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Market analysis of micro-irrigation systems in Vellore district, South India

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Abstract

This study examines the micro-irrigation system market in Vellore district, Tamil Nadu, India, focusing on adoption trends and market dynamics. Data was collected using a structured questionnaire from 90 farmers across different blocks and analysed alongside data from major micro-irrigation companies (anonymized as Firm A, Firm B, Firm C, Firm D and Firm E). Water scarcity emerged as the primary driver of micro-irrigation adoption, with farmers seeking to conserve resources. Another key factor is labour reduction, as micro-irrigation systems streamline processes and minimize manual effort. M/S Firm A leads the market with a 32.7 % share, followed by Firm B (30.76 %), Firm D (25 %) and Firm C (11.53 %). Despite Firm A's dominance, cost variations of up to 20 % among companies influence farmers' purchasing decisions based on affordability and perceived value. The study highlights micro-irrigation's potential to enhance agricultural productivity and water-use efficiency by delivering water directly to plant roots, minimizing wastage. Promoting affordable technologies and strengthening extension services can equip farmers with the skills needed to maximize these benefits. Additionally, fostering a supportive policy environment can encourage wider adoption. This research offers valuable insights for policymakers, companies and farmers, emphasizing the need for collaborative efforts to enhance sustainable In India, the adoption of micro-irrigation has been encouraged through various government schemes aimed at improving on-farm water management practices and improve agricultural outcomes in Vellore district. Addressing key drivers and barriers can help create a more efficient and productive agricultural sector in the region.

Keywords

agri-input; market analysis; market share; micro-irrigation; water scarcity

Introduction

Water demand in agriculture can be significantly reduced through methods such as implementing micro-irrigation systems like drip and sprinkler irrigation, adopting water-efficient crop varieties, practicing rainwater harvesting, promoting soil moisture retention techniques and enhancing water use efficiency through advanced precision farming technologies (1). Watershed and water resource development through big, medium, small and minor irrigation projects are among the supply-side management approaches. The second is through enhanced water management technologies and procedures, which are part of demand management practices (2). The primary interventions in water conservation and crop productivity are micro-irrigation (MI) technologies such as drip and sprinkler

irrigation systems. Evidence shows that upto 40 % to 80 % of water can be saved and water use efficiency (WUE) can be enhanced up to 100 % in a properly designed and managed MI system compared with 30-40 % under conventional practice (3). Previous works provides evidence that water use efficiency can be increased by 50-90 % (4).

There are plenty of advantages in using a micro-irrigation system. When compared to the traditional surface method of irrigation, MI has proven to be an effective way for conserving water and enhancing water use efficiency. For various crops, productivity gains via micro-irrigation are predicted to range from 20 % to 90 %. Traditional flood irrigation produces lower yields (5). Water loss is minimized due to reduced water loss in transportation evaporation, runoff and deep percolation. Through fertigation, a drip irrigation system efficiently delivers nutrients directly to plant roots, reducing fertilizer consumption and minimizing waste (6). This precise application enhances nutrient absorption while preventing runoff, making it a sustainable agricultural practice. Additionally, it improves crop yield and soil health over time. Growers will be able to apply water and agrochemicals more precisely and site-specifically using emerging computerized GPS-based precision irrigation technologies. These technologies, designed for self-propelled sprinklers and micro-irrigation systems, will be supported through wireless sensor networks (7).

Global micro-irrigation industries are highly concentrated with the top five companies controlling over 60 % of the market. The market is expected to double in the coming years, driven by government initiatives to enhance water conservation and efficiency through micro-irrigation systems (8). The market's significant participants include M/S Jain Irrigation Systems Limited, M/S Netafim Limited, M/S Lindsay Corporation, M/S Rivulus Irrigation Limited and M/S The Toro Company etc. (9).

However, in the case of India, major firms such as M/S Jain Irrigation Systems Ltd. and M/S Netafim dominate the Indian micro-irrigation market. These companies are expanding their market presence through mergers and acquisitions, strategic collaborations and product innovations. Additionally, start-ups such as M/S FlyBird Farm Innovations and M/S Conser Water Technologies are integrating Artificial Intelligence (AI) and the Internet of Things (IoT) into micro-irrigation systems, offering innovative services to Indian farmers. M/S Jain Irrigation System Limited, M/S Netafim, M/S Kodhari Agritech Private Limited, M/S Finolexplasson Industries Private Limited are major players, as far as the Indian market is concerned (10).

Table 1 presents data on state-wise central assistance, area covered and farmers benefited under micro -irrigation (PMKSY-PDMC) from 2015-16 to August 2021. Tamil Nadu, where Vellore district is located, has received Rs. 1920.83 crore in central assistance, covering 832847 hectares and benefiting 676775 farmers during this period. This substantial allocation highlights the state's focus on promoting micro-irrigation practices, which plays a significant role in shaping the local market dynamics.

Table 1. State-wise central assistance, area covered and farmers benefited under micro-irrigation (PMKSY-PDMC) in India (2015-16 to August 2021)

States/UTs	Central assistance released (Rs. in Crore)	Area covered under micro irrigation (Area in Hectare)	Number of farmers benefitted for micro irrigation
Andaman & Nicobar Islands	0.70	-	-
Andhra Pradesh	2104.16	743992	659343
Arunachal Pradesh	88.40	6898	16040
Assam	91.03	18456	21157
Bihar	90.61	18692	15777
Chhattisgarh	240.64	105621	113438
Goa	2.80	868	803
Gujarat	1612.55	815700	575968
Haryana	218.19	65136	64699
Himachal Pradesh	116.85	10486	13448
Jammu & Kashmir	58.07	1090	1073
Jharkhand	145.64	23758	32023
Karnataka	2309.15	1246354	1294014
Kerala	42.53	3166	4809
Ladakh	2.40	-	-
Madhya Pradesh	792.40	236817	156619
Maharashtra	1760.46	655177	751110
Manipur	121.36	8609	11039
Meghalaya	31.73	-	-
Mizoram	104.47	3265	6039
Nagaland	136.64	4350	5581
Odisha	231.40	42725	59508
Puducherry	2.03	-	-
Punjab	53.18	6540	4855
Rajasthan	822.82	333947	216192
Sikkim	136.24	6297	17382
Tamil Nadu	1920.83	832847	676775
Telangana	679.32	247555	230035
Tripura	51.50	-	-
Uttar Pradesh	521.79	232487	154288
Uttarakhand	176.80	21276	36040
West Bengal	176.70	52152	49500
India	14843.39	5744261	5187555

(Source: Lok Sabha unstarred question No. 3565, dated on 10.08.2021)

Although micro-irrigation has been extensively studied in leading agricultural states like Gujarat and Maharashtra, where adoption levels are high, very little research has focused on smaller, water-scarce regions like Vellore district in Tamil Nadu. Vellore's semi-arid climate and recurring water shortages create both challenges and opportunities for adopting micro-irrigation systems. To develop effective strategies for improving adoption in such regions, it is essential to understand the specific factors influencing farmers' decisions and market dynamics. This study bridges that gap by analyzing the micro-irrigation market in Vellore and providing insights that can guide policymakers and stakeholders in promoting sustainable irrigation practices.

The primary objective of this study is to analyze the micro-irrigation market in Vellore district, focusing on understanding the role of key market players (anonymized as Firm A, Firm B, Firm C, Firm D and Firm E) and assessing the impact of government support. By examining the broader trends presented in Table 1, this study seeks to evaluate how large-scale government interventions have influenced the growth, adoption and competition among micro-irrigation firms in Vellore district. This macro-level data provides essential context for assessing the

operational efficiency, market penetration and performance of the firms analyzed in this study.

This study provides valuable insights for agricultural policy by highlighting how micro-irrigation adoption can improve water-use efficiency and reduce labour dependency. Policymakers can use these findings to design targeted subsidies and awareness programs, promoting wider adoption (11). Additionally, understanding the cost variations and market dynamics can help regulate pricing and ensure fair competition. For agricultural practice, the study emphasizes the need for farmer training to ensure the effective use and maintenance of micro-irrigation systems, ultimately contributing to sustainable agricultural growth.

Materials and Methods

For this study, Vellore district was purposively selected because it ranks as the sixth-largest district in Tamil Nadu and has adopted a micro-irrigation system. Three blocks in Vellore district, namely Anaicut, Madhanur and Kaniyambadi, were purposefully selected based on the maximum area under horticultural crops cultivation and micro-irrigation systems. From each selected block, 30 farmers were chosen, making a total of 90 farmers. Additionally, the 10 company representatives were selected from major micro-irrigation companies operating in the Vellore district. These representatives held positions in sales, marketing, or management and were chosen based on their knowledge of the local micro-irrigation market and their interactions with farmers. Their role in the study was to provide insights into market trends, company strategies and challenges in the micro-irrigation sector (12).

The questionnaire was developed through a multi-stage process to ensure content validity and relevance. An initial literature review identified key variables related to farmer demographics, irrigation practices, micro-irrigation adoption and company information. Expert consultation with agricultural scientists, economists and survey specialists refined the questionnaire. Content validity was assessed through expert review and face validity via pilot testing with 10 farmers. Informed consent was obtained from all participants prior to their involvement in the study. Participants were provided with a detailed explanation of the study's purpose, procedures, risks and benefits. They were also informed of their right to withdraw from the study at any time without penalty. Verbal informed consent was obtained from all participants and this consent was documented in the study records. Primary data were collected using a comprehensive, well-structured questionnaire through personal interviews (13).

The collected data was analyzed using SPSS software. Percentage analysis was employed to describe the distribution of categorical variables, such as farmer demographics and company market share. This method provides a clear and straight forward way to understand the proportion of responses within each category. To prioritize the factors influencing farmer's decisions to adopt micro-irrigation systems, the relative importance index was calculated. This technique allows for the ranking of different factors based on their perceived importance, providing valuable insights into the key drivers of micro-irrigation adoption. By using the relative importance index, the study identifies the most critical factors that influence farmers' adoption decisions.

Percentage analysis

This tool was found useful in determining the market share of different companies in terms of marketing of micro-irrigation system (14).

Relative Importance Index (RII)

This statistical tool is used to evaluate and rank the significance of various quality factors based on respondent feedback. It is calculated using a Likert scale, where each point corresponds to a weighting (W) assigned to a factor, reflecting its perceived importance. The RII was calculated by using equation.

$$RII=\sum W/A*N \qquad \text{(Eqn. 1).}$$

Where,

W: Weighting given to each factor by the respondent

A: the highest weight in the research

N: Total number of respondents

The greater the value of the RII, the more important each of the components becomes.

Obtained from equation above. The RII is used to rank the factors and it is different for each factor (15).

Results and Discussion

Table 2 highlights competition in the micro-irrigation system market is intense, with M/S Firm A leading with a 32.65 % market share followed by M/S Firm B at 30.76 %. These firms dominate due to extensive farmer engagement, effective marketing efforts and quick installation services. M/S Firm D also holds a notable share at 25 %, while M/S Firm C has a lower presence at 11.53 %. In contrast, M/S Firms E, F and G have no recorded market penetration, highlighting their negligible presence (16). Understanding factors influencing farmer choices and the competitive landscape requires further research (17).

The results revealed a statistically significant association between the blocks and the farmers' choice of micro-irrigation system providers (x^2 (6) = 10.5, p = 0.04). This indicates that farmer preferences for specific companies vary significantly across the different blocks,

Table 2. Market competition and their shares among sample farmers in the study area

Companies	Anaicut (Block 1)	Kaniyambadi (Block 2)	Madhanur (Block 3)	Overall
Firm A	6 (31.57)	8 (44.44)	3 (20)	17 (32.69)
Firm B	6 (31.57)	4 (22.22)	6 (40)	16 (30.76)
Firm C	4 (21.05)	0 (0)	2 (13.33)	6 (11.53)
Firm D	3 (15.78)	6 (33.33)	4 (26.66)	13 (25)
Firm E	0 (0)	0 (0)	0 (0)	0 (0)
Firm F	0 (0)	0 (0)	0 (0)	0 (0)
Firm G	0 (0)	0 (0)	0 (0)	0 (0)
Total	**19 (100)**	**18 (100)**	**15 (100)**	**52 (100)**

Q1 (Figures in the parentheses indicate percentage)

suggesting that local factors play a crucial role in their decision-making process. These variations underscore the need for further research to understand the specific factors driving farmer choices and the barriers hindering the market penetration of M/S Firms E, F and G.

Compared to semi-arid regions like Maharashtra or Rajasthan, Vellore's micro-irrigation market is highly concentrated, with two firms dominating over 60 %, unlike the fragmented markets typically seen elsewhere. This likely results from Firms A and B's strong local presence. The complete absence of Firms E, F and G, contrasting with niche market presence in diverse regions like the Indo-Gangetic plains, highlights high barriers to entry in Vellore. Further research is needed to understand these regional differences in farmer choices and market penetration.

Market analysis

Market analysis is an important component of any business plan. This section illustrates the knowledge about the existing market. Different parameters of marketing mix *viz.,* product, price, place and promotion are used to analyse the micro-irrigation market (18).

Product line

Table 3 M/S Firm A and B dominate the micro-irrigation market with the widest product range, including drip, sprinkler and smart irrigation systems, as well as green energy solutions. This comprehensive product portfolio likely contributes to their market leadership (19). In contrast, competitors focus primarily on core irrigation products, with limited offerings in emerging areas like smart irrigation and green energy. Expanding product lines to meet evolving farmer needs could be crucial for these companies to gain market share (20).

Table 3. Different product categories available with micro-irrigation manufacturing companies

Companies	Drip irrigation system	Sprinkler irrigation system	Filter & dosing pump, injectors	Smart irrigation projects	Green energy products
Firm A	✓	✓	✓	✓	✓
Firm B	✓	✓	✓	✓	✓
Firm C	✓	✓	✓	✓	×
Firm D	✓	✓	✓	×	×
Firm E	✓	✓	✓	×	×
Firm F	✓	✓	✓	×	×
Firm G	✓	✓	✓	×	×

Price

Table 4 presents a price comparison of key components between M/S Firm A and C.

For instance, PVC pipes and laterals have similar pricing across firms. However, certain components are significantly more expensive for M/S Firm C. Control valves cost ₹450 for Firm C compared to ₹356 for Firm A. Similarly, screen filters are priced at ₹2500 for Firm C, while Firm A offers them for ₹2400. The price difference is even greater for venturi manifolds, which cost ₹3000 for Firm C but only ₹2250 for Firm A. While M/S Firm C's products are generally more expensive, the price difference varies across components. For farmers, cost considerations are crucial and a detailed cost-benefit analysis considering factors such as product quality, durability and after-sales service is essential before making purchasing decisions (21). To gain a competitive edge, companies should focus on offering value-added services, such as installation support, training and maintenance, in addition to competitive pricing (22).

Table 5 reveals significant variations in micro-irrigation system costs across different crops, with vegetable cultivation incurring substantially higher expenses (Rs. 112944.22) compared to fruit/orchard cultivation (Rs. 69000). This disparity is likely attributed to factors such as crop-specific water requirements, planting density and additional system components needed for vegetables. Drip irrigation emerges as the preferred method for both crops, emphasizing its efficiency. While the higher initial investment in vegetable irrigation systems might seem substantial, the potential for increased yields and returns, coupled with water scarcity concerns, could justify the expense (23).

Table 6 shows micro-irrigation system costs vary significantly based on crop, spacing and system type. Drip irrigation, while highly efficient, can be costly for crops like vegetables, often exceeding Rs. 100000 per hectare due to complex system requirements. In contrast, wider spacing in orchards can reduce drip system costs to around Rs. 40000 per hectare. Sprinkler systems, though less efficient, are generally cheaper for flowers and plantations, typically

Table 4. Price comparison between top players for the micro-irrigation system components (Rs. = Rupees)

S. No.	Particulars	Firm A product price/unit (Rs.)	Firm C product price/unit (Rs.)	Price differentiation (Rs.)
1	Pvc pipe 75mm, Class 2: 4kg/cm^2	63.00	63.00	0
2	Pvc pipe 63mm, Class 2: 4kg/cm^2	43.00	43.00	0
3	Lateral 16mm, Class 2: 2.5kg/cm^2	7.00	7.00	0
4	Emitting pipe 16mm, class2, 60cm/4lph	9.49	9.60	0.11
5	Control valve 63mm	356.00	450.00	96
6	Control valve 50mm	240.00	320.00	80
7	Flush valve 63mm	75.00	75.00	0
8	Air release valve 1	110.00	110.00	0
9	Non-Return valve 1.5	600.00	625.00	25
10	Throttle valve 2	750.00	835.00	85
11	Screen Filter 20m3/hr	2400.00	2500.00	100
12	Venturi & Mainfold 2	2250.00	3000.00	750
13	By pass assembly 1.5*1.5	650.00	750.00	100

(Source: Company representative)

Table 5. Average price quoted by various micro-irrigation firms for one hectare

S. No.	Particulars	Recommended micro-irrigation system	Average price (Rs.)
1	Fruit or orchard crops	Drip irrigation	69000.00
2	Vegetable crops	Drip irrigation	112944.22
3	Flower crop	Sprinkler irrigation	57842.00

(Source: Company representative)

Table 6. Cost incurred for installation of micro-irrigation systems for each individual crop grown by sample farmers (n=52)

S. No.	Crop	Recommended micro-irrigation system	Spacing	Cost (Rs/ha)	Subsidy extended per ha. (excluding GST)	
					Small/ marginal farmers (100 subsidy)	Other farmers (75 % subsidy)
1	Guava	Drip	6 m x 6 m	29257	29257	21943
2	Guava		5 m x 5 m	33074	33074	24805
3	Coconut		8 m x 8 m	24795	24795	18596
4	Banana		2 m x 2 m	64828	64828	48621
5	Banana		1.5 m x 1.5 m	75755	75755	56816
6	Banana		1.8 m x 0.6 m	72442	72442	54331
7	Mango		10 m x 10 m	22426	22426	16820
8	Vegetables, Gloriosa, Coleus		1.2 m x 0.6 m	101012	101012	75759
9	Flowers and plantation Crops	sp Sprinkler		18630	18630	13973
		Rain Gun		27230	27230	20423

(Source: Author's estimate)

ranging from Rs. 30000 to Rs. 50000 per hectare. Tailoring systems to specific crop needs and considering factors like subsidies is crucial for economic viability (24).

Marketing channel (Fig. 1)

Manufacturers play a crucial role in the micro-irrigation distribution network by designing, producing and assembling essential components such as pipes, emitters, filters, valves and fertigation units (25). These companies invest in research and development to enhance product efficiency, durability and water-saving capabilities. They also ensure compliance with industry standards and government regulations, which impact product performance and adoption. Additionally, manufacturers collaborate with dealers and company representatives to provide technical training, promotional support and after-sales services, ensuring that farmers receive reliable and effective irrigation solutions (26).

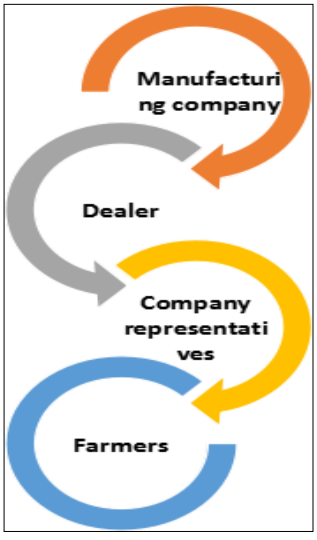

Fig. 1. Distribution channel for micro-irrigation products.

Promotional strategies adopted by micro-irrigation companies

Table 7 highlights that micro-irrigation system promotion relies on a combination of strategies, with direct marketing by company representatives being the most effective (27.88 %). This approach, which includes demonstrations, pamphlet distribution and targeted campaigns, enables personalized interactions that address farmer queries in real time, enhancing trust and adoption. Recommendations by horticulture and agriculture officers, contributing 24.15 %, leverage their credibility to promote adoption by providing technical guidance and information on government subsidies and schemes, thereby lowering financial barriers for farmers. Farmer group influence (18.08 %) facilitates peer-to-peer learning and collective decision-making, encouraging adoption through the validation of successful experiences. Training programs (17.55 %) provide hands-on exposure to system operations, equipping farmers with practical knowledge and boosting confidence in using the technology effectively (27). Trade fairs and agricultural melas, although contributing a lower 12.35 %, expose farmers to diverse technological options and foster supplier-farmer interactions, allowing them to compare systems and assess their suitability (28). While each strategy has its unique strengths, an integrated approach that blends personalized direct marketing, trusted endorsements from government officers, peer-driven knowledge sharing, practical training and exposure

Table 7. Important promotional strategies adopted by micro-irrigation companies

Factors	Percentage
Marketing strategies adopted by company representative (demonstrations, pamphlets distribution, campaigning etc.)	27.88
Recommendation by Horticulture/ Agriculture officers	24.15
Influence of farmer's group	18.08
Farmer's visit during training program	17.55
Trade fair/ Mela	12.35

(Source: Author's estimate)

through trade fairs ensures a more comprehensive outreach. This multi-pronged strategy maximizes farmer awareness, builds confidence in technology adoption and ultimately enhances the impact of micro-irrigation promotion efforts (29).

Case study: Impact of drip irrigation on vegetable farming in Vellore district

Mr. Ramesh Kumar, a progressive farmer from Kaniyambadi Block, Vellore District, Tamil Nadu, cultivated tomatoes and brinjal on his 3-acre farm using conventional flood irrigation, which resulted in inconsistent yields and high irrigation costs due to erratic rainfall and water scarcity. He adopted a drip irrigation system supplied by Firm A, with a 50 % subsidy under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). The transition resulted in a 35 % reduction in water consumption, enabling more efficient irrigation, while crop yields increased by 18 % for tomatoes and 12 % for brinjal due to consistent water application. Additionally, operational costs decreased by 20 % as labor requirements were minimized, leading to an overall profit increase of 15 %, prompting Mr. Ramesh to expand the drip system across his entire farm. Reflecting on the experience, Mr. Ramesh shared, "Drip irrigation not only reduced my water usage but also improved my yield. The system is easy to maintain and I can irrigate with precision, even during dry spells."

Market drivers and factors influencing to purchase among sample respondents

As per Table 8, the adoption of micro-irrigation systems is primarily driven by water scarcity, labor shortages and economic considerations. Farmers seek to conserve water, reduce labor input, increase yields and improve overall efficiency. The systems ability to deliver water precisely to plant roots, coupled with potential cost savings on inputs like fertilizers, makes them attractive. Additionally, user-friendly systems that simplify operations are gaining popularity. The analysis of the Relative Importance Index (RII) for market drivers influencing micro-irrigation system adoption, based on responses from 52 participants, reinforces these findings. Minimizing water consumption (RII = 0.52) and reducing labor costs (RII = 0.49) emerged as the most influential factors, followed by minimizing weed growth (RII = 0.48) and time-saving benefits (RII = 0.48). Cost savings and increased crop yield (both RII = 0.47) are also significant contributors, while factors such as ease of maintenance (RII = 0.43), uniform water distribution (RII = 0.41) and easy handling (RII = 0.40) play a less critical role. The mean RII is 0.46, with a standard deviation of 0.036, indicating minimal variability in responses (30). The Spearman's Rank correlation coefficient (0.95) highlights a strong agreement among respondents on the ranking of drivers. Pareto analysis further shows that the top four drivers contribute to 80 % of the total importance, emphasizing their critical role in influencing adoption decisions. A chi-square test ($\chi^2 \approx 27.41$) indicates a significant deviation from a uniform distribution, further confirming the dominance of key drivers. Overall, the findings suggest that addressing water and labor efficiency concerns remains pivotal for enhancing micro-irrigation adoption, while improving system usability can further drive acceptance among farmers (31).

The adoption of micro-irrigation systems is influenced by demographic factors such as age, education, farm size, income and gender. Younger, educated and higher-income farmers are more likely to adopt due to awareness and financial capacity, while older, less-educated and marginal farmers may hesitate despite subsidies. Women prefer micro-irrigation for labor-saving benefits and experienced farmers adopt based on proven success, especially with high-value crops. Social networks and agricultural extension services enhance trust and awareness. To promote adoption, micro-irrigation organizations should align strategies with farmer needs, focus on water-saving and cost-effective designs and provide comprehensive training to drive market growth (32).

The table's findings on market drivers for drip irrigation coincide with previous works (33) who highlight the importance of water conservation (34) who emphasize cost reduction. Additionally, some reports (35) discusses factors such as labour cost reduction and government subsidies. These authors collectively suggest that drip irrigation is a micro-irrigation system that promotes water and nutrient conservation and is widely adopted to improve crop yields and overall agricultural productivity.

Conclusion

This study examined the micro-irrigation system market in Vellore district, Tamil Nadu, India, revealing that water scarcity and labor reduction are primary drivers of micro-irrigation adoption. M/S Firm A leads the market, but cost variations among companies influence farmers' purchasing decisions. The research highlights micro-irrigation's potential to enhance agricultural productivity and water-

Table 8. Market drivers of micro-irrigation system (n=52)

S. No.	Market drivers	Relative Importance Index	Importance
1	Minimize consumption of water	0.52	1
2	Labour cost reduction	0.49	2
3	Minimize weed growth	0.48	3
4	Time saving method	0.48	4
5	Cost saving	0.47	5
6	Increase in crop yield	0.47	6
7	Reduce in fertilizer consumption	0.45	7
8	User friendly and easy maintenance of field operations	0.43	8
9	Distributes water evenly in cropping area	0.41	9
10	Easy handling	0.4	10

(Source: Author's estimate)

use efficiency. However, this study is not without limitations. Data was collected using a structured questionnaire from 90 farmers across different blocks and analyzed alongside data from major micro-irrigation companies. The reliance on survey data may introduce potential biases and the findings are specific to the Vellore district, limiting generalizability to other regions. Additionally, the study's cross-sectional nature provides a snapshot of the market at a single point in time and may not capture evolving market dynamics.

To promote wider adoption of micro-irrigation and enhance its benefits, policymakers should consider several targeted strategies. Firstly, they should implement subsidies and financial incentives that directly address the cost barriers faced by smallholder farmers, ensuring affordability and perceived value. Secondly, invest in strengthening agricultural extension services to provide comprehensive training and support to farmers on the effective use and maintenance of micro-irrigation systems. This will help maximize the benefits of these systems and ensure their sustainable use. Future research should focus on several key areas. Longitudinal studies could provide insights into the long-term impacts of micro-irrigation adoption on agricultural productivity, water resources and farm incomes.

Further research is needed to evaluate the effectiveness of different policy interventions and to explore innovative business models that can improve access to micro-irrigation technologies. Additionally, investigating the role of digital technologies, such as AI and IoT, in optimizing micro-irrigation systems could offer valuable insights for enhancing water-use efficiency and promoting sustainable agriculture. This study contributes to both theoretical and practical understandings of micro-irrigation markets.

Theoretically, it provides empirical evidence on the key factors influencing adoption behavior and market dynamics in a specific agricultural context. Practically, the findings offer valuable insights for policymakers, companies and farmers. For policymakers, the study highlights the need for targeted support and regulatory frameworks to promote sustainable irrigation practices. For companies, it underscores the importance of competitive pricing, product diversification and value-added services to enhance market share and meet evolving farmer needs. For farmers, it emphasizes the potential of micro-irrigation to improve water-use efficiency, reduce labor dependency and enhance agricultural productivity. Overall, this research contributes valuable insights to promote sustainable agricultural practices in water-scarce regions.

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Authors' contributions

GS contributed to the conceptualization, methodology and formal analysis of the article. GS also played a significant role in the writing and reviewing of the manuscript. PA was responsible for the data collection, investigation and validation. PA also assisted in the writing and editing process, ensuring the accuracy and coherence of the article.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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