ha)	19942	19899	15880	43	4062
Main product value	226009	225522	179973	487	46036
By-product value	6217	6200	5664	17	553
Gross income	232226	231722	185637	504	46589
Net income	126733	120438	71759	6295	54975

Source: Primary data collection (2023)
Note: Figures in the parentheses indicate the percentage of the total cost

Safe region

It is evident from the table 3, safe region follows similar trend with over-exploited and critical + semi-critical region including operational cost, annual establishment cost, productivity and net income. The yield difference of coconut crop under G_1 is highest with the average yield of 20943 nuts/ha, the yield difference of G_1 over G_2 and G_3 are 140 nuts/ha and 3030 nuts/ha, respectively. The Average net income of G_1 is ₹1.37 lakhs/ha is higher than G_2 with ₹1.31 lakhs/ha and G_3 with ₹87791/ha, the difference in net income of G_1 irrigation of coconut in safe region over G_2 and G_3 are ₹6237/ha and ₹49089/ha. All regions have comparable costs, but yields differ. The reduced use of water in particular regions was the cause of the yield difference.

Table 3: Cost of cultivation of coconut under different water management technology in safe region, (Rs/ha)

Particulars	Safe				
	G_1 (1)	G_2 (2)	G_3 (3)	Difference between solar over G_2 and G_3	
				(1-2)	(1-3)
Human labour	19500 (18.16)	19500 (17.39)	32158 (28.24)	0	-12658
Machine power	2900 (2.70)	2900 (2.59)	2900 (2.55)	0	0
Fertilizers and manures	7100 (6.61)	7100 (6.33)	8000 (7.03)	0	-900
Plant protection chemicals	500 (0.47)	500 (0.45)	500 (0.44)	0	0
Weeding	7289 (6.79)	7289 (6.50)	10125 (8.89)	0	-2836
Irrigation	3000 (2.79)	11000 (9.81)	6350 (5.58)	-8000	-3350
Miscellaneous	1500 (1.40)	1500 (1.34)	1500 (1.32)	0	0
Interest on working capital	2925 (2.72)	3485 (3.11)	4307 (3.78)	-560	-1382
Operation cost (I)	44714 (41.63)	53274 (47.52)	65840 (57.82)	-8560	-21126
Rental value of land	24800 (23.09)	24800 (22.12)	25000 (21.95)	0	-200
Land revenue	45 (0.04)	45 (0.04)	45 (0.04)	0	0
Depreciation	1242 (1.16)	1242 (1.11)	1252 (1.10)	0	-10
Annual establishment cost	29879 (27.82)	26451 (23.59)	16589 (14.57)	3428	13290
Interest on fixed capital	6716 (6.25)	6305 (5.62)	5146 (4.52)	411	1570
Fixed cost (II)	62682 (58.37)	58843 (52.48)	48033 (42.18)	3839	14650
Total cost (I+II)	107396 (100.00)	112117 (100.00)	113873 (100.00)	-4721	-6476
Average yield (nuts/ha)	20943	20803	17913	140	3030
Main product value	235776	234200	201664	1576	34113
By-product value	8500	8560	8200	-60	300
Gross income	244276	242760	209864	1516	34413
Net income	136880	130643	87791	6237	49089

Source: Primary data collection (2023)

Note: Figures in the parentheses indicate the percentage of the total cost

Conclusion

The analysis revealed that SPIS with drip irrigation enhanced crop productivity and profitability in all regions with reduced irrigation cost. Farmers utilizing SPIS demonstrated higher average yields of coconut and increased net incomes compared to those employing conventional irrigation methods. Furthermore, the study highlights the regional disparities in costs, yields and net incomes, emphasizing the need for tailored approaches to address varying groundwater situations and climatic conditions. Policymakers should prioritize incentivizing SPIS adoption through enhanced financial support and awareness programs. Additionally, investment in infrastructure and technical assistance can further facilitate widespread adoption. Embracing SPIS represents a crucial step towards sustainable agriculture, resource conservation and economic resilience in water-scarce regions.

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