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GROSS MARGIN ANALYSIS OF CHILI PEPPER AND OKRA CULTIVATED UNDER RAINFED AND SUPPLEMENTARY IRRIGATION IN THE NORTHERN REGION OF GHANA

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ABSTRACT

Aim of the study

Although supplementary irrigation (SI) systems have emerged as a potential solution to mitigate the impact of drought spell in crop production, there is a lack of comprehensive research that specifically analyze the gross margin associated with the use of supplementary irrigation systems for okra and chili pepper production. The aim of this study was to evaluate the efficiency and to conduct cost-benefit analysis of SI systems in the production of the studied crops in northern Ghana.

Materials and methods

The study was a 4 × 2 × 2 factorial design with three replications, using the Randomized Complete Block Design (RCBD). The research treatments were: 4 levels of NPK fertilizer, rainfed and supplementary irrigation (SI) with spray tubes irrigation system. NPK was applied at a rate of 0 $kg \cdot ha^{-1}$ (control), 150, 200, 250 $kg \cdot ha^{-1}$, and 0 $kg \cdot ha^{-1}$ (control), 100, 150 and 200 $kg \cdot ha^{-1}$ for okra and chili pepper respectively.

Results and conclusion

The results revealed that chili pepper produced a marketable yield of 2067.41 $kg \cdot ha^{-1}$ in SI and 1441.60 $kg \cdot ha^{-1}$ in rain-fed cultivation. Regarding okra cultivation, SI gave a marketable yield of 1415.70 $kg \cdot ha^{-1}$ whereas 1135.10 $kg \cdot ha^{-1}$ was obtained from rainfed plots. For chilli pepper, at an average cost of USD 1324.80/ha and USD 1146.70/ha, a gross margin (GM) of USD 516.40/ha and USD 137.00 was attained for SI and rainfed cultivation, respectively, representing a statistically significant difference at 5% ($p < 0.006$). In the case of okra, a cost of USD 1540.20/ha and USD 1362.20 was invested in SI and rain-fed cultivation system respectively, and a gross margin (GM) of USD 254.00/ha and USD 76.20/ha was attained. The GM per USD spent on chili pepper was USD 0.39 for SI and USD 0.12 for rain-fed system, whereas the GM per USD spent on okra was USD 0.16 and USD 0.06 in the respective systems of cultivation. The cost-benefit ratio (BCR) for okra was estimated at 1.16 for SI, and at 1.06 for rainfed cultivation, whereas for chilli pepper, the respective BCR values were 1.39 for SI and 1.12 for rainfed system. In conclusion, SI provided higher revenues, resulting in a gross margin capable of covering production costs and leaving a significant profit margin compared to the rain-fed system. Therefore, farmers in regions experiencing drought periods are advised to use SI along with appropriate management practices to increase crop productivity.

Keywords: supplementary irrigation (SI), rainfed, gross margin, yield, cultivation of chili pepper and okra

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INTRODUCTION

Previous studies have shown that about 85% of the rural poor in Sub-Saharan Africa are dependent on agricultural production, making crops the mainstay of local populations' livelihood (Nnadi et al., 2021; Kyei-Baffour, 2023). On the other hand, agriculture has been found to consume over 70% of the world's water supply, and in drought-stricken developing countries agricultural water use can even reach up to 90% of all resources (Russo et al., 2014). Similarly, permanent irrigation uses around 70% fresh water (Abigail, 2019). Thus, to ensure food security, research should be conducted in developing countries to increase the potential of supplementary irrigation (SI) systems for agriculture (Katic et al., 2013).

The impact of climate variability, such as erratic rainfall patterns, negatively affects crop productivity, resulting in low volume and poor quality yields (Unami et al., 2015). Therefore, it is important to cope with the significant negative impact of "erratic rainfall and high evaporation" on crop productivity, and small-scale farmers should adopt periodic supplementary irrigation. It is essential even for highly profitable crops to complement unpredictable rainfed agriculture.

In Ghana, most vegetable farmers typically grow pepper and okra under rainfed conditions, despite cultivating crops with theoretically high economic value and high yield potential. Both crops require sufficient water and moist soil throughout the growing season for optimal output. However, water shortages, which are so prevalent in northern Ghana due to erratic rainfall, coupled with increasing competition from population growth, have significantly hindered crop production in recent years (Konyeha and Alatise, 2013). The productivity of chili pepper and okra is highly impacted by water availability. Previous studies by Akangaamkum (2023) revealed that supplementary irrigation (SI) systems offer a potential solution to water scarcity in rain-fed agriculture, but there is limited research on the economic benefits and gross margin analysis of using SI in the cultivation of these crops.

This study aims to fill the gap by providing key literature relevant to the gross margin analysis of SI systems in chili pepper and okra production, for the benefit of farmers, policymakers, and stakeholders involved in agricultural development. This paper will compare a cost-benefit analysis of growing such plants using two distinct water management techniques–rainfed and supplementary irrigation system–in order to determine which approach provides farmers with maximum productivity and profitability. The article will further contribute to the literature on how these two systems could help farmers in the area. Additionally, it will also provide policy recommendations on the economic feasibility of rainfed and supplementary irrigation production in Northern Ghana. Researchers, scholars, and development partners looking for ways to improve agricultural productivity in Ghana may also find this study useful.

MATERIAL AND METHODS

Study area

The study was carried out at the West African Centre for Water, Irrigation and Sustainable Agriculture (WACWISA) located within the University for Development Studies, Nyankpala campus in the Guinea Savannah Agro-Ecological Zone. It lies 16 km (10 miles) from Tamale, the regional capital of the northern region of Ghana, at 167 m above sea level. The region is located between 9°24'N latitude and 0°59'W longitude. Its average annual temperature is 28.5°C, with the lowest temperature being 15°C and the highest temperature being 42°C (Fig. 1). The soil in the study area is brown, with an admixture of gravel and a moderately drained sandy loam texture. Common crops grown here include pepper, okra, eggplant, tomatoes, maize, groundnut, cowpea, and soybeans, among others. The area was chosen due to its characteristic erratic and variable rainfall distribution, which frequently causes moisture stress at critical stages of crop growth, making it an ideal location to evaluate the performance of supplementary irrigation in improving crop yields.

Treatment, experimental design and land preparation

The study was a 4 × 2 × 2 factorial experiment. It was replicated three (3) times, and the field layout was developed using the Randomized Complete Block Design (RCBD). The treatments were: four levels of

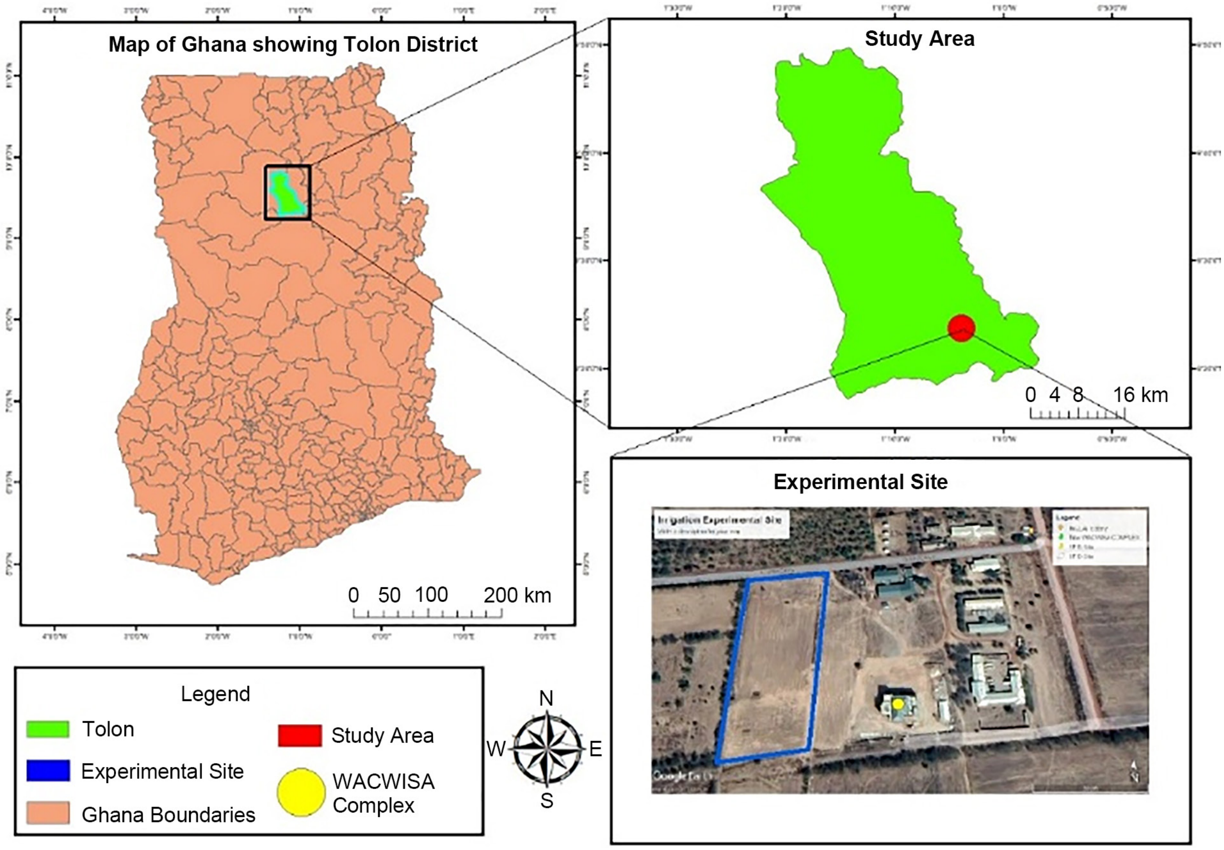

Fig. 1. Map of the study area (Source: authors' own elaboration)

NPK fertilizer, with rainfed and supplementary irrigation (SI) system, for chili pepper and okra. The supplementary irrigation was delivered using the spray tubes irrigation system. The supplementary irrigation and rainfed fields were differentiated to avoid any interference between supplemental irrigated plots and non-supplemental irrigated (rainfed) plots. The levels of NPK that was applied to okra were: 0 kg · ha^{-1} (control), 150 kg · ha^{-1}, 200 kg · ha^{-1} and 250 kg · ha^{-1} whereas the levels of NPK applied to chili pepper were: 0 kg · ha^{-1} (control), 100 kg · ha^{-1}, 150 kg · ha^{-1} and 200 kg · ha^{-1}. The variation in fertilizer levels was due to okra's higher nutrient requirements compared to chili pepper. The experiment included one local variety of chili pepper (Shamsi 1) and one local variety of okra (Essoumtem). These varieties were chosen based on their availability and compatibility with the weather conditions in the research area. The chili pepper seeds were nursed on a nursery bed size of 2 m × 2 m for a period of four (4) weeks whereas the okra was planted directly on the experimental plots. Both rainfed and supplementary irrigation beds were initially irrigated to a saturation that would enable seedlings to recover from the transplanting shock. Okra and chili pepper were planted on identical size plots (10.6 m × 8.4 m each), within a planting area of 5 m × 2.2 m per plot. Under each crop, 12 beds each were demarcated for SI and rainfed treatments.

Estimation of gross margin (GM)

GM analysis was conducted by assessing production costs and revenues. Production inputs, including seeds, fertilizers, crop protection chemicals (insecticides, fungicides etc.), water costs, irrigation system expenses, and labor were considered for both chili pepper and okra. The cost of water for SI was calculated as irrigation system charges, with parameters like water cost and equipment factored into the SI estimation. GM was determined using equations 1 – 6 below.

$$GM = TR - TVC \quad (1)$$

where:
- GM – gross margin,
- TR – total revenue and TVC = total variable cost.

TR and TVC are indicated as:

$$TR = \text{Quantity of output } (Q_i) \times \text{Unit price } (P_i) \text{ (USD 0.89)} \quad (2)$$

This explains the total revenue generated by selling the produce, where Q_i is the quantity of produced crop and P_i is the price per unit.

$$\text{TVC} = \text{Quantity of inputs } (X_i) \times \text{Price } (P_i) \quad (3)$$

The formula Quantity of inputs (X_i) × Price (P_j) calculates the overall cost of a specific input, with X_i representing the quantity used and P_j representing the price per unit. This aids in determining total production costs.

$$GM = \sum_{i=1}^{n} P_i\, Q_i - \sum_{j=1}^{n} P_j\, X_j \quad (4)$$

where:
- P_i – output price average i,
- Q_i – output quantity average i,
- P_j – average price of input j (USD per kg),
- X_j – average quantity of input j (kg per ha).

P_i is the average selling price of output i, and Q_i is the average quantity of output i produced. P_j refers to the average cost of input j (in USD per kg), while X_j is the average amount of input j used per hectare. The study used equation 5 and 6 to estimate the GM for the test crops.

$$GM_p = \sum_{i=1}^{n} P_{pi}\, Q_{pi} - \sum_{j=1}^{n} P_{pj}\, X_{pj} \quad (5)$$

$$GM_o = \sum_{i=1}^{n} P_{oi}\, Q_{oi} - \sum_{j=1}^{n} P_{oj}\, X_{oj} \quad (6)$$

where: GM_p and GM_o are GM for Chili pepper and okra, P_{pi} and Q_{pi} are the average price and average quantity of Chili pepper, P_{pj} and X_{pj} are the average cost of pepper production, P_{oi} and Q_{oi} are the average price and average quantity of okra, P_{oj} and X_{oj} are the average cost of okra production.

GM_p and GM_o represent the gross margins for chili pepper and okra, respectively.

P_{pi} and Q_{pi} are the average price and quantity of chili pepper, while P_{pj} and X_{pj} are the average cost and quantity of inputs used in chili pepper production; similarly, P_{oi} and Q_{oi} are the average price and quantity of okra, and P_{oj} and X_{oj} are the average cost and quantity of inputs used in okra production.

Estimation of okra and chili pepper productivity

Productivity is defined in this study as the output (chili pepper and okra yield produced) per unit input (plot area) (Martey et al., 2019).

$$\text{Productivity} = \frac{Output\ (kg)}{Input\ (ha)} \quad (7)$$

Productivity is determined as the total output in kilograms (kg) divided by the input area in hectares (ha). It assesses land use efficiency by indicating the amount of produce obtained per unit area of land.

Gross margin per USD spent on input

The study employed Ayodele (2016) methods to analyze the cost in USD spent on supplementary and rainfed system. GM per USD spent explains the gross margin earned for every dollar invested in production. It is a measure of cost-efficiency, showing how much profit is generated from each unit of investment in inputs. This measures the rate of return as:

$$GM \text{ per } USD \text{ spent} = \frac{GM}{TVC} \quad (8)$$

(Data on gross margin and total variable cost from Table 8)

where:
- GM – gross margin,
- TVC – total variable cost.

Benefit cost ratio (BCR)

The agricultural economic indicator known as BCR was used to estimate the cost and returns of business ventures. It typically takes the form of a ratio showing the potential of a growing business. BCR is the indicator used to assess the potential of a SI and rainfed system in the production of chili pepper and okra. When the ratio is more than one, the production is profitable; when it is less than one, it is not. Break-even is indicated by a ratio of one.

$$BCR = \frac{TR}{TVC} \tag{9}$$

(Data on total revenue and total variable cost from Table 9)

where:
- TR – total revenue,
- TVC – total variable cost.

Gross margin comparison of the test crop under the two systems (rainfed and SI)

The study computed the level of benefits on investment per hectare, and estimated the means of total variable costs and GM on a hectare basis. To assess the variations in the gross margins per hectare for the okra and chili pepper farm enterprises under SI and rainfed systems, the paired p-value was used to test the means, and a least significant difference (LSD) at 5% was adopted to compare treatment means.

Statistical analysis

The data was analyzed using ANOVA to evaluate the significant differences among the various GMs of the experimental plots. LSD at 5% was used to compare treatment means.

RESULTS

The productivity and profitability of chili pepper and okra

The average return on investment for chili pepper under SI and rainfed systems is presented in Table 1. A yield of 18.400 kg and 12.830 kg was obtained from SI and rainfed cultivation on an area of 0.0089 ha. The resulting productivity ($kg \cdot ha^{-1}$) of SI chili pepper was 2067.41 $kg \cdot ha^{-1}$ (2.07 tons/ha) whereas that of rainfed chili pepper amounted to 1,441.60 $kg \cdot ha^{-1}$ (1.44 tons/ha), indicating a significant increase of about 43.5% with SI ($p < 0.05$).

For okra, yield was also significantly affected ($p < 0.001$) by supplementary irrigation and rainfed systems. A marketable yield of 12.600 kg and 10.102 kg was achieved from SI and rainfed systems, from a plot size of 0.0089 ha resulting in a productivity of 1,415.70 $kg \cdot ha^{-1}$ (i.e. 1.42 tons/ha) and 1,135.10 $kg \cdot ha^{-1}$ (i.e. 1.14 tons/ha) for SI and rainfed respectively (Table 1). However, national production averages in Ghana oscillate around 5.5 $t \cdot ha^{-1}$ (Sugri et al., 2015). The significance of steady moisture availability for okra growth and development is revealed by the 25% increase in productivity under SI. Higher yields are the result of SI ability to lessen the impact of irregular rainfall, especially during crucial growth phases (flowering and fruit development).

Yield of chili pepper and okra under fertilizer levels

The fertilizer levels applied at 0 $kg \cdot ha^{-1}$, 100 $kg \cdot ha^{-1}$, 150 $kg \cdot ha^{-1}$ and 200 $kg \cdot ha^{-1}$ for chili pepper, and 0 $kg \cdot ha^{-1}$,150 $kg \cdot ha^{-1}$, 200 $kg \cdot ha^{-1}$ and 250 $kg \cdot ha^{-1}$ for okra did not significant influence the yield at 11 weeks after transplanting and sowing. The results are presented in Table 2 and 3.

Table 1. Productivity and profitability of chili pepper and okra (Source: authors' own elaboration)

Crop	Area (ha)	Output/yield (kg)		Productivity ($kg \cdot ha^{-1}$)		P-Value
		SI	Rainfed	SI	Rainfed	
Chili pepper	0.0089	18.400	12.830	2,067.41	1,441.60	0.001
Okra	0.0089	12.600	10.102	1,415.70	1,135.10	0.006

SI – supplementary irrigation, ha – hectare, kg – kilogram

Table 2. Influence of fertilizer levels on productivity of chili pepper at 11 weeks after transplanting (Source: authors' own elaboration)

Crop	Fertilizer levels			
	$0\ kg \cdot ha^{-1}$	$100\ kg \cdot ha^{-1}$	$150\ kg \cdot ha^{-1}$	$200\ kg \cdot ha^{-1}$
Chili pepper	15.64	18.00	15.87	15.02
LSD (5%)	5.695			
P-Value	0.705			

Table 3. Influence of fertilizer levels on productivity of okra at 11 weeks after sowing (Source: authors' own elaboration)

Crop	Fertilizer levels			
	$0\ kg \cdot ha^{-1}$	$150\ kg \cdot ha^{-1}$	$200\ kg \cdot ha^{-1}$	$250\ kg \cdot ha^{-1}$
Okra	26.3	39.2	48.1	50.1
LSD (5%)	20.59			
P-Value	0.098			

Gross margin analysis of chili pepper and okra production

Due to simplicity and accuracy of the gross margin method, the latter has been recommended as a useful formula for analyzing farm income (Kasonga, 2018). This was calculated by deducting the total cost of production from the gross revenue earned by the farming enterprise. As with irrigation schemes in similar areas, the cost of water for the systems was projected to be the same as the cost of irrigation water. As building a water reservoir is not a common irrigation practice in northern Ghana, the cost of water is included in the cost of irrigation scheme's maintenance and rehabilitation.

Chili pepper gross margin estimation

In the SI system, the projected total cost of producing chili pepper amounted to USD 1324.80/ha, while in the rainfed system, it amounted to USD 1146.70/ha (Table 4). The marketable yield (2,067.41 $kg \cdot ha^{-1}$) multiplied by the unit price (USD 0.89 per kg) was used to estimate the USD 1840.80 income earned from SI crops. Additionally, the marketable yield (1,441.65 $kg \cdot ha^{-1}$) and the unit price (USD 0.89 per kg) were used to estimate the revenue of USD 1283.70 that was earned from rainfed crops. Originally calculated per unit area cultivated, the GM of chili pepper was subsequently adjusted to per hectare. The GM of USD 516.40 in SI and USD 137.00 in rainfed system was calculated by subtracting the production costs from the revenue. The difference of GM between SI and rainfed systems was statistically significant at 5% ($p < 0.006$) (Table 5).

Table 4. Costs (USD) of inputs used for chili pepper production from land preparation to harvesting (Source: authors' own elaboration)

Inputs	Quantity	Unit cost (USD)	Total/ (USD)	SI estimated cost (USD) per mean area (0.0089 ha)	Rainfed estimated cost (USD) per mean area (0.0089 ha)	SI estimated cost (USD) per ha	Rainfed estimated cost (USD) per ha
Seeds	50 (2 packs)	1.3	2.6	1.3	1.3	146.2	146.2
Fertilizer	Bowls (3)	1.0	3.1	1.5	1.5	173.2	173.2
Tecknokel	1L	4.4	4.5	2.2	2.2	250.1	250.1
Cost of water	Cost of water	***	***	0.4	***	41.1	***
Irrigation kits	Cost of irrigation kits	***	***	1.2	***	137.0	***
Ploughing	Cost of ploughing	2.7	2.7	1.4	1.4	153.9	153.9
Labor	Cost of labor	4.8	4.8	2.4	2.4	269.4	269.4
Harvesting	Cost of harvesting	2.7	2.7	1.4	1.4	153.9	153.9
Total				11.80	10.20	1324.80	1146.70

Table 5. Gross margin (USD) of chili pepper production from land preparation to harvesting (Source: authors' own elaboration)

Average	Estimated amount per mean area 0.0089 ha		Estimated amount per ha	
	SI	Rainfed	SI	Rainfed
Total marketed produce/revenue	16.40	11.40	1840.80	1283.70
Total input cost	11.80	10.20	1324.50	1146.70
GM	4.6a	1.2b	516.40a	137.00
LSD (5%)	2.45		275.67	
P-value	< .001		< .001	

GM – gross margin, SI – supplementary irrigation, RF – rainfed; different letters denote significant difference between treatments

Okra gross margin estimation

In the SI system, the estimated total cost of production was USD 1540.20/ha, while in the rainfed system, it amounted to USD 1362.20 (Table 6). The GM of okra was determined by subtracting the total cost of production, estimated per unit of the cultivated area and adjusted to per hectare, from the total revenue received after the sale of the produce. By multiplying the marketable yield (1,415.70 kg · ha^{-1}) by the unit price (USD 1.27 per kg), the expected revenue from SI system was USD 1793.90. Additionally, the marketable yield (1,135.14 kg · ha^{-1}) was multiplied by the unit price (USD 1.27 per kg) to estimate the revenue of USD 1438.40 derived from rainfed system (Table 5). The GM of USD 254.0 in SI system and USD 76.20 in rainfed system, respectively, was calculated by subtracting the production cost from the revenue. According to Table 7, the GM of SI and rainfed systems was at the 5% level of significance (p < 0.001).

Table 6. Costs (USD) of inputs used for okra production from land preparation to harvesting (Source: authors' own elaboration)

Inputs	Quantity	Unit cost (USD)	Total cost (USD)	SI estimated cost (USD) per area 0.0089 ha	Rainfed estimated cost (USD) per area 0.0089 ha	SI estimated cost (USD) per ha	Rainfed estimated cost (USD) per ha
Seeds	1 tin	5.5	5.5	2.7	2.7	307.8	307.8
Fertilizer	4 bowls	1.0	4.1	2.1	2.1	230.9	230.9
Insecticides	K-Optimal 250 ml (1 bottle)	0.8	0.8	0.4	0.4	46.2	46.2
Fungicides	Mancozeb (250 g)	0.8	0.8	0.4	0.4	46.2	46.2
Cost of water	Cost of water	***	***	0.4	***	41.1	***
Irrigation kits	Cost of irrigation kits	***	***	1.2	***	137.0	***
Ploughing	Cost of ploughing	2.7	2.7	2.7	2.7	307.8	307.8
Labor	Cost of labor	4.8	4.8	2.4	2.4	269.4	***
Harvesting	Cost of harvesting	2.7	2.7	1.4	1.4	153.9	153.9
Total				13.70	12.10	1540.20	1362.20

Table 7. Gross margin (USD) of okra production from land preparation to harvesting (Source: authors' own elaboration)

Average	Estimated amount per mean area 0.0089 ha		Estimated amount per ha	
	SI	Rainfed	SI	Rainfed
Total marketed produce/revenue	16.0	12.8	1,793.9	1438.4
Total input cost	13.7	12.1	1,539.9	1362.2
GM	3.30a	0.70b	254.00a	76.20b
LSD (5%)	1.48		166.46	
P-value	<.001		<.001	

Gross margin (GM) per USD invested

The results in Table 8 show the gross margin per USD invested for both okra and chili pepper grown under supplementary irrigation (SI) and rainfed conditions. This economic indicator analyzes the profitability of each USD invested in the production, which aids in determining the efficacy of various water management strategies. The study found a significant difference in the return on investment between the two chili pepper producing systems. For chili pepper grown under supplementary irrigation, the average gross margin per USD invested was USD 0.39. This means that for every USD spent on inputs and production under SI, the farmer received an additional USD 0.39 USD in profit. In comparison, chili pepper grown under rainfed conditions yielded an average gross margin of just USD 0.12 per USD invested, showing significantly poorer profitability. Rainfed chili pepper cultivation yielded a profit of only USD 0.12. Also, USD 0.16 and USD 0.06 were the GM per USD spent on okra cultivated under SI and rainfed system respectively (Table 8). This implies that, for every USD spent, a profit of USD 0.16 and USD 0.06 will be achieved from crops cultivated under SI and rainfed system, respectively.

Benefit cost ratio (BCR)

To evaluate the economic feasibility of both supplementary irrigation (SI) and rain-fed cropping systems, the benefit cost ratio (BCR) was determined. The BCR calculates return on investment by comparing total revenue (TR) to total variable cost (TVC) incurred during production. A BCR greater than 1 implies that the investment's returns surpass its costs, implying that the enterprise is profitable.

As reported in Table 9, the research revealed the BCR value of 1.39 in return for every USD 1.00 invested in supplementary irrigated chili pepper, resulting in a 39% profit above the cost. Under rainfed conditions, the return was 1.12 for every USD invested. This clearly demonstrates that, while both systems are profitable, supplementary irrigation provides much greater returns, most likely due to more consistent and higher yields from a reliable water supply.

Similarly, the BCR for okra under supplementary irrigation was 1.16, compared to 1.06 under rainfed conditions. Though the profit margins are lower than for chili peppers, both BCRs still surpass one, demonstrating that okra production is economically viable under both water management systems. However, like

Table 8. Gross margin (GM) of the test crops per USD invested in their production (Source: authors' own elaboration)

Crop	GM per ha (USD)		TVC per ha (USD)		GM per USD	
	SI	Rainfed	SI	Rainfed	SI	Rainfed
Chili pepper	516.40	137.00	1,324.80	1146.70	0.39	0.12
Okra	254.00	76.00	1,540.20	1362.20	0.16	0.06

SI – supplementary irrigation, GM – gross margin, TVC – total variable cost

Table 9. Benefit cost ratio (BCR) of the test crops under rainfed and supplementary irrigation (SI) (Source: authors' own elaboration)

	Revenue per ha (USD)		TVC per ha (USD)		BCR per ha (USD)	
Crop	SI	Rainfed	SI	Rainfed	SI	Rainfed
Chili pepper	1,840.80	1283.70	1,324.80	1146.70	1.39	1.12
Okra	1,793.90	1438.40	1,540.20	1362.20	1.16	1.06

with chili pepper, supplementary irrigation yields a somewhat higher return, demonstrating its ability to boost productivity and profitability even in crops with lesser commercial value.

Comparison of gross margin analysis of chili pepper and okra

The two separate farming enterprises were examined in this analysis, and a farmer may select one based on the perceived advantages. This was accomplished by contrasting the two crops' marketability, profit margins, and production costs. Okra is a crop that is more vulnerable to numerous diseases and pests. The findings show that, in contrast to chili pepper, growing okra demands more financial resources for commercial pest and disease control. This is reflected in the cost (and price) of okra per hectare, which is higher than that of chili peppers because it requires more capital to buy various variable inputs like fungicides and insecticides and fertilizers, and that fact makes it riskier and more prone to losses. This conclusion aligns with Asravor et al. (2016) who reveal that chili pepper is a profitable crop when compared with other vegetables, and as such is indeed a "green gold" in Ghana if farmers intensify its cultivation.

DISCUSSION

Productivity and profitability of chili pepper and okra

The output of cultivation was significantly higher under SI system compared to the rainfed system for chili pepper – with significant difference at the level of 5% (Table 1). However, the yield of chili pepper under both systems fell below national average of 8.30 $t \cdot ha^{-1}$ and an achievable level of 32.0 $t \cdot ha^{-1}$ (Akolgo, 2021). According to a study by Boateng et al. (2024), the timing of irrigation is critical for chili peppers, especially during the flowering and fruiting stages. Their study showed yield improvements of up to 50% when compared to rainfed systems.

This result is consistent with research by Mensah et al. (2024) who found that depending on the timing and frequency of irrigation, supplementary irrigation improves okra yields by 20–40%. Calvache and Reichardt (1999) revealed that low moisture content during critical periods reduces yield of crops. Mogaji and Oloruntade (2017) concluded that SI induced okra to produce more branches, which resulted in more flowering and fruiting. The work of Brandenberger et al. (2018) confirmed that when supplementary irrigation under rainfed is employed, it keeps soil moisture at optimum levels, influencing vegetable growth and consequently yield.

Chili pepper gross margin estimation

Due to improved yields and better produce quality, SI systems generated higher GM by over 200–300% when compared to rainfed systems, according to a study by Nangia et al. (2018) on vegetable production in semi-arid regions of Africa. This closely aligns with the findings of this study, which showed that SI produced more than 3.7 times the GM of rainfed output. Similar to the study's findings, Mensah et al. (2024) found that SI produced a GM of about USD 547.90/ha for chili pepper output in northern Ghana, and USD 171.20/ha under rainfed systems. According to Amankwah-Yeboah et al. (2023), SI increases production costs by 15–30%, but the yield gains are frequently 2–5 times greater than those of rainfed system. These findings are supported by the cost differential of about USD 178.10/ha, which demonstrates that even though SI has greater initial cost, the net economic returns significantly exceed the investment. The higher marketable yield in SI as opposed to rainfed fields is another factor contributing to the discrepancy in GM. The findings of this study conforms with Origa (2011) who observed a difference in GM between SI and rainfed tomatoes.

Okra gross margin estimation

Due to continuous water availability, Nangia et al. (2018) found that the GM of okra under SI in semi-arid regions was roughly 2.5–4 times greater than in rainfed systems. These conclusions are closely supported by the study's results, which indicate a GM of more than 3.3 times higher in SI when compared to rainfed system. Amankwah-Yeboah et al. (2023) discovered that SI increases GMs for okra production in northern Ghana from USD 68.50/ha in rainfed systems to USD 274.0/ha in supplementary irrigated systems. Amankwah-Yeboah et al. (2023) concluded that SI increases production costs by roughly 15–25%, which is similar to the cost difference in this paper. However, the investment in SI is financially feasible due to the proportionate GM gains. According to Origa (2011), the extra cost incurred is essential since it basically contributes to increasing productivity and hence increasing GM compared to the rainfed system.

Gross margin (GM) per USD invested and benefit cost ratio (BCR)

The results showed that the average gross margin per USD invested in okra cultivation under supplementary irrigation was USD 0.16, whereas for rainfed system, it was USD 0.06 (Table 8). On the average, the mean gross margin of USD invested in chili pepper was USD 0.39 whiles that of okra was USD 0.12 indicating that, chili pepper is more profitable than okra. This agrees with the findings by Asravor et al. (2016) and Akolgo (2021) who reported that chili pepper is profitable and indeed could be the "green gold" of Ghana if its production is intensified by farmers alongside good management practices. Similarly, Amankwah-Yeboah et al. (2023) found that because crops under SI systems have better access to supplementary irrigation water and consequent yield improvements, they often generate 2.5–4 times higher GM per USD invested than rainfed systems.

The results on BCRs correspond with the findings by Bwala and John (2018) whose study revealed that supplementary irrigated vegetable methods regularly yield greater BCRs than rainfed systems. They demonstrated that BCR values under irrigation ranged from 1.3 to 1.5, which is comparable to the outcomes of chili peppers and okra under SI.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The economic analysis of chili pepper and okra production revealed notable variations in the total cost of production and gross margin between the SI and rainfed systems. Despite the higher production cost, the SI system generated a significantly higher revenue, sufficient to cover production costs and still yield a significant profit. Conversely, the rainfed system, while incurring lower costs, yielded a lower gross margin – significantly lower than SI.

Recommendation

Therefore, it is recommended that farmers in drought-prone regions adopt the SI system alongside appropriate management for higher crop productivity. Also recommended is additional research and demonstration on other high-value crops which respond to SI, with a focus on low-cost spray tube systems in different locations. Additionally, exploring strategies to enhance rainfed system efficiency may contribute to narrowing the profitability gap between the two systems.

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REFERENCES

Abigail, A.A. (2019). Environmental Consequences and Profitability Analysis of Dry Season Small-Scale Irrigation Farming in the Bawku West District of the Upper East Region, Ghana. University of Ghana, Legon.

Akangaamkum, A.T. (2023). Effect of Supplementary Irrigation and Fertilizer Levels on Growth and Yield of Chili Pepper (Capsicum Annuum L.) and Okro (Abelmoschus esculentus L.) in Northern Region of Ghana.

Akolgo, J.A. (2021). Estimating the Productivity and Profitability of Rice and Pepper on Fields of the Irrigation

Company Upper Region (ICOUR) in Ghana. Current Agriculture Research Journal, 9(2), 106–119. https://doi.org/10.12944/carj.9.2.05

Amankwah-Yeboah, P., Yeboah, S., Osei, G., Waaley, L., Kyeremateng, P., Agyeman, K., Aruna, F., Adomako, J., Danquah, E., Ampong, A. (2023). Critical attributes and considerations for selecting irrigation systems for wastewater. Journal of the Ghana Institution of Engineering, 23(2), 64–75.

Asravor, J., Onumah, E.E., Osei-Asare, Y.B. (2016). Efficiency of chili pepper production in the volta region of Ghana. Journal of Agricultural Extension and Rural Development, 8(6), 99–110.

Ayodele, M.A. (2016). The impact of Macro-Economics indices on the development of project finance in Nigeria. Вестник Евразийской Науки, 8/2 (33), 59.

Boateng, E.N.K., Atampugre, G., Mariwah, S., Mensah, I., Johnson, F.A., Furst, C., Nyarko, B.K. (2024). Spatial and multivariate assessment of access to water for sustainable agriculture intensification in semi-arid Ghana. PLOS Water, 3(10), e0000283.

Brandenberger, L., Shrefler, J., Damicone, J., Rebek, E. (2018). Okra production. Oklahoma Cooperative Extension Service.

Bwala, M.A., John, A.U. (2018). Profitability analysis of paddy production: a case of agricultural zone 1, Niger State Nigeria. Journal of the Bangladesh Agricultural University, 16(1), 88–92.

Calvache, M., Reichardt, K. (1999). Effects of water stress imposed at different plant growth stages of common bean (Phaseolus vulgaris) on yield and N2 fixation. Crop Yield Response to Deficit Irrigation., 121–127.

Kasonga, F.C. (2018). Gross Margin Analysis of Irrigated Beans: A Case of Khosolo Extension Planning Area. Advances in Crop Science and Technology, 06(06). https://doi.org/10.4172/2329-8863.1000402

Katic, P.G., Namara, R.E., Hope, L., Owusu, E., Fujii, H. (2013). Rice and irrigation in West Africa: Achieving food security with agricultural water management strategies. Water Resources and Economics, 1, 75–92.

Konyeha, S., Alatise, M.O. (2013). Evapotranspiration and leaf area index (LAI) of irrigated okra (Abelmoschus esculentus L. Monech) in Akure, South-Western City of Nigeria. International Journal of Engineering Research and Technology, 2(9), 2880–2888.

Martey, E., Kuwornu, J.K.M., Adjebeng-Danquah, J. (2019). Estimating the effect of mineral fertilizer use on Land productivity and income: Evidence from Ghana. Land Use Policy, 85, 463–475.

Mensah, A., Adams, F., Nimoh, F., Frempong, F., Onumah, E.E., Nartekie, N.B. (2024). Safeguarding sustainability: Exploring safety practice adherence among urban vegetable farmers in Ghana. Journal of Agribusiness and Rural Development, 1(71).

Mensah, D. (2020). Factors that affect development of organic tomato value chain in Ghana.

Mogaji, K.O., Oloruntade, A.J. (2017). Growth and Yield of Okra under Sprinkler Irrigation System in Owo, South-Western Nigeria. Journal of Agriculture and Veterinary Sciences, 9(3).

Nangia, V., Oweis, T.Y., Kemeze, F.H., Schnetzer, J. (2018). Supplemental irrigation: A promising climate-smart practice for dryland agriculture.

Nnadi, O.I., Ogbodo, F.N., Ohagwu, A.V, Onyia, C.C., Nnadi, U.V, Ozioko, R.I. (2021). Effectiveness of climate change adaptation measures used by women garden egg farmers in Enugu State, Nigeria. Journal of Agricultural Extension, 25(4).

Origa, L.O. (2011). Effect of supplemental irrigation on growth, yield and economic returns of onion (allium cepa) and tomato (solanum lycopersicum) in Kibwezi district, Eastern Kenya. University of Nairobi, Kenya.

Russo, T., Alfredo, K., Fisher, J. (2014). Sustainable water management in urban, agricultural, and natural systems. Water, 6(12), 3934–3956.

Sugri, I., Abdulai, M.S., Larbi, A., Hoeschle-Zeledon, I., Kusi, F., Agyare, R.Y. (2015). Participatory variety selection of okra (Abelmoschus esculentus L.) genotypes for adaptation to the semi-arid agro-ecology of Northern Ghana. African Journal of Plant Science, 9(12), 466–475.

Unami, K., Mohawesh, O., Sharifi, E., Takeuchi, J., Fujihara, M. (2015). Stochastic modelling and control of rainwater harvesting systems for irrigation during dry spells. Journal of Cleaner Production, 88, 185–195.

ANALIZA ZYSKU BRUTTO Z UPRAWY PAPRYKI CHILI I OKRY W WARUNKACH NAWADNIANIA DESZCZOWEGO I UZUPEŁNIAJĄCEGO W PÓŁNOCNYM REGIONIE GHANY

ABSTRAKT

Cel pracy

Chociaż systemy nawadniania uzupełniającego wyłoniły się jako potencjalne rozwiązanie łagodzące wpływ suszy na produkcję upraw, to wciąż brak kompleksowych badań, które szczegółowo analizowałyby zysk brutto związany ze stosowaniem systemów nawadniania uzupełniającego w produkcji okry i papryki chili. Celem pracy była ocena efektywności oraz przeprowadzenie analizy kosztów i korzyści płynących z zastosowania nawadniania uzupełniającego w produkcji badanych upraw w północnej Ghanie.

Materiał i metody

Badanie przeprowadzono w układzie czynnikowym 4 × 2 × 2 z trzema powtórzeniami, wykorzystując układ losowych bloków kompletnych (RCBD). Zastosowano następujące zabiegi badawcze: 4 poziomy nawożenia NPK, nawadnianie deszczowe i uzupełniające z wykorzystaniem systemu nawadniania opartego na rurach i zraszaczach. Nawożenie NPK stosowano w dawkach 0 kg · ha^{-1} (kontrola), 150, 200, 250 kg · ha^{-1} oraz 0 kg · ha^{-1} (kontrola), 100, 150 i 200 kg · ha^{-1} odpowiednio dla upraw okry i papryki chili.

Wyniki i wnioski

Wykazano, że papryka chili wydała plon handlowy wynoszący 2067,41 kg · ha^{-1} w uprawie z nawadnianiem uzupełniającym i 1441,60 kg · ha^{-1} w uprawie deszczowej. W odniesieniu do uprawy okry, nawadnianie uzupełniające przyniosło plon handlowy wynoszący 1415,70 kg · ha^{-1}, podczas gdy z działek nawadnianych deszczem uzyskano 1135,10 kg · ha^{-1}. W przypadku papryki chili, przy średnim koszcie 1324,80 USD/ha i 1146,70 USD/ha, uzyskano marżę brutto wynoszącą odpowiednio 516,40 USD/ha dla uprawy z nawadnianiem uzupełniającym i 137,00 USD dla uprawy nawadnianej deszczem, co stanowi istotną statystycznie różnicę na poziomie 5% ($p < 0,006$). W przypadku okry zainwestowano odpowiednio 1540,20 USD/ha i 1362,20 USD w system uprawy z nawadnianiem uzupełniającym i nawadnianej deszczem, przy czym marża brutto wyniosła odpowiednio 254,00 USD/ha i 76,20 USD/ha. Marża brutto z każdego 1 USD zainwestowanego w uprawę papryki chili wyniosła 0,39 USD dla uprawy z nawadnianiem uzupełniającym i 0,12 USD dla systemu nawadnianego deszczem, podczas gdy w przypadku okry wartości te wyniosły odpowiednio 0,16 USD i 0,06 USD. Wskaźnik korzyści/kosztów dla okry oszacowano na poziomie 1,16 w przypadku upraw z nawadnianiem uzupełniającym, a 1,06 dla uprawy nawadnianej deszczem, podczas gdy dla papryki chili analogiczne wartości tego wskaźnika wyniosły 1,39 dla nawadniania uzupełniającego i 1,12 dla nawadniania deszczem. Podsumowując, nawadnianie uzupełniające zapewniło wyższe przychody, co przełożyło się na marżę brutto pozwalającą pokryć koszt produkcji i pozostawiło znacząco wyższą marżę zysku w porównaniu z systemem nawadnianym deszczem. Z tego powodu rolnikom w regionach doświadczających okresów suszy zaleca się stosowanie nawadniania uzupełniającego (w połączeniu z właściwą praktyką zarządzania uprawami) w celu zwiększenia produktywności.

Słowa kluczowe: nawadnianie uzupełniające, nawadnianie deszczowe, marża brutto, plony, uprawa papryki chili i okry