Statistical Analysis of Growth and Installation Cost of Sprinkler Irrigation System in Bikaner District of Rajasthan, India

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ABSTRACT

Aims: The aim of this study is to assess the growth and economic feasibility of sprinkler irrigation systems in water-stressed regions, specifically Rajasthan and India, to promote sustainable agriculture and mitigate water scarcity challenges.

Study design: Mixed-Methods study design

Methodology: The study analyzes time series data from 2005 to 2022 to estimate the Compound Annual Growth Rate (CAGR) for the area under sprinkler irrigation system in Rajasthan and India. This research also investigates the economic feasibility of sprinkler irrigation systems in Bikaner district of Rajasthan, India, where water resources are limited. STATA 18.0 was used to perform the statistical analysis.

Results: The findings reveal a significant growth in sprinkler-irrigated areas in both regions. The research findings reveal significant CAGR values of 27.9 per cent for Rajasthan and 18.6 per cent for India, highlighting the growing acceptance and importance of sprinkler irrigation system. The 2-inch sprinkler system emerges as the most feasible choice, with a short payback period, high net present worth, internal rate of return, and benefit-cost ratio.

Conclusion: The research underscores the significance of sprinkler irrigation system technologies in enhancing water-use efficiency, agricultural productivity, and rural livelihoods. Policy recommendations are provided to promote the adoption of water-efficient irrigation practices in combating water scarcity and achieving sustainable agriculture.

Keywords: Sprinkler irrigation system, Compound Annual Growth Rate (CAGR), Rajasthan, India, Water management, Sustainable agriculture, and Economic feasibility

1. INTRODUCTION

Water, the essence of life and a precious natural resource, sustains all living beings on our planet. Despite the vast expanse of water covering 97 percent of the Earth's surface, only a mere three percent is freshwater, and much of it is trapped in glaciers and polar ice caps. Groundwater and the small fraction found in surface water bodies constitute the accessible freshwater resources. However, the distribution of freshwater is uneven, with many regions facing acute water scarcity, especially in arid and semi-arid areas. This global water crisis poses a significant threat to agricultural productivity, food security, and rural livelihoods, making efficient water management a pressing concern (Swaminathan & Banerjee, 2014; Kumar & Sharma, 2019 Gautam et al.,2020 and Singh & Saran, 2020). In India, agriculture forms the backbone of the economy and plays a pivotal role in sustaining millions of livelihoods. While the agriculture sector's share in the Gross Domestic Product (GDP) has gradually declined due to economic diversification, its significance remains indisputable. With the country's burgeoning population and advancing economic development, the demand for water has surged, straining already limited water resources. Erratic rainfall patterns, water pollution (Thakur & Sharma, 2016), and indiscriminate groundwater extraction have intensified water scarcity, posing severe challenges for farmers and threatening the stability of the agricultural sector (Hiremath et al., 2021). To combat the adverse impacts of water scarcity and promote sustainable agriculture, innovative solutions are essential (Harsha, 2017).

Micr- irrigation system, including sprinkler irrigation and drip irrigation, has emerged as a promising technology offering multiple benefits to farmers and the environment (Mishra & Gupta, 2018). These advanced irrigation techniques enable precise and efficient water delivery directly to the plant's root zone, reducing water wastage and evaporation. Furthermore, sprinkler irrigation system has demonstrated positive outcomes, such as increased crop yields, reduced energy consumption, and minimized use of chemical inputs, leading to sustainable farming practices and improved farmer incomes (Singh & Yadav, 2015). Despite the proven advantages of sprinkler irrigation system, its adoption remains relatively low in India, with significant untapped potential (Konar & Dev, 2015 and Narayanamoorthy et al., 2020). The state of Rajasthan, known for its arid landscapes and limited water resources, presents an ideal setting to investigate the impact of sprinkler irrigation system on agricultural productivity and farm income (Choudhary & Singh, 2017). Understanding the growth rate of sprinkler irrigation in Rajasthan and India is crucial for formulating effective policies to encourage its wider adoption and maximize its potential benefits (Patel and Prajapati, 2020).

This research aims to investigate the growth rate of the sprinkler irrigation system in Rajasthan and India by analyzing time series data from 2005 to 2022. The study relies on secondary data from various reputable sources, such as government reports, research papers, and agricultural statistics at a glance, to estimate the Compound Annual Growth Rate (CAGR) for the area under sprinkler irrigation system. The findings of this study have far-reaching implications, offering valuable policy recommendations to promote the efficient utilization of water resources, enhance agricultural productivity, and bolster rural livelihoods. Recognizing the importance of sprinkler irrigation system, the government has taken initiatives to support its adoption, and this research aims to contribute to the ongoing efforts in ensuring a water-efficient and productive agricultural sector. Ultimately, by comprehending the impact of sprinkler irrigation system on farm income in Bikaner district of Rajasthan, this study seeks to pave the way for sustainable water management practices and a more resilient agricultural sector in India.

2. METHODOLOGY

The present study is based on secondary data analysis, and it aims to investigate the impact of the sprinkler irrigation system on farm income in the Bikaner district of Rajasthan. The study also assesses the growth rate of the sprinkler irrigation system in both Rajasthan and India. To achieve these objectives, the study utilizes a quantitative research design and relies on data collected from various published secondary sources. Since the study is based on secondary data analysis, information on the area under the sprinkler irrigation system in Rajasthan and India from 2005 to 2022 is collected from various published sources. These sources may include government reports, agricultural statistics, research papers, and relevant databases. The data is obtained for specific years, and the time series data is used to estimate the Compound Annual Growth Rates (CAGR) for the sprinkler-irrigated areas in both regions. To estimate the CAGR for the area under the sprinkler irrigation system, the study used the log-linear model, which is a common approach for analyzing growth rates over time. The equation used for this analysis is:

$\log Y_t = a + bt$ .... (1)

Here, Y_t represents the area of the sprinkler irrigation system at time t, and 'a' and 'b' are the regression coefficients derived from the log-linear model.

The equation (1) can be further elaborated as:

$Y_t = Y_o(1+r)^t$ .... (i)

Taking the logarithm on both sides of equation (i), we get:

$\text{Log } Y_t = \text{Log } Y_o + t * \text{Log } (1+r)$ .... (ii)

Equation (ii) can be rewritten as:

$Y = a + bt$ .... (iii)

Where:

$Y = \text{Log } Y_t$

$a = \text{Log } Y_o$

$b = \text{Log } (1+r)$

In this context, Yt represents the area under the sprinkler irrigation system at a particular time, 'a' is a constant, 't' is the time variable in years (1, 2, ..., n), and 'b' is the regression coefficient that indicates the rate of change or growth rate in the series.

The annual compound growth rate (r) can be calculated using the formula:

r = (Antilog b) - 1

When multiplied by 100, the compound annual growth rate (CAGR) (per cent) is obtained, representing the percentage growth rate in the area under the sprinkler irrigation system for the specified period.

The study uses statistical tools such as regression analysis to estimate the regression coefficients 'a' and 'b' in the log-linear model. The R-squared value (R^2) is also calculated to determine the goodness of fit of the model, indicating how well the model explains the variation in the data. Overall, the methodology for estimating the CAGR for the sprinkler irrigation system in Rajasthan and India involves data collection, log-linear modeling, statistical analysis, and considerations for validity, reliability, and ethical practices. The findings obtained through this methodology will provide valuable insights into the growth and significance of sprinkler irrigation system in addressing water management challenges and enhancing agricultural productivity in the region.

Economic feasibility refers to the assessment of whether a particular project, investment, or initiative is financially viable and worthwhile. In the context of agricultural practices, economic feasibility involves evaluating the potential benefits and costs of adopting specific technologies or techniques to optimize resource utilization and enhance productivity. In the case of sprinkler irrigation systems, economic feasibility is determined by analyzing key financial indicators, such as the payback period, net present worth (NPW), internal rate of return (IRR), and benefit-cost ratio (B:C ratio).

1. Payback Period: The payback period is the time required for the initial investment in the sprinkler irrigation system to be recovered through annual net cash revenues. A shorter

payback period indicates that the investment can be recouped faster, making the project financially more attractive and less risky.

Payback period Payback period (years) = Investment of the project /Annual net cash revenue

2. Net Present Worth (NPW): NPW is the sum of the present value of net cash flows (revenues minus costs) over the lifetime of the sprinkler irrigation system. It takes into account the time value of money by discounting future cash flows to their present value using a discount rate. A positive NPW indicates that the investment generates a surplus of value, making it economically viable.

$$NPW = \frac{P_i}{(1+i)^{t_1}} + \frac{P_i}{(1+i)^{t_2}} + \frac{P_i}{(1+i)^{t_3}} + \cdots \frac{P_i}{(1+i)^{t_n}} - C$$

Where, P = Net cash flow in nth year (years); i = Discount rate; t = time period (years); C = Initial cost of investment

3. Internal Rate of Return (IRR): IRR represents the annualized rate of return at which the net present worth of cash flows becomes zero. In other words, it is the discount rate at which the present value of cash inflows equals the present value of cash outflows. A higher IRR suggests a more profitable investment.

IRR= [Lower discount rate] + [Difference between the two discount rate] x

$$\frac{Present\ worth\ of\ cash\ flow\ at lower\ discount\ rate}{(Absolute\ difference\ between\ the\ present\ worth\ of\ the\ cash\ flow\ at\ the\ two\ discount\ rates)}$$

4. Benefit-Cost Ratio (B:C Ratio): The B:C ratio compares the present value of gross income (benefits) to the present value of total costs. A B:C ratio greater than 1 indicates that the benefits outweigh the costs, making the investment economically feasible.

$$B - C\ ratio = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^n}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^n}}$$

$$B{:}C\ ratio = \frac{Gross\ income/ha}{Total\ Cost/ha}$$

To determine the economic feasibility of adopting sprinkler irrigation systems, farmers and policymakers use these financial indicators to assess the potential returns, risks, and overall benefits of the investment. A positive outcome in terms of payback period, NPW, IRR, and B:C ratio indicates that sprinkler irrigation is a financially viable and prudent choice, promoting efficient water management, sustainable agriculture, and improved farm income.

3. RESULTS AND DISCUSSION

The research findings in Table 1 reveal a significant growth in sprinkler-irrigated areas in both Rajasthan and India. The adoption of sprinkler irrigation systems has gained prominence as an effective solution to address water scarcity and enhance agricultural productivity. This sets the stage for a comprehensive discussion on the factors driving this growth, the significance of micro irrigation in sustainable agriculture, and the implications for water management and food security in the region.

Table 1: Compound growth rate of area under sprinkler irrigation system in Rajasthan and India. (2005-06 to 2021-22)

S. no.	Growth Rates	Rajasthan	India
1	CAGR per cent	27.9	18.6
2	B (Regression coefficient)	1.279*	1.186*
3	R^2	0.532	0.293

Source: Ministry of Agriculture& farmer welfare (Compound growth rate *is Significant at 1per cent level)

The results presented in Table 1 shows a significant growth of sprinkler irrigated areas in Rajasthan at a 1 per cent level. This growth can be attributed to the state's water scarcity and undulating land, which makes the sprinkler irrigation system more suitable than conventional methods. Rajasthan stands as a major state in India concerning the area under sprinkler irrigation, and its compound growth rate from 2005-06 to 2021-22 was calculated to be 27.9 per cent, with a positively significant 'b' value of 1.279. Rajasthan constitutes 10.41 per cent of India's geographical area, with a population accounting for 5.5 per cent of the total. Approximately 2/3rd of the state is desert, and it is divided into 16 basins, out of which only two, Chambal and Mahi, receive sufficient rainfall and yield. The combined availability of surface water in Rajasthan is 43.26 BCM, with 25.38 BCM available within the state boundaries, and 17.88 BCM allocated from various interstate treaties. The total surface water availability accounts for 1.16 per cent of the national resources, while the total ground water availability accounts for 1.72 per cent. However, only 31 out of the 249 blocks are in a safe condition in terms of water availability. The state experiences a wide variation in district-wise average rainfall, ranging from 158.0 mm in Jaisalmer to 968.0 mm in Sirohi. The significant growth in sprinkler-irrigated areas in Rajasthan can be attributed to specific factors relevant to the region. Due to its geographical location and limited water resources, Rajasthan faces acute water scarcity, making sprinkler irrigation an attractive option for farmers. The efficient water usage and reduced wastage offered by sprinkler irrigation allow farmers to optimize water usage by delivering water directly to the root zone of plants, minimizing evaporation and ensuring efficient irrigation. The government of Rajasthan has actively promoted sprinkler irrigation through various initiatives, including the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and the Rajasthan Agricultural Competitiveness Project (RACP), which provide subsidies and financial assistance to farmers adopting sprinkler irrigation systems. These initiatives aim to enhance water-use efficiency and improve agricultural productivity in the state. The increasing availability and affordability of sprinkler irrigation system have played a pivotal role in this growth. Various awareness campaigns, training programs, and workshops have been conducted in Rajasthan to educate farmers about the benefits of sprinkler irrigation. Agricultural extension services, NGOs, and government agencies actively disseminate knowledge about the advantages of sprinkler irrigation, including water conservation, increased crop yield, and reduced production costs. Demonstration farms and pilot projects have also been set up in Rajasthan to showcase the benefits of sprinkler irrigation system, enabling farmers to witness its impact firsthand and encouraging its adoption on their own farms. While the exact extent of sprinkler-irrigated areas in Rajasthan may vary across districts and regions, the collective efforts of the government, technological advancements, and increasing awareness have significantly contributed to the growth of sprinkler-irrigated areas in the state. This growth is vital for sustainable agriculture in a water-stressed region like Rajasthan, as it promotes efficient water management, improves crop productivity, and enhances the livelihoods of farmers.

Similarly, India has also experienced a positive and significant growth in the area under sprinkler irrigation, at a 1 per cent level. The compound growth rate for the country was found to be 18.6 per cent, with a positively significant 'b' value of 1.186. This growth in sprinkler-irrigated areas in India can be attributed to several factors. Firstly, increasing awareness among farmers about the importance of water conservation and sustainable farming practices has prompted them to shift from traditional flood irrigation to more efficient sprinkler irrigation. This shift is particularly crucial in water-scarce regions where conserving water resources is of utmost importance. Secondly, the government of India has been actively promoting sprinkler irrigation through various initiatives and subsidies, including the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). Launched in 2015, PMKSY aims to provide end-to-end solutions in the irrigation supply chain, including sprinkler and drip irrigation systems. The program has played a vital role in encouraging farmers to adopt sprinkler irrigation by offering financial assistance and technical support. Moreover, the increasing availability and affordability of sprinkler irrigation system have also contributed to its growth. Technological advancements and economies of scale have made sprinkler systems more accessible to farmers across different income levels. The growth of sprinkler-irrigated areas in India has not only led to improved water management but also enhanced agricultural productivity.

Table2: Cost of Installation of Sprinkler Irrigation System in Bikaner District of Rajasthan

S. No.	Item	Size of pipe								
A		2 inch (63mm)			2.5 inch (75mm)			3 inch (90mm)		
		Qty.	Unit Price	Total Cost	Qty.	Unit Price	Total Cost	Qty.	Unit Price	Total Cost
1	HDPE pipes with quick action coupler of 6 meter long	120	630	75600	140	825	115500	160	1120	179200
2	Sprinkler coupler with foot batten assembly	2	320	640	10	340	3400	15	450	6750
3	Sprinkler nozzles (0.75 inch)	100	400	40000	120	420	50400	140	500	70000
4	Riser pipe (0.75X 75cm diameter	100	120	12000	120	120	14400	140	120	16800
5	Connecting nipple	1	320	320	1	320	320	1	320	320
6	Bend with coupler 90 degrees (albo)	1	250	250	1	280	280	1	480	480
7	Tee with coupler	1	350	350	1	380	380	1	500	500
8	End plug	2	100	200	2	110	220	2	220	440
B	Total system cost			129360			184900			274490
C	Transportation and installation charges @ 10 per cent	0.1		12936	0.1		18490	0.1		27449
D	Total cost (B+C)			142296			203390			301939

The table 2 represents the itemized cost for installing sprinkler irrigation systems with different pipe sizes, namely 2-inch (63mm), 2.5-inch (75mm), and 3-inch (90mm) on the per hectare basis. The costs are broken down for various components required for the sprinkler system installation. Component A includes the quantities and unit costs of the materials needed for the system. It consists of HDPE pipes with quick action couplers of 6-meter length, sprinkler couplers with foot batten assembly, sprinkler nozzles (0.75 inch), riser pipes (0.75X 75cm diameter), connecting nipples, bends with couplers (90 degrees), tees with couplers, and end plugs. The quantities vary based on the pipe size. Component B represents the total system cost for each pipe size, which includes the total costs of the items in Component A. Component C accounts for transportation and installation charges at 10 per cent of the total system cost (Component B). Finally, Component D shows the total cost, which is the sum of the total system cost (Component B) and the transportation and installation charges (Component C).

For the 2-inch pipe size, the total cost is Rs. 142,296. For the 2.5-inch pipe size, the total cost is Rs. 203,390. And for the 3-inch pipe size, the total cost is Rs. 301,939. The 2-inch system has the lowest total cost and highest feasibility, followed by the 2.5-inch and 3-inch systems. Considering the cost-effectiveness and feasibility, the 2-inch sprinkler irrigation system appears to be the best choice for farmers in the study area. These cost estimates are crucial for farmers and agricultural practitioners to make informed decisions about adopting sprinkler irrigation systems. The data in the table provides a clear understanding of the expenses involved in setting up each pipe size, aiding farmers in selecting the most suitable option based on their budget and requirements. Additionally, it offers insights for policymakers and agricultural organizations to formulate effective strategies and incentives for promoting the adoption of water-efficient irrigation technologies like sprinkler irrigation systems. By investing in such irrigation practices, farmers can potentially enhance crop productivity, optimize water usage, and improve overall agricultural sustainability.

Table 3: Economic Feasibility of sprinkler irrigation system in Bikaner district of Rajasthan.

S. No.	Particulars	Size of HDPE Pipe		
		2 inches	**2.5 inches**	**3 inches**
1	Payback period (years)	1.038	1.165	1.370
2	Net Present Value (NPV) (Rs.)	968800.52	900261.92	802439.35
3	Internal Rate of Return (IRR) (per cent)	43.15	41.08	37.48
4	B-C Ratio	1.28	1.26	1.22

The research findings presented in Table 3 provide valuable insights into the economic feasibility of sprinkler irrigation systems with different pipe sizes (2-inch, 2.5-inch, and 3-inch). The study evaluates the payback period, net present worth (NPW), internal rate of return (IRR), and benefit-cost ratio (B:C ratio) associated with each pipe size to determine their profitability and investment recovery potential. The payback period is a critical indicator that reveals the time required for a farmer to recoup the initial investment made on the sprinkler irrigation system. The results shows that all three pipe sizes offer short payback periods, indicating that the investment made on these systems would be recovered within one year. The 2-inch sprinkler irrigation system has the shortest payback period of 1.038 years, followed by the 2.5-inch system with 1.165 years. The 3-inch system, with its higher cost, exhibits the highest payback period of 1.370 years.

The net present worth (NPW) analysis assesses the profitability of the investment over its lifetime. It considers the present value of cash inflows (gross returns) and cash outflows (costs) at a specific discount rate. The NPW values calculated at a discount factor of 7 per cent indicate that the 2-inch sprinkler irrigation system has the highest NPW of ₹ 968800.52, followed by the 2.5-inch system with ₹ 900261.92, and the 3-inch system with ₹ 802439.35. These positive NPW values indicate that all three systems are economically feasible investments. The internal rate of return (IRR) measures the annualized return rate that equates the present value of cash inflows to the present value of cash outflows. A higher IRR indicates a more profitable investment. The results reveal that the 2-inch sprinkler system has the highest IRR of 43.15 per cent, followed by the 2.5-inch system with 41.08 per cent, and the 3-inch system with 37.48 per cent. These findings further support the economic viability of all three systems. The benefit-cost ratio (B:C ratio) compares the present value of gross returns to the present value of costs. A B:C ratio greater than 1 indicates a financially feasible investment. The analysis shows that all three systems have B:C ratios above 1, signifying that they offer positive returns on investment. The 2-inch sprinkler system has the highest B:C ratio of 1.28, followed closely by the 2.5-inch system with 1.26, and the 3-inch system with 1.22.

The economic feasibility analysis of sprinkler irrigation systems with 2-inch, 2.5-inch, and 3-inch pipe sizes reveals their profitability and investment recovery potential. All three systems prove to be economically viable options for farmers in the study area. The 2-inch system stands out as the most feasible choice due to its shorter payback period, higher net present worth, internal rate of return, and benefit-cost ratio. These findings have significant implications for agricultural practitioners and policymakers, highlighting the importance of adopting water-efficient irrigation technologies like sprinkler systems to enhance crop productivity, optimize resource utilization, and promote sustainable agricultural growth in water-stressed regions.

4. CONCLUSION

The research findings reveal a remarkable compound annual growth rate (CAGR) in the area under sprinkler irrigation in both Rajasthan and India. Rajasthan exhibited a higher CAGR of 27.9 per cent compared to India's 18.6 per cent from 2005-06 to 2021-22. These growth rates demonstrate the increasing acceptance and effectiveness of micro irrigation systems in addressing water scarcity and enhancing agricultural productivity. The efficient water usage and reduced wastage offered by sprinkler irrigation system make it an attractive option for farmers in the region. Government efforts, such as PMKSY and RACP, have played a vital role in encouraging farmers to adopt sprinkler irrigation, leading to substantial growth. India's significant CAGR in the adoption of sprinkler irrigation highlights increasing awareness among farmers about the importance of water conservation and sustainable farming practices. The active promotion of micro irrigation through initiatives like PMKSY has facilitated adoption across the country. Advancements in sprinkler technology and improved affordability have contributed to positive growth. The research emphasizes the crucial role of micro irrigation in addressing water management challenges in agriculture and improving water-use efficiency and productivity. The study highlights the need for continued efforts to promote the adoption of micro irrigation systems, particularly in water-stressed regions, to ensure optimal water utilization and enhance farmers' livelihoods. In conclusion, the study's CAGR results indicate a positive shift towards more efficient and sustainable agricultural practices through the adoption of sprinkler irrigation systems. The implications are far-reaching, contributing to water conservation, food security, and rural development. The adoption of micro irrigation becomes even more critical for the future of agriculture in India, necessitating further research and policy measures to support its widespread adoption for a water-efficient and productive agricultural sector.

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