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Cost-benefit analysis of traditional and modern irrigation methods

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Abstract
Latur district of Maharashtra was purposively selected for present study due to its recurrent droughts, heavy dependence on groundwater, and the coexistence of both traditional and modern irrigation systems. A total of 180 farmers, 60 from each irrigation methods were selected purposively, data was collected through personal interviews using a pre-tested schedule. The data were collected for the year agricultural year 2024-25. Costs of cultivation were estimated using standard CACP cost concepts, covering both physical inputs (human labour, bullock and machine power, seeds, fertilizers, manures, plant protection, depreciation) and monetary inputs (land revenue, interest on working and fixed capital). Initial capital investment per hectare was highest for drip irrigation (₹ 3.93 lakh), followed by sprinkler (₹ 3.14 lakh) and surface irrigation (₹ 2.53 lakh). The higher costs in modern systems were due to specialized infrastructure, yet annual operating and maintenance costs were lower—particularly for sprinkler irrigation (₹ 11,140/ha) compared to surface (₹ 15,250/ha). Crop-wise cost analysis showed that sprinkler irrigation reduced cultivation expenses for soybean, chickpea, and sorghum, while drip irrigation for sugarcane had higher costs but delivered much higher yields.

Keywords: Cost of cultivation, CACP, drip irrigation, sprinkler irrigation

Introduction
India's net irrigated area has expanded significantly since independence, reaching about 79.31 million hectares in 2022-23 (Government of India, 2023a) [4]. The main sources of irrigation include canals, tanks, tube wells, and other groundwater structures, with groundwater accounting for over 64% of the total irrigated area (Government of India, 2024) [5]. Despite recent policy efforts, the share of micro-irrigation (drip and sprinkler) in total irrigated area remains modest. As of 2020-21, micro-irrigation covered around 13.6 million hectares, representing only about 17% of India's net irrigated area (Department of Agriculture & Farmers Welfare [DA&FW], 2021) [2]. This gap highlights the potential for expanding water-efficient technologies. Latur district is a representative and critical case within Marathwada. It has experienced recurrent droughts, a predominately agrarian economy, and heavy reliance on both rainfall and groundwater. Several recent district-level studies and reports document the vulnerability of agriculture in Latur to meteorological shocks, the adverse socio-economic impacts of repeated droughts, and pressure on groundwater resources (falling water tables, failed borewells). These conditions make Latur a priority area for assessing irrigation technologies that can improve water-use efficiency and economic returns for farmers.

Objective
1. To compare costs and benefits of traditional and modern irrigation systems

Methodology
A purposive sampling technique was used for the selection of the district, talukas, villages and sample farmers. Taluka wise list of farmers having modern irrigation systems like drip and sprinkler irrigation were collected from Agriculture Department of Zilla Parishad, Latur and 60 farmers each using drip and sprinkler irrigation system were selected proportionately from all tehsils of Latur district. Similarly, 60 farmers following traditional irrigation systems were

selected randomly across the Latur district. Thus, total sample constitutes of 60 drip users, 60 sprinkler users, and 60 following traditional method. Primary data required to fulfil the objectives were collected from the selected respondents through personal interview method by developing a pre-tested schedule. The data gathered on cultivation costs (expenditure) for all surface, drip and sprinkler farmers were compiled, and the percentage of expenditure on each aspect of cost relative to the total costs was calculated. To workout cost of cultivation of different crops, the standard cost concepts of CACP, New Delhi was used.

Materials and Methods

Cost concepts

a) Cost A_1: It includes the following

1. Wages of hired human labour
2. Value of hired and owned bullock labour
3. Value of hired and owned machine labour
4. Value of seed (farm and purchased seeds)
5. Value of manures (owned and purchased)
6. Fertilizers
7. Depreciation
8. Irrigation charges
9. Land revenue
10. Interest on working capital.

In short,

a) Cost A_1 = All paid cost + depreciation + land revenue + Interest on working capital + miscellaneous cost
b) Cost A_2 = Cost A_1 + Rent paid for leased-in land
c) Cost B_1 = Cost A_1 + Interesst on fixed capital (excluding land)
d) Cost B_2 = Cost B_1 + Rental value of owned land + rent for leased-in-land
e) Cost C_1 = Cost B_1 + Imputed value of family labour
f) Cost C_2 = Cost B_2+ Imputed value of family labour
g) Cost C_3 = Cost C_2+ 10 percent of Cost C_2 as management cost
h) Cost of production

Results and Discussion

This objective aims to evaluate and compare the costs (input use, labour, fertilizer, machinery) and benefits (gross income, net returns, and cost-benefit ratio) associated with traditional (surface) and modern (drip and sprinkler) irrigation systems. These findings will help to determine which system offers better economic efficiency, supports sustainable agricultural practices, and aligns with the livelihood goals of farmers in the study area.

1. Classification of Sample Farmers by Irrigation System

The table 1 shows classification of farmers that indicated small and marginal categories dominated all irrigation systems. Surface irrigation users comprised 45.00% marginal and 40.00% small farmers, together representing 85.00% of users. Drip irrigation was most adopted by small farmers (51.67%), followed by marginal (31.67%) and semi-medium (15.00%) categories. Sprinkler irrigation showed a similar pattern with 55.00% small, 28.33% marginal, and 13.33% semi-medium farmers. Medium farmers accounted for only 1.67-3.33% across modern systems, with no large landholders in any category. The dominance of small and marginal farmers in all irrigation types reflects the fragmented landholding structure in the study area. Higher adoption of surface irrigation among low landholding groups aligns with its lower capital requirements and accessibility. In contrast, the greater proportion of small (rather than marginal) farmers in drip and sprinkler adoption suggests that slightly larger holdings facilitate investment in modern systems.

2. Average Landholding and Irrigated Area

Drip irrigation recorded the highest average landholding (1.54 ha) and gross irrigated area (3.02 ha), followed by sprinkler irrigation (1.44 ha; 2.32 ha gross) and surface irrigation (1.27 ha; 2.37 ha gross). Net irrigated area equaled landholding size in all systems, but gross irrigated area exceeded net area in modern systems due to water-use efficiency. (Table 2) The data illustrate the capacity of modern systems to extend irrigated coverage beyond cultivated land, reflecting their superior water distribution and reduced losses. The closer alignment between gross and net areas in drip and sprinkler systems indicates minimal conveyance loss, unlike surface irrigation where seepage and evaporation reduce efficiency. These findings reinforce the technical advantage of modern systems for maximizing land and water productivity in semi-arid regions.

3. Initial Capital Investment

Table 3 indicated that per hectare investment was highest in drip irrigation (₹ 3,93,338.76), followed by sprinkler (₹ 3,14,794.93) and surface irrigation (₹ 2,53,154.91). In modern systems, additional costs for equipment and installation were significant—₹ 1,19,433.33 and ₹ 5,158.33 for drip, and ₹ 28,692.97 and ₹ 1,091.66 for sprinkler. Water source development was the largest cost component in all systems. The higher capital intensity of modern irrigation reflects the cost of specialized infrastructure. Although surface irrigation appears more affordable initially, the long-term benefits of efficiency and yield improvement in modern systems can offset higher entry costs.

4. Annual Operating and Maintenance Cost

Surface irrigation incurred the highest operating cost (₹ 15,250.02/ha), mainly from energy (₹ 10,466.70) and repairs (₹ 2,831.66). Drip irrigation cost ₹ 13,838.36/ha, with slightly higher energy expenses but lower labour and repair costs. (as indicated in table 4) Sprinkler irrigation had the lowest operating cost (₹ 11,139.99/ha), owing to reduced energy use. Lower recurring costs in modern systems demonstrate their long-term economic advantage. Sprinkler irrigation, in particular, combines low energy use with moderate labour needs, making it attractive for sustained profitability. While drip incurs higher pumping costs, its efficiency in water application reduces other expenses, validating its viability in resource-scarce settings.

5. Crop-wise Cost of Cultivation

It is revealed from table 5 that sprinkler irrigation reduced per hectare costs for soybean (₹47,367.93 vs ₹48,955.54 in surface), chickpea (₹ 39,456.51 vs ₹42,248.76), and sorghum (₹ 33,361.52 vs ₹ 35,305.97). Drip irrigation for sugarcane recorded higher costs (₹ 1,59,864.79) than surface (₹ 1,32,975.32). Cost reduction in field crops under sprinkler systems is attributed to efficient water delivery, reduced weed pressure, and lower labour demand. Higher sugarcane costs under drip may reflect the investment in fertigation and intensive input use for yield maximization, which can still be profitable due to substantial yield gains.

6. Crop-wise Yield under both irrigation system

Sprinkler irrigation improved yields for soybean (19.68 vs 16.48 q/ha), chickpea (11.31 vs 10.21 q/ha), and sorghum (22.6 vs

18.84 q/ha) compared to surface. Drip irrigation for sugarcane yielded 1,142.9 q/ha, surpassing 799.44 q/ha under surface. (table 6) Yield gains under modern systems reflect precise and uniform water application, which optimizes root-zone moisture and reduces stress. The exceptional sugarcane performance under drip underscores its suitability for water-intensive, high-value crops, with benefits in both productivity and resource efficiency.

7. Crop-wise Gross Income

It is seen from table 7 that sprinkler irrigation increased gross income for soybean (₹83,186 vs ₹69,647.98), chickpea (₹ 53,486.40 vs ₹48,593.04), and sorghum (₹67,495 vs ₹ 53,468). Drip irrigation in sugarcane generated ₹ 3,55,553/ha compared to ₹ 2,49,007.20 under surface. The income advantage of modern systems is directly linked to higher yields and improved quality. Drip irrigation in sugarcane demonstrates significant revenue potential, justifying its higher capital cost.

8. Crop-wise Net Returns

Net returns were higher in sprinkler irrigation for soybean (₹ 35,818.07 vs ₹ 20,692.44), chickpea (₹ 14,029.89 vs ₹6,344.28), and sorghum (₹ 34,133.48 vs ₹ 18,162.03). Drip irrigation in sugarcane yielded ₹ 1,95,688.21 compared to ₹ 1,16,031.88 under surface. (Table 8) Modern systems substantially improve profitability per hectare. The sharp rise in net returns, especially for sugarcane under drip, supports the case for targeted adoption of micro-irrigation in high-value crops. These results corroborate other studies showing 20-60% net return gains from modern irrigation.

9. Input Use Comparison

Table 9 shows that surface irrigation had the highest labour (₹ 32,518.2/ha), machine labour (₹ 36,756.8), fertilizer, seed (₹ 57,795.8), and agrochemical costs (₹8,390.42). Drip and sprinkler systems used fewer inputs, with sprinkler having notably lower seed costs (₹ 5,933.75). Input efficiency in modern systems reduces costs and environmental pressure. Lower seed and agrochemical use in sprinkler systems indicate better crop establishment and pest management efficiency, while drip minimizes labour and fertilizer needs, supporting precision farming practices.

10. Cost-Benefit Analysis

It is seen from Table 10 that the Benefit-cost ratios were higher in sprinkler irrigation for soybean (1.6 vs 1.29), chickpea (1.23 vs 1.04), and sorghum (1.84 vs 1.37). Drip irrigation in sugarcane achieved the highest ratio (2.02) compared to 1.70 under surface. These ratios confirm the superior economic efficiency of modern systems. Sprinkler irrigation offers strong returns for field crops, while drip irrigation maximizes profitability in water-intensive crops like sugarcane. Such evidence supports policy efforts to promote micro-irrigation adoption in drought-prone areas.

Table 1: Classification of sample farmers by type of irrigation system used

Sr. No.	Land holding size	Surface		Drip		Sprinkler	
		No.	Percent	No.	Per cent	No.	Per cent
1	Marginal (<1ha)	27	45.00	19	31.67	17	28.33
2	Small (1-2 ha)	24	40.00	31	51.67	33	55.00
3	Semi-medium (2-4 ha)	8	13.33	9	15.00	8	13.33
4	Medium (4-10 ha)	1	1.67	1	1.67	2	3.33
5	Large (above 10 ha)	0	0.00	0	0.00	0	0.00
	Total	60	100.00	60	100.00	60	100.00

Table 2: Average land holding and irrigated area by irrigation type

Sr. No.	Irrigation system	Land holding(ha)	Gross irrigated area (ha)	Net irrigated area(ha)
1	Surface	1.27	2.37	1.27
2	Drip	1.54	3.02	1.54
3	Sprinkler	1.44	2.32	1.44

Table 3: Initial capital investment per hectare on traditional and modern irrigation systems (₹)

Sr. No.	Components	Surface	Drip	Sprinkler
1	**Water source**			
	i) Bore well	45763.33	61966.34	55801.1
	ii) Open well	172204.98	168684.10	193710.51
2	Pump set and motor	13721.67	17963.33	17365.3
3	Distribution network	21464.93	20133.33	18133.39
4	Drip/sprinkler system cost	-	119433.33	28692.97
5	Installation and setup	-	5158.33	1091.66
	Total investment	253154.91	393338.76	314794.93

Table 4: Annual operating and maintenance cost of traditional and modern irrigation systems

Sr. No.	Particulars	Surface	Drip	Sprinkler
1	Electricity/diesel cost	10466.7	11066.7	8133.33
2	Labour charges	1128.33	1033.33	1308.33
3	Repairs and maintenance	2831.66	1738.33	1698.33
4	Other miscellaneous cost	823.33	-	-
	Total operating and maintenance cost	15250.02	13838.36	11139.99

Table 5: Crop wise cost of cultivation under each irrigation system (₹/ha)

Sr. No.	Crop	Surface	Drip	Sprinkler
1	Soybean	48955.54	-	47367.93
2	Chickpea	42248.76	-	39456.51
3	Sorghum	35305.97	-	33361.52
4	Sugarcane	132975.32	159864.79	-

Table 6: Crop wise yield (qt/ha) under each irrigation system

Sr. No.	Crop	Surface	Drip	Sprinkler
1	Soybean	16.48	-	19.68
2	Chickpea	10.21	-	11.31
3	Sorghum	18.84	-	22.6
4	Sugarcane	799.44	1142.9	-

Table 7: Crop wise gross income under each irrigation system (₹/ha)

Sr. No.	Crop	Surface	Drip	Sprinkler
1	Soybean	69647.98	-	83186.00
2	Chickpea	48593.04	-	53486.40
3	Sorghum	53468.00	-	67495.00
4	Sugarcane	249007.20	355553.00	-

Table 8: Crop wise net returns per hectare (₹)

Sr. No.	Crop	Surface	Drip	Sprinkler
1	Soybean	20692.44	-	35818.07
2	Chickpea	6344.28	-	14029.89
3	Sorghum	18162.03	-	34133.48
4	Sugarcane	116031.88	195688.21	-

Table 9: Comparison of input costs under different irrigation systems (₹/ha)

Sr. No.	Input	Unit	Surface	Drip	Sprinkler
1	Labour (Male + Female)	Man/day	32518.2	14663	18492.5
2	Machine labour	Hrs	36756.8	8426	23340
3	Fertilizer				
	a) Urea	Kg	1770.98	1274.86	896.1
	b) SSP	Kg	2599.74	1397.57	1922.34
	c) MOP	Kg	7530.52	3995.2	4336.96
4	Seed	Kg	57795.8	52213.26	5933.75
5	Agrochemicals	ml/gm	8390.42	1393.51	2210.32

Table 10: Comparative cost-benefit analysis by irrigation system and crop

Sr. No.	Crop	Surface	Drip	Sprinkler
1	Soybean	1.29	-	1.6
2	Chickpea	1.04	-	1.23
3	Sorghum	1.37	-	1.84
4	Sugarcane	1.70	2.02	-

Conclusion

The comparative analysis of traditional (surface) and modern (drip and sprinkler) irrigation systems in the Latur district revealed marked differences in economic performance, resource efficiency, and profitability. Modern irrigation users generally possessed slightly larger landholdings and achieved greater gross irrigated areas, indicating superior water-use efficiency. While initial capital investment per hectare was highest for drip irrigation (₹ 3.93 lakh), followed by sprinkler (₹ 3.15 lakh) and surface (₹ 2.53 lakh), annual operating and maintenance costs were lowest in sprinkler systems (₹ 11,140/ha), reflecting long-term cost advantages. Crop-wise results showed that modern systems consistently reduced input costs, enhanced yields, and improved gross and net returns, with sugarcane under drip irrigation generating the highest net returns (₹ 1.96 lakh/ha) and benefit-cost ratio (2.02). Field crops like soybean, chickpea, and sorghum performed better under sprinkler irrigation, achieving higher yields, incomes, and benefit-cost ratios compared to surface methods. Input use analysis confirmed that modern systems substantially reduced labour, machinery, fertilizer, and agrochemical costs, improving production efficiency. Overall, the findings underscore that despite higher initial investments, modern irrigation technologies offer significant long-term economic gains, water savings, and sustainability benefits, making them a viable strategy for enhancing agricultural productivity and farmer incomes in semi-arid regions.

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