American Journal of Agriculture and Forestry
2025, Vol. 13, No. 4, pp. 178-187
https://doi.org/10.11648/j.ajaf.20251304.12

Research Article

Profitability of Market Garden Production in South Benin: Financial Index of Irrigation Systems on Farmers' Income

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Abstract

This study looks into the profitability of irrigation systems for market gardeners in South Benin. The coexistence of multiple irrigation systems in market gardening without a clear understanding of their economic effects, combined with the contextual variability of previous studies and the evolving costs of equipment acquisition and operation, justifies the need for an updated analysis of financial profitability in South Benin. This area has good weather for farming, but gardeners are facing changing rainfall due to climate change. The objective of this study is to assess and compare the financial profitability of the main irrigation systems in order to provide evidence-based guidance for producers and policymakers seeking sustainable and cost-effective water management solutions. Total of 729 market gardeners were surveyed chosen with randomization and data about their background in farming, watering practices, and money matters was collected. This data was analyzed using statistical methods under Stata version 15, such as descriptive statistics, frequency distributions, and inferential statistics like t-tests of student, Chi 2 of pearson and analysis of variance (ANOVA) test. The study focused on socioeconomics characteristics description, financial rentability indicators calculation and comparison by irrigation systems. The results show that vegetable growers are profitable no matter the irrigation system used including perforated pipe irrigation, center pivot irrigation, drip irrigation, manual watering other methods than the above, or no method at all. Market gardeners average approximately 374,232 XOF in turnover, 260,548 XOF in value added, 162,626 XOF in gross income, and 159,352 XOF in net income, regardless of irrigation methods. However, their net income varies a lot. The manual watering type turned out to be the most profitable, with drip irrigation coming in second. The study also found that other variables like crop choice, training, and market access also influence the market gardeners' profit. While this study focuses on short-term profit, more research needs to be done to understand how different watering methods affect long-term profit, water use, and environment.

Keywords

South Benin, Market Gardening, Watering Methods, Money-Making Small Farmers

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Received: 26 June 2025; **Accepted:** 9 July 2025; **Published:** 30 July 2025

1. Introduction

South Benin agriculture, a land etched and resilience presents an enigmatic puzzle [20]. The area is characterized by a precarious ecosystem that combines favorable climate with fragile topography hence; it is farming market gardening season [1]. In This area, agriculture involves smallholder farmers whose engagement ensures food security as well as promoting local economic dynamism [6]. But there is an ongoing battle against the elements behind this wealth of productivity. It is argued that rainfall variability, persistently poor soil fertility, and scarce access to irrigation water are constant constraints on market gardening and compromising this field [2]. This scenario makes irrigation appear like a hope provider, solution to deep-seated bottlenecks, and an avenue through which profitability among South Benin's market gardeners could be achieved [2]. Thus, irrigation can transform lives by ensuring that farmers can manage their own water supply. It helps farmers make decisions regarding when and where they should irrigate for maximum production while also avoiding losses due to over-irrigation or under-irrigation. Market gardeners in south Benin utilize various irrigation systems, each with its own unique topography. When selecting a system to employ, there are several factors that must be considered. These include farm size, access to capital, water availability and the type of crop being grown. Knowing this diversity is important as it represents the complex environment within which market gardeners operate.

The impact of irrigation on food productivity and consequently farmers' revenue has been extensively documented. This claim is confirmed by numerous studies conducted worldwide. For example, an examination of Kenya showed that switching to irrigated agriculture greatly improved farming practices and resulted into increased yields and more income [14]. Similarly, another study on tomato production demonstrated how cost-effective irrigation systems can be indicating economic viability of this technology [13]. But this must be recognized that irrigation cannot be done in the same way for all circumstances. The importance of irrigation in mitigating climate change challenges and ensuring food security is not disputable, but suitable designs depend on the context [8]. This recognition has given rise to an intense scientific discourse on creation and employment of new precision irrigation techniques [3]. These latest systems collect real-time information about crop health and field conditions to ensure efficient use of water. Entire world has witnessed examples of success stories through adoption of progressive irrigation technology. Research shows that Subsurface Drip Irrigation (SDI) can significantly increase yields of vegetables, fruits, and other crops if site-specific considerations are mad [25]. Such approach ensures efficient utilization of water resources minimizing waste as well as enhancing environmental friendliness. The article is to communicate about the improvement of small subsistence farmers' livelihood by being a central cause of productivity and thereby maximizing their outputs. These success stories are evidence for how much transformative impact new irrigation technology can have in regions like South Benin where resources are rather limited.

This study builds on the promising strides made towards efficient irrigation technology, focusing on the particular regional context of South Benin. This study aims to show the profitability of vegetable famers. The objective is to be to unravel how different irrigations methods applied by market gardeners determine whether or not they are viable economically. The hope is that through understanding what financially water costs mean in different types of irrigation systems, we can help others who are focused on agricultural development in Southern Benin - where it is happening today.

2. Methodology

2.1. Study Area

The study was conducted in southern Benin. Benin is a country in West Africa, surrounded by Togo to the west, Nigeria to the east, Niger to the northeast, Burkina Faso to the northwest, and the Atlantic Ocean to the south. South Benin is mainly located along the Atlantic coast, bordered by the Atlantic Ocean to the south. The choice of the study area is justified by the high market garden production in southern Benin [5]. Soils in southern Benin are generally nutrient-rich, especially in alluvial areas and near rivers, which is beneficial for market gardening [12].

2.2. Sampling Method

The study employed a stratified random sampling technique to select a representative sample of 729 market gardeners out of 1600 from six departments in South Benin. This approach ensured that the sample reflected the diversity of market gardeners in terms of irrigation practices, and crop types. To further refine the sample, additional criteria were applied such as support advised by projects/programs in the area, as well as their proximity to major consumption centers. The total sample of 729 markets gardeners was distributed across the three departments in proportion to their respective populations of market gardeners.

Table 1. *Sampling table.*

Department	Total Population Survey	Sample Size
Atlantique	272	90
Couffo	73	38
Littoral	131	53
Mono	166	99

Department	Total Population Survey	Sample Size
Ou én é	607	312
Zou	308	137
Total	1600	729

2.3. Data Collection

Data collection involved a structured household survey: A comprehensive questionnaire was designed via Kobo collect to gather detailed information from each market gardener. Data collection was carried out by trained enumerators who were fluent in the local languages and familiar with agricultural practices in the region. To ensure data quality, a rigorous data validation process was implemented, including cross-checking responses and verifying data against official records. The data collected can be categorized into quantitative and qualitative. Quantitative variables involved farm size, yields, production costs, income, and expenditure and qualitative variables included the type of irrigation system used and other socioeconomic or demographics information of market gardeners.

2.4. Data Analysis

The data was analyzed using statistical methods such as descriptive statistics, frequency distributions, and inferential statistics (t-tests, Chi 2, ANOVA). These methods were used to describe socioeconomics characteristics of the sample studied, evaluate and compare the financial rentability of irrigation system used. To assess the financial profitability of vegetable production under different irrigation systems, a detailed financial analysis was conducted. This involved calculating the following key financial indicators:

1) Gross Product Value (GPV)

From the study of [23] the given formula

$$GPV = GP*Pu \quad (1)$$

Where GPV is the Gross Product Value, GP is the quantity produced and Pu the selling price unit of the product, here in XOF per unit.

2) Value Added (VA)

This indicator represents the wealth generated by the production process, reflecting the difference between the total revenue from sales and the cost of inputs that disappears with production [15].

$$VA = GPV - IC \quad (2)$$

Where GPV is the Gross Product Value and IC is the Intermediate Consumption. IC refers to the value of goods and services consumed as inputs in the production process, excluding fixed assets. In agriculture, this includes costs like seeds, fertilizers, and wages for seasonal labor [15].

3) Gross Operating Income (GOI)

This formula is taken from the study of [15]

$$GOI = VA - (LC + Financial\ expenses + Taxes) \quad (3)$$

Where GOI is the Value Added, and LC the Labor Costs in XOF/hour. This indicator represents the profit earned from agricultural operations, taking into account the value added by production and the expenses associated with hired labor, other expenses and taxes [15]

4) Net Operating Income (NOI)

$$NOI = GOI - D \quad (4)$$

Where GOI is the Gross Operating Income, and D the depreciation.

This indicator represents the economic gain or loss of the agent. If positive, it indicates that the activity is profitable, if negative, it means there is loss [15].

3. Results

3.1. Qualitative Socioeconomics Characteristics of Market Gardeners

3.1.1. Living Area of Market Gardeners

The table 2 presents the socio-economic and demographic characteristics of the respondents.

Table 2. *Living area of market gardeners.*

Variables		Man		Woman		Set		Chi2 (p)
		Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
Living area	Urban area	32.89%	67.11%	35.21%	64.79%	33.64%	66.36%	0.11 (0.73)
	Rural area	21.33%	78.67%	37.80%	62.20%	28.09%	71.91%	16.53 (0.00)

Source: Survey data, 2023

Young people represent 33.64% compared to 66.36% of adults in urban areas. However, there is a significant difference between sex and age category. Thus, there are fewer young men (21.33%) compared to adult men (78.67%) and fewer young women (37.80%) compared to adult women (62.20%).

3.1.2. Intellectual and Marital Status of Market Gardeners

The table 3 shows the intellectual and marital status of the respondents with education level, literacy level and marital status.

Table 3. *Intellectual and marital status of market gardeners.*

Variables		Man		Woman		Set		Chi2 (p)
		Young	*Adult*	Young	Adult	Young	Adult	
Professional training		8.25%	91.75%	9.43%	90.57%	8.67%	91.33%	0.06 (0.80)
Education level	None	14.41%	85.59%	29.44%	70.56%	21.03%	78.97%	13.71 (0.00)
	Primary	27.43%	72.57%	54.55%	45.45%	36.31%	63.69%	11.75 (0.00)
	Secondary 1st Cycle	13.04%	86.96%	50.00%	50.00%	27.63%	72.37%	12.40 (0.00)
	Upper Secondary 2nd cycle	76.47%	23.53%	25.00%	75.00%	63.04%	36.96%	10.08 (0.00)
	University level	62.96%	37.04%	100.00%	0.00%	66.67%	33.33%	1.66 (0.19)
Marital status	Married	19.08%	80.92%	36.59%	63.41%	26.09%	73.91%	26.33 (0.00)
	Single / Divorced	97.14%	2.86%	100.00%	0.00%	97.37%	2.63%	0.08 (0.76)
Literacy level	None	24.80%	75.20%	37.30%	62.70	29.82%	70.18%	11.25 (0.00)
	Advanced	50.00%	50.00%	0.00%	0.00%	50.00%	50.00%	1.70 (0.19)
	Elementary	22.58%	77.42%	35.71%	64.29%	26.67	73.33%	

Source: Survey data, 2023

Regarding training, a minority of young people (28.09%) among the respondents have received vocational training while the majority of adults (91.33%) have benefited from such training. The results in relation to the level of education show a significant difference between age category and gender at levels below university. While university level is strongly represented by young people (66.67%) for both men and women, the lower levels (no level, primary, secondary 1st cycle, upper secondary cycle) are represented by adults, both men and women. This result is confirmed for the literacy level of the respondents, where the level none is dominated by adults (70.18%) as well as the elementary level (73.33%). The majority of adult men surveyed are married (80.92%) as are adult women (63.41%). The category of divorced or single is highly represented by young people (97.37%), both men and women.

3.1.3. Ways of Acquisition of the Site

The table 4 introduce the different method respondents acquire their site for their activities.

Table 4. *Mode of acquisition of site.*

Variables		Man		Woman		Set		Chi (p)
		Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
Method of acquiring the	Purchase	53.85%	46.15%	30.00%	70.00%	47.22%	52.78%	1.64 (0.19)
	Inheritance	17.41%	82.59%	34.02%	65.98%	22.82%	77.18%	10.24 (0.00)

Variables		Man		Woman		Set		Chi (p)
		Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
site	Donation	40.00%	60.00%	42.86%	57.14%	41.38%	58.62%	0.02 (0.87)
	Rental	34.94%	65.06%	54.24%	45.76%	42.96%	57.04%	5.24 (0.02)
	Loan	22.22%	77.78%	15.79%	84.21%	19.57%	80.43%	0.29 (0.58)
	Pledge	62.50%	37.50%	0.00%	100.00%	45.45%	54.55%	3.43 (0.06)
	Making available	20.69%	79.31%	34.62%	65.38%	27.27%	72.73%	4.02 (0.04)

Source: (Data survey, 2023)

As for the method of acquisition of the site, adults are mostly represented, whether by purchase (52.78%), inheritance (77.18%), donation (58.62%), rental (57.04%), loan (80.43%), pledge, making available, however there is a significant difference between the age category and the sex of the respondents for the acquisition by inheritance. Adult males (82.59%) and adult females (65.98%) are much more likely to acquire the site through inheritance compared to young males (17.41%) or young females (34.02%).

3.1.4. Different Crops Produced by the Market Gardeners

The main crops produced at the sites include amaranth, carrots, cabbage, coret, basil, nightshade, chilli, tomato, onion and okra.

Table 5. *Vegetables/ Crops.*

Variables	Man		Woman		Set		Chi2 (p)
	Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
Amaranth	13.64	86.36	50.00	50.00	36.21	63.79	7.81 (0.00)
Carrots	32.73	67.27	39.29	60.71	34.94	65.06	0.35 (0.55)
Cabbage	40.00	60.00	92.31	7.69	64.29	35.71	8.29 (0.00)
Coret	33.33	66.67	0.00	100.00	22.45	77.55	6.87 (0.00)
Basil	76.92	23.08	0.00	100.00	62.50	37.50	6.15 (0.01)
Nightshade	32.65	67.35	26.92	73.08	29.70	70.30	0.39 (0.52)
Chilli	22.49	77.51	47.62	52.38	29.31	70.69	13.99 (0.00)
Tomato	50.00	50.00	100.00	0.00	71.43	28.57	6.30 (0.01)
Onion	0.00	100.00	21.05	78.95	12.50	87.50	3.12 (0.07)
Okra	7.35	92.65	14.63	85.37	10.09	89.91	1.49 (0.22)

Source: Survey data, 2023

The chi-square test shows a big difference between men, women, and age groups in the crops they grow. This gap exists for almost all crops and points out that adults grow most crops. But young people grow a lot of certain crops. For instance, young men grow a lot of basil (76.92%). Young women grow all the tomatoes (100%) and most of the cabbage (92.31%).

3.1.5. Irrigation System

The respondents use different ways to water their crops. They use perforated pipe irrigation, center pivot irrigation, drip systems, and manual watering.

Table 6. Type of irrigation system used.

Variables	Man		Woman		Set		Chi2 (p)
	Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
Perforated pipe irrigation	32.11%	67.89%	40.00%	60.00%	35.20%	64.80%	1.16 (0.28)
Center pivot irrigation	25.00%	75.00%	0.00%	0.00%	25.00%	75.00%	-------
Drip irrigation	0.00%	100.0%	0.00%	0.00%	0.00%	100.0%	-------
Manual Watering	24.10%	75.90%	37.24%	62.76%	29.54%	70.46%	9.54 (0.00)
Other	57.14%	42.86%	27.27%	72.73%	38.89%	61.11%	1.60 (0.20)
None	10.00%	90.00%	0.00%	100.0%	9.30%	90.70%	0.33 (0.56)

Source: (Data survey, 2023)

The survey shows that adults, both men and women make up the biggest group of producers, no matter what irrigation method they use. But the Chi 2 statistical test reveals a big difference between sex and age groups when it comes to using manual watering for irrigation. In fact, more adult men (75.90%) and adult women (62.76%) choose this system compared to young men (24.10%) or young women (37.24%).

3.2. Quantitative Socio-economic Characteristics of Market Gardeners

Descriptive statistics for quantitative variables are summarized in Table 7.

Table 7. Statistics of quantitative variables.

Variables	Man		Woman		Set		t(p)
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev	
Age	43.81	14.24	38.87	10.47	41.91	13.14	5.01 (0.00)
Experience in market gardening	13.54	8.92	9.39	6.41	11.95	8.29	6.76 (0.00)
Household size	6.88	3.74	6.35	1.97	6.68	3.19	2.21 (0.01)
Site area	6.34	7.55	6.18	10.80	6.28	8.93	0.23 (0.40)
Developed Area	8.363	66.57	2.98	3.98	6.29	52.34	1.34 (0.08)
Planted Area	0.34	0.64	0.29	0.30	0.32	0.53	1.15 (0.12)

Source: Survey data, 2023

The study participants are men and women with an average age of 41.91 years (±13.14) and about 12 years of market gardening experience. A Student's t-test shows that women are younger averaging 38 years old with 9 years of experience. Men are older averaging 43 years old with more experience around 14 years. However, the average household size is at least 6 people regardless of gender. Agricultural land is becoming scarce in the study area. On average, the surveyed market gardeners have access to 6.8 (±8.93) hectares of agricultural land. The typical space used for growing market garden crops covers 6.29 (±52.34) hectares in total, with men using more land at 8.36 (±66.57) hectares. This difference has significance at the 10% level. The same pattern shows up in planted areas, which average 0.32 ha (±0.53). When looking at the numbers, there is no big difference between the average areas that men and women cultivate.

3.3. Comparative Assessment of the Financial Profitability of Irrigation Systems

3.3.1. Financial Profitability Indicators

To determine the type of irrigation system that is more financially profitable, financial profitability indicators were calculated.

The results are recorded in the table below. These results show that, on average, market gardeners have a turnover of approximately 374,232 XOF, a Value Added of approximately 260,548 XOF, a Gross Operating Income of 162,626 XOF, and a Net Operating Income of 159,352 XOF, regardless of the type of irrigation used. Since the Net Income is positive, the market gardener manages to be profitable regardless of the type of irrigation used.

Table 8. *Financial profitability.*

Variables	Mean	Std. Dev.	Min	Max
Gross Product Value	374232.2	295101.2	58750	1579500
Value Added	260548.8	258605	-346784	1509000
Gross Operating Income	97922.35	93646.94	0	445000
Net Operating Income	162626.4	210017.3	-430786	1304000

Source: Survey data, 2023

3.3.2. Difference in Income According to Irrigation Methods

To compare the average net operating income based on the types of irrigation used by the surveyed market gardeners, an ANOVA test was used.

Table 9. *ANOVA to assess difference in income according to irrigation methods.*

Type of irrigation system	Mean	Std. Dev.	Anova
Perforated pipe irrigation	89497.353	160783.99	
Center pivot irrigation	135643.75	75874.554	
Drip	157475	0	F= 6.07
Manual Watering	188555.47	225317.23	p= 0.00
Other	133412.61	55010.588	
None	145841	236553.15	

Source: Survey data, 2023

The economic analysis shows distinct profitability among irrigation systems in southern Benin market gardening, with manual watering having the best financial returns of 188,555 XOF. It may be attribute to its low capital requirements and minimal operational costs in labor abundant smallholder settings. With 157,475 XOF, drip irrigation ranks second reflecting its efficiency but in water use by higher initial infrastructure investments. Center pivot system generates 135,643 XOF and unspecified alternative systems 133,412 XOF exhibit suboptimal performance, likely constrained by energy costs and technical maintenance demands unsuitable for resource-limited farmers. The profitability of perforated tape systems took the last rank with 89,497 XOF, show severely limited viability, potentially due to frequent clogging and high replacement costs in fine textured soils in certain areas. These findings emphasize that profitability is contingent on contextual factors including labor dynamics, input accessibility, and environmental conditions rather than technological sophistication alone.

4. Discussion

The results showed that gender, age, education, and land

ownership, influence the market gardeners' choice of irrigation systems. The prevalence of adults in rural areas is similar with the research of [24] who find that technology adaptation and economic opportunities often push young people towards urban areas. However, this trend may have negative implications for agricultural development, as adults may have limited access to innovative farming practices and technologies. Also, findings on the higher levels of education among youth align with those of [17]. They suggested that young generations may have greater access to educational opportunities. Thus, young market gardeners are more picking modern irrigation systems because they know more about new technologies. However, this disparity could hinder the adoption of innovative farming practices among older generations. The prevalence of heritage as a land acquisition method aligns with the land reform policies implemented in Benin [16]. These policies may not be sufficient to address the challenges faced by young people, who often lack access to inherited land. Our analysis of crop production patterns suggests that farmers are adapting to changing market demands. However, limited access to information and resources may hinder their ability to diversify their production and explore new market opportunities [19]. The prevalence of traditional irrigation methods among adults may be attributed to their limited exposure to modern technologies. Promoting the adoption of more efficient irrigation practices could enhance agricultural productivity and resilience. Moreover, the research showed that market gardeners in South Benin made money no matter which irrigation system they used proving that all systems were sound. Also, earlier studies from the same author, in Malanville Benin, have shown that manual watering cut down on food shortages for farmers [20]. This fits with what we found hinting that irrigation is a useful way to boost both profitability and food security in the area. Still, some systems brought in more cash than others. Manual watering topped the list for profits, drip irrigation coming in second. Other methods like perforated pipe irrigation and center pivot irrigation didn't make as much money, but they still paid off in the end. However, let us notice that some studies assume that Motor pump is the most irrigation system used together with rainwater and flood water system [16]. Factors other than the irrigation system type probably had an impact on profitability, including the type of crop selected, market access, or management practices, and training [22]. The recent authors analyze the advantages and limitations of watering systems in this case manual and drip irrigation systems on small-scale farms. According to [7, 10], manual watering is valued for its low initial cost and ease of access for poor farmers, although it is very labor-intensive and unsuitable for large areas [18]. Despite these limitations, it can improve yields and incomes compared with rain-fed agriculture [9]. On the other hand, drip irrigation, while requiring a high initial investment [7, 26], offers high water-use efficiency, reduces labor requirements and significantly improves crop yields [4, 18]. However, its adoption remains hampered by obstacles such as costs, lack of technical knowledge and limited access to markets [11, 26], highlighting the need for targeted support policies to encourage its dissemination among smallholders. Furthermore, an emphasis should be put in the different elements that shaped the choice of irrigation system, like how easy it was to get water, what people knew about the tech, and how much money they had. For instance, education, access to credit, extension services, soil quality, ownership of mobile phone and the amount of herbicide or fertilizer applied [21]. Some market gardeners might have liked old ways like watering system because they knew how to use them or they didn't cost much to start. Others might have picked newer systems like drip irrigation to save water and cut down on their work. What this study found matters to policy makers and development groups in South Benin. Pushing for better irrigation systems, like drip irrigation, can help use water more cut down on production costs, and make market gardening more profitable. Specific actions like training, credit access, and tech help can boost market gardeners' ability to use new tools and better their lives. Also, rules that make it easier to get and keep land can create better conditions for farming growth. However, these policies may not be sufficient to address the challenges faced by young people, who often lack access to inherited land.

5. Conclusion

This study investigates the profitability of different watering systems in South Benin and the drivers of market gardeners' choice of them. While all systems are profitable, manual watering is more than others. The socioeconomic characteristic of market gardeners and their access to certain resources impact financial profitability indicators. To help market gardeners use better watering systems and improve their incomes, policymakers and stakeholders can focus on this study findings. Even though this study highlighted the decision factors to improve the water management and the profitability on market gardening, more studies are necessary to look at how different watering systems affect market garden profits over time, including environmental and social impact. The research on what makes farmers choose certain watering systems can give useful info to help target support.

Abbreviations

XOF	West African CFA Franc
Std	Standard Deviation
Anova	Analysis of Variance

Author Contributions

Olouhitin Mouléro Franck Ronald Adjobo: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing

Laurencia Olushola Odjo: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing –

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Josué Yisségnon Gouwakinnou: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Supervision, Validation

Amos N'dah: Methodology, Visualization, Writing – review & editing

Alain Constant Lodehou: Methodology, Visualization, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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