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FINANCIAL AND ECONOMIC ANALYSIS OF TOMATO CULTIVATION UNDER MULTIPLE PRODUCTION SYSTEMS: A CASE STUDY OF DISTRICT BAHAWALPUR, PAKISTAN

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ABSTRACT

Hydroponic farming offers an environmentally friendly alternative to conventional soil-based agriculture, while progressive farming employs a resource-intensive approach to enhance productivity. This research, carried out in 2020 in Pakistan's Bahawalpur district, evaluated the financial performance of tomato cultivation across three farming systems: soil-based, hydroponic, and progressive. Data from 110 farmers were analyzed using cost analysis, MANOVA, ANOVA, and descriptive statistics. Key financial indicators, including return on sales (ROS), return on investment (ROI), operating ratio (OR), personnel cost ratio (PCR), and Asset turnover Ratio, were assessed. The findings indicate that although hydroponic farming involves costs nearly 25 times higher than soil-based farming, it generates profits approximately 10 times greater due to significantly higher yields. Progressive farming showed efficient resource utilization and profitability, while soil-based farming demonstrated greater financial flexibility. With a production cost of Rs.17.3 per kg for hydroponic tomatoes compared to Rs.17.5 for soil-based methods, hydroponics was highlighted as a more efficient option. The study identifies hydroponic farming as a sustainable and high-yield solution, especially in areas with limited land or low soil fertility. However, its widespread adoption requires overcoming barriers such as high initial investments, lack of technical knowledge, and limited awareness of this innovative farming method.

KEYWORDS: *Solanum lycopersicon;* hydroponic system; soil system; economic comparison; land use efficiency; financial performance; Pakistan

INTRODUCTION

The tomato (*Solanum lycopersicon* L.) is an economically important vegetable crop worldwide, including in Pakistan traditional methods of soil-based crop production are currently grappling with serious challenges, and its production has suffered from many pests and disease problems (Akhtar *et al.,* 2019, Anwer *et al.,* 2019). In response, the adoption of soil-less cultivation techniques, specifically hydroponics, has emerged as a promising alternative to enhance the yield of vegetables, herbs, and ornamental plants. This transition comes at a time of heightened climate variability, urbanization, and an increasing global population, where issues like phosphorus deficiency and the environmental impact of agrochemicals have come to the forefront. These challenges coincide with potential stagnation in crop output per unit area and the deterioration of arable land due to factors such as irrigation practices and soil salinity (Verdoliva *et al.,* 2021). Traditional soil-based agriculture remains the predominant method of food production. Innovative approaches such as improved irrigation technologies, poly houses, crop rotation, and intercropping are gaining momentum. However, it's important to acknowledge the trade-offs that come with these new strategies (Gomiero *et al.,* 2011). Conventional farming practices often rely heavily on agrochemicals to boost efficiency, resulting in negative repercussions like soil degradation and erosion (AlShrouf, 2017). Moreover, the depletion of soil microbes and inadequate management of water resources in the face of changing weather patterns pose further threats to sustainable soil-based agriculture (Barman *et al.,* 2016; Barbosa *et al.,* 2015).

The allure of hydroponic farming has surged on a global scale, driven by its effective resource utilization and the production of high-quality food. Concurrently, soil-based agriculture confronts multiple challenges, including urbanization, climate-related disasters, chemical usage, and reduced soil fertility. Overcoming these challenges, and the associated biophysical, economic and social barriers has prompted the rise of hydroponics as a viable alternative (Nyakach *et al.,* 2017). The Food and Agriculture Organization of the United Nations predicts that with a global population expected to reach 9.7 billion, the specter of food shortages will loom even larger by 2050, demanding innovative farming solutions.

Beyond the issue of vanishing arable land due to urban expansion and industrial growth, conventional agricultural practices also bear ecological consequences. This necessitates the evolution of food production methods to ensure sustainability. Switching the growing medium offers potential benefits for both long-term productivity and the preservation of dwindling land and water resources, making soilless agriculture a compelling solution (Butler and Oebker, 2006).

Tomatoes, a staple in diet around the world, are the second most cultivated vegetable crop after potatoes in terms of production (FAO, 2018). Tomatoes play a crucial role in both cash and industrial crops in many regions, especially in Pakistan where they are integral to culinary practices. The increasing demand for tomatoes, driven by population growth and urbanization, underscores their significance. This rising demand necessitates efficient cultivation methods to meet it. Despite their importance, there remains untapped potential for enhancing tomato cultivation methods.

The year 2020 witnessed a global production of over 187 million tons of fresh tomatoes, with a total cultivated area exceeding 5 million hectares. Tomatoes are commonly grown using both soil-based and hydroponic systems, and the outcomes of these methods have been compared. Research has shown that hydroponically grown tomatoes exhibit favorable attributes such as better sugar-to-acid ratios, increased firmness, and higher vitamin C content when compared to soil-grown counterparts (Kunsch *et al.,* 1994; Benoit and Ceustermans, 1987). Notably, soil-based cultivation has also demonstrated its advantages, with soil-grown tomatoes showcasing better quality attributes like higher dry matter content (Granges, 1980). However, the comparison between hydroponic and soil-based systems, especially in the context of vegetable yield per unit area in urban environments, remains an understudy area (Wang *et al.,* 2023).

In the Bahawalpur region, hydroponic systems have garnered limited attention, as traditional soil-based and progressive farming methods continue to dominate tomato cultivation. However, factors such as land degradation, population growth, and urban expansion are increasingly limiting available arable land. The slow uptake of hydroponic farming practices in the Bahawalpur district has contributed to food insecurity, accentuated by the inability of conventional soil-based systems to meet food demands.

This study aims to address the existing gap by evaluating the economic implications of different tomato cultivation methods in the Bahawalpur district. Bahawalpur was chosen for its strategic significance, particularly due to the establishment of the Bahawalpur Hydroponic Research Farm, developed by the Urban Unit in collaboration with the local government for research purposes. The preceding data highlights Bahawalpur's performance in tomato production over the last eight years. Although Bahawalpur is not among the top tomato-producing regions, the hydroponic study

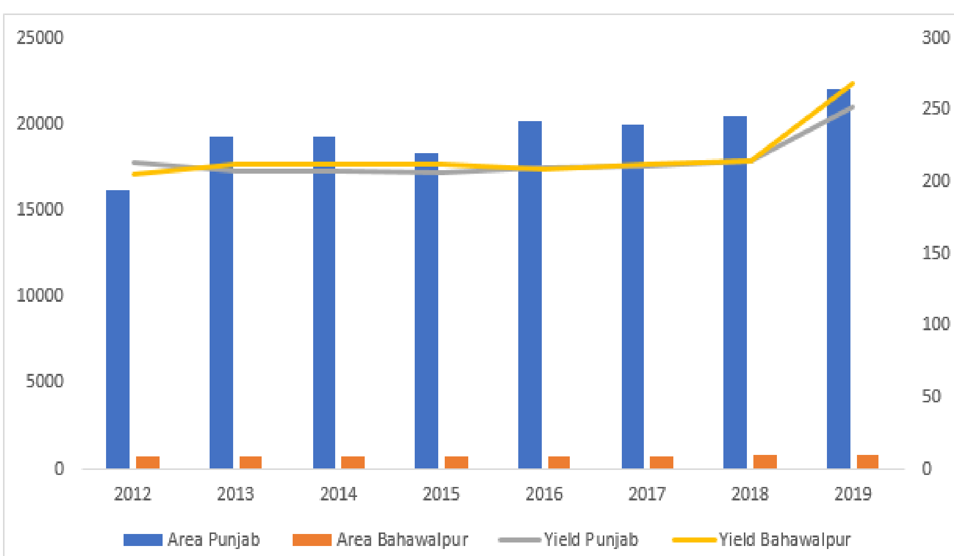

Fig. 1: The Area and yield of Tomato Crop and share of Bahawalpur in Punjab

and soil-based analysis focus on this area to account for the elimination of regional climatic factors in both systems.

By comparing soil-based, hydroponic, and advanced farming systems, this study seeks to identify opportunities for enhancing tomato productivity and profitability. The analysis of productivity and costs will provide valuable insights to inform policy recommendations for the sustainable integration of hydroponic farming within the context of evolving agricultural dynamics. With tomato consumption steadily increasing and the growing need for efficient production to meet rising demand, this research holds significant importance in shaping future agricultural practices.

MATERIALS AND METHODS

Functional form of farming systems

selection of hydroponic system*:* For this research, the hydroponic-based tomato production system was established with the support of the municipal authority. Due to the limited number of hydroponic farms in the region, a purposive sampling technique was employed to select 10 farmers who provided data on the expenses and sales associated with hydroponic farming systems. In contrast, data on soil-based tomato farming was collected using a random sampling technique from farmers in the surrounding areas of the hydroponic farms within Bahawalpur district. This approach ensured that the climatic factors affecting both farming systems were consistent, thereby allowing for a more accurate comparison.

Functional form of the model*:* In tomato production, the hydroponics approach requires the assessment of costs and benefits. Costs indicate system investments, whereas profit represents the return on investment. Expenditures in the form of investments are incurred in every manufacturing process to produce potential benefits. These expenses are divided into two categories:

a. Fixed cost (FC) or capital cost: Fixed costs are incurred one time and include expenses associated with the construction and setup of the hydroponic production unit, such as machinery and equipment.

b. Variable cost (VC) or operational cost: Variable costs are ongoing and vary due to the capital-intensive nature of the hydroponic production system.

The profit (P) from hydroponic tomato production is calculated, using the following equation:

P (S, H) = R (S, H) - C (S, H) ……………………1

Where:

P:represents the profit (PKR)

S:denotes the type of tomato (Soil-based or Hydroponic)

H:indicates the farming system (Hydroponic)

R:stands for income generated from tomato sales

C:represents the total cost of hydroponic tomato production, including both fixed and variable costs.

For further analysis, the total costs of production (C) are divided into two categories:

C = FC + VC …………………………. 2

Production methodology for traditional farming system: The production approach for the conventional soil-based agricultural system will be explained so as to allow for comparative examination. Plant development in a hydroponic system is influenced by elements such as the amount and type of water used, as well as the temperature of the enclosed habitat. Water volume and ambient temperatures are directly related to several characteristics impacting plant development, including plant height, leaf length, inflorescence, head thickness, number of leaves, and fruit set.

All of these variables are affected due to water constraint during the weekly cycle, affecting plant productivity and overall barn configuration. At high temperatures, water shortage reduces average growth greatly, which is exacerbated by conditions such as bad water quality, high pH, and excessive electrical conductivity. Plant development slows when temperature rises and water supply decreases.

Methodology: In this study, various farming frameworks are considered, based on the definition of the outcome, technological applications, and practices employed. The three farming systems studied are as follows:

Progressive farming: Progressive farmers actively mitigate risks associated with agricultural practices by participating in rigorous training programs that demonstrate careful and consistent cultivation practices. Modern irrigation systems, such as drip irrigation or spray irrigation, are employed, and a focus on the use of the latest technological innovations in crop production is emphasized.

Soil-Based farming: In soil-based farming, crops are cultivated in nurseries and the soil. Conventional methods, including the use of composts and pesticides, are employed.

Hydroponic farming: Hydroponic farming involves growing crops in a nutrient solution containing essential nutrients. The plant's roots are in direct contact with the fertilizer solution, while the plant itself grows on a latent substrate, such as coir.

Data collection: Data for this study was gathered from numerous farms in the Bahawalpur district, with a focus on the year 2020. Primary data collected from farmers was used to differentiate between hydroponic, traditional (soil-based), and progressive farming systems. The sample size for hydroponic farming was limited due to the dispersed nature of hydroponic farms and difficulties in visiting some producers during the research period. For the purposes of this paper, farming systems were divided into progressive farming systems, soil-based systems, and hydroponic-based systems.

Financial success measures: The following financial success measures were selected based on previous studies (Hyblova and Skalicky 2018; Zorn *et al.* 2018):

Return on sales (ROS): ROS is calculated using the production data of farmers and represents the ratio of revenue (R) to production (P).

Return on investment (ROI): ROI is the ratio of revenue (R) to investment (I) and evaluates the profitability of the farming system.

Investment turnover ratio (ITR): ITR is the ratio of production (P) to investment (I) and assesses the efficiency of investment utilization.

Operating ratio (OR): OR represents the ratio of investment (I) to production (P) and helps analyze operating costs.

Personnel cost ratio (PCR): PCR is the ratio of fixed costs (FC) to production (P) and assesses labor costs.

Earnings before interest and taxes (EBIT)

To estimate ROS and ROI, EBIT is used as it allows evaluating a farmer's primary operations without the influence of tax expenses or capital structure costs on revenue. All operational revenues, including operating agricultural subsidies, are considered in the ROS and ROI calculations.

The financial performance formulas used in this study are as follows:

Return on Sales (ROS): ROS = R / P....................3 .

Return on Investment (ROI): ROI = R / I...............4

Operating Ratio (OR): OR = I / P...........................5

Personnel Cost Ratio (PCR): PCR = FC / P..........6

Investment Turnover Ratio (ITR): ITR = P / I.........7

RESULTS AND DISCUSSION

Progressive farmer:

C =FC+VC ………………………2

C = 45236 + 164449

C = 209685

The total cost of land-based tomatoes is Rs 209,685 per acre.

PS= $R_p – C_p$ ……………………1

811361 - 209685

Pp = 601676

Hydroponic tomato cost analysis: The cost of the production cost,

the total cost is Rs. 1,08,632 at Mandi Gate.

PS=RS-CS…………………………………….. 1

118400-108632

PS=9768

Hydroponic tomato cost analysis: The cost of the structure is approximately Rs.1,6,000,000. While the cost of hydroponic tomatoes is Rs. 2,585,000 per acre which includes the cost of the structure, administration, cost of hydroponic tomatoes is Rs. 2,585.000 per acre which includes the cost of the structure, administration, marketing, tillage, energy, seeds, nutrients, coco peat, and other costs. The description of these costs is described in Table 4, the production of hydroponic

Table 1: Cost analysis of Soil-based farming system

Total fixed costs			
Operations / Entries	**Average number of operations / units/acres**	**Price/unit Rs**	**Cost/acre Rs**
Irrigation			
(Abiana /Acre)		56.3	100
Private well (3 hours/irrigation)	6	1,000	6,000
Tillage costs for irrigation (M.Days)	6	525	3,150
Cleaning of streams (M.Days)	1	525	525
Total			**9,775**
Rental of the land for 6 months @ 50,000 / 50,000 PA	50,000	0.05	25,000
Farm income tax.			48
Management fees for 6 months per	6	150	900
Total Fixed Costs			**35,723**

***Table 1 shows the total fixed cost of tomato on a land basis which is Rs 9,775 per acre including irrigation cost of Rs 35,723 per acre, land lease as described by the grower of Rs 25,000 per acre, the revenue - Tax per acre paid is Rs. 48 and the administration fee is Rs. 900 per acre.**

Table 2: In-depth analysis of ground tomato

Operations / Entries	Average number of operations/ units/ acres	Price/unit Rs	Cost/acre Rs
Plowing for soil preparation			
Plow deep	0.3	1,279	384
Plows / cultivators	2	800	1,600
Boards	2	400	800
Upgrade	0.3	1,300	390
Total			**3,174**
Seedbed preparation			
Ploughing boards	2	800	1,600
Total			**1,600**
Sow and sow the works			
Seeds (kg)	0.12	2,000	240
Nursery breeding	1	5,000	5,000
Make beds with First	1	1,280	1,280
Uprooting, transplanting, and transport	4	525	2,100
Total			**8,620**
Farmyard manure			
farmyard manure (wagon)	3	1,100	3,300
Manure spreading and transport labour (man-days)	3	525	1,575
Total			**4,875**
Fertilizer: (bag)			
Urea	1.5	1,640	2,460
ODA	1	3,750	3,750
POS/MOP	1	3,100	3,100
Transportation	3.5	20.99	73,465
Fertilizer application (man-days)	2	525	1,050
Total			**10,433**
Crop protection			
Treatments	6	500	3,000
Hoeing / Soiling & Weeding	6	525	3,150
Total			**6,150**
Harvest			
Pick ripe fruit	40	525	21,000
Handling & Transportation	10	525	5,250
empty pockets.	493	12	5,916
Total			**32,166**
Total Variable Costs			**60,868**

***The total variable cost of soil-based tomato is Rs. 60,868 per acre including the cost of preparatory tillage, seedbed preparation, sowing and seeding work, manure, fertilizer, plant protection, and harvest values are shown in Table 2.**

Table 3: Production and Cost Analysis of Ground Tomatoes

Description	Costs
Yield per hectare	5,920 (kg)
Cost per kg at farm level	17.5 (R)
Cost per 40 kg at farm level	700 (Rs)
marketing costs	34 (Rs/40kg)
Cost per 40kg at Mandy Gate	734 (Rs)
Investment incentive @25%	170 (Rs)

***The description of the production and cost of ground tomatoes is given in the Table 3.**
C=FC+VC 2
C=35,723+ 60,868
C= 96,591
The total cost of land-based tomatoes is Rs 96,591 per acre.
Further analysis shows that production per acre is
5920 kg and cost per kg at farm level is Rs 17.5 and cost per 40 kg at farm level is Rs 700, marketing expenses per 40 kg are 34 rupees. The cost per 40 kg at Mandy Gate is Rs. 734. So, including this cost in the production cost,
the total cost is Rs. 1,08,632 at Mandi Gate.
PS=RS-CS.. 1
118400-108632
PS=9768

Table 4: Cost analysis of growing tomatoes in soil hydroponics per acre

S. No	Description	Unity	Unit cost Rs.	Quantity	Month	The total cost of Rs.
1	Manager	nobody	75,000	1	6	450,000
2	Marketing Manager	nobody	40,000	2	6	480,000
3	Plow	nobody	20,000	6	6	720,000
4	Energy costs (water & electricity		40,000	1	6	240,000
5	Seed	pieces	5	11000	6	55,000
6	Nutrient	kg/ liter	125,000	1	6	125,000
7	Coconut peat	block	4	1000	6	40,000
8	Different costs				6	75,000
9	Marketing (packaging material, transport, etc.)					400,000
				Total cost		**2,585,000**
10	Production				150000 (kg)	
11	Production costs per kg				17.2333	17.3
12				selling price	25	25
				Total revenue		**3,750,000**
				Net revenue		**1,165,000**

***Taking the cost and profit functions of the two equations shows that the cost of soil crops is Rs. 1,08,632 per acre, which is almost 25 times less than the cost of hydroponics which is Rs. 25,85,000 per acre. Although the further analysis shows that the gain and production of hydroponics are much higher than that of growing in soil as discussed earlier.**

Table 5: Descriptive Statistics

Financial indicators				
Indicator	**Descriptive statistics**	**Hydroponics**	**Soil Based**	**Progressive**
ROS	mean median	26.37	27.03	27.10
	Std. dev.	2.41	5.52	5.46
	min.	21.47	16.50	19.46
	max.	28.48	37.23	37.33
ROI	mean median	1.54	1.34	5.00
	std. dev.	0.17	0.32	0.98
	min.	1.34	0.75	3.56
	max.	1.84	2.04	6.87
OR	mean median	17.18	20.54	5.46
	std. dev.	1.70	3.44	0.77
	min.	14.70	14.57	4.40
	max.	20.10	28.19	6.74
PCR	mean median	1.39	6.29	1.51
	std. dev.	0.08	0.48	0.15
	min.	1.27	5.50	1.32
	max.	1.52	7.11	1.74
ITR	mean median	0.06	0.05	0.19
	std. dev.	0.01	0.01	0.02
	min.	0.05	0.04	0.15
	max.	0.07	0.07	0.23

***Table 5. Represents descriptive statistics of the finan¬cial indicators of farm type of hydroponic farming systems, soil-based farming, and progressive farming system in the Bahawalpur district.**

tomatoes per acre is 150,000 kg. Total sales at an average selling price of Rs 25 is Rs 3,750,000. Such is tomatoes per acre is 150,000 kg. Total sales at an average selling price of Rs 25 is Rs 3,750,000. Such is the victory of hydroponic tomatoes.

PH=RH-CH

3750000–2585000

PH= 1,165,000 per acre.

Profit for hydroponics is Rs. 1,165,000 per acre.

Analyzing financial indicators across different farm types reveals interesting patterns. Progressive farmers exhibit slightly higher Return on Sales (ROS) compared to soil-based farming, but the hydroponic system shows relatively lower ROS. Further analysis highlights the significance of return on sales for each farm type. Return on Investment (ROI) plays a positive role in progressive farming, surpassing hydroponic and soil-based methods. This indicates greater profitability among progressive farmers, potentially due to their adoption of advanced techniques, quality raw materials, effective marketing, pest control, and efficient financing. Operational Ratio (OR) and Personnel Cost Ratio (PCR) evaluate operating and labor expenses, aligning with findings from Hampl (2020). Decreasing OR indicates efficient cost management and revenue generation in progressive farming. Soil-based farming demonstrates financial flexibility, notably seen in PCR values (mean/median of 6.29), reflecting wage levels and fixed costs.

The Investment Turnover Ratio (ITR) of 0.19 indicates progressive farmers' effective resource utilization in Bahawalpur district compared to hydroponic and soil-based methods. The impact of technology dissemination on production benefits progressive farming significantly. In contrast, soil-based farming requires substantial investments to enhance efficiency.

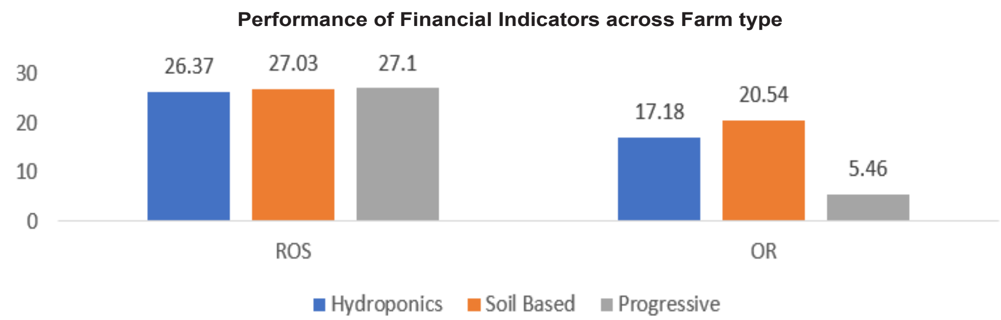

Fig. 2: Performance of financial indicators

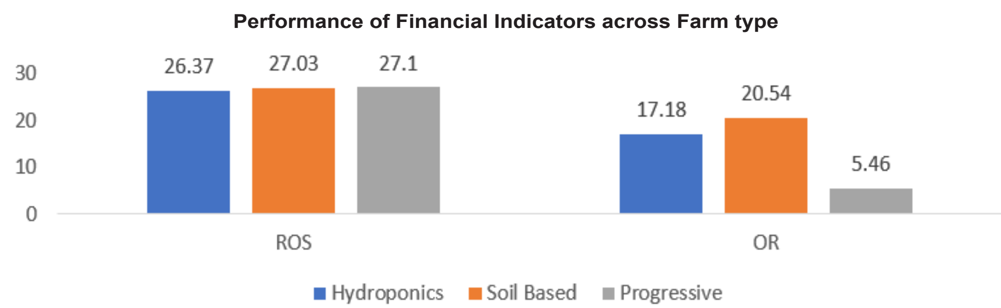

Fig. 3: Performance of financial indicators

Table 6: Results of MANOVA

Factor	F statistics	P-value	Significance
Wilks' lambda	322.29	0.0000	***
Lawley-Hotelling trace	256.86	0.0000	***
Pillai's trace	403.10	0.0000	***
Roy's largest root	2.285	0.049	**

***Table 6 represents the Multivariate analysis of variance (MANOVA). This test has been performed to test the statistical significance. The same conclusions were drawn by (Hampl, 2020) that the effect of all financial indicators has a significant effect at 0.01 differences on all farm types i.e., Progressive farming, hydroponic farming, and soil-based farming system. A MANOVA produces Pillai's trace, which is a test statistic. It is a number ranging from 0 to 1. All financial parameters have a positive significant impact on the classifications of farm types, as shown in the table below. This finding elucidates the findings of a study done by (Hampl, 2020).**

Table 7: Results of ANOVA

	F-statistics	*P*-value	significance
ROS	0.07	0.9313	ns
ROI	335.57	0.0000	***
OR	102.82	0.0000	***
PCR	992.14	0.0000	***
ITR	689.65	0.0000	***

***Table 7 exhibits the results of a one-way Analysis of Variance. It shows the statistical significance of variations in financial analysis indicators discovered by ANOVA. The significance of differences found implies that the chosen farming system has an effect on ROS, OR, PCR, and ITR, as well as the effect of farm type on ROI, OR, and PCR.**
Similar to (Hampl, 2020), the effect of the farm type on a farm's ability to invest in order to earn a profit, as measured by ROI, is statistically meaningful.

Table 8: Comparison between soil and hydroponic tomato production

Description	On the ground	Hydroponics
Land use efficiency	• Less because: • Changes in soil fertility; weed competition • Poor availability of water	Because no soil is used, there are no issues with large planting densities (more plants per square meter).
Water use efficiency	Less because: • Water shortage • High evaporation losses • Less irrigation efficiency	A typical approach would require 1/30 the quantity of water for the same region.
Soil degradation	Raised as a result of inadequate irrigation efficiency, and high fertilizer & pesticide dosages, which result in issues such as waterlogging and salinity.	• No land is used • the system is, therefore, safely made in.
Usefulness of resources	More land, labor, and capital necessary	• Productive and efficient • Using both natural and artificial resources
Resource conservation	Natural resources, like water-based fertilizer, are exploited in an ad hoc manner. (They are only required once, and they should not be squandered like this important resource.)	Entirely natural resources, like water fertilizers, are used cyclically and repeatedly.
Competition with weeds	High competition	Little to no weed risk
Location effect	Rent affects production because of the different climate conditions elsewhere.	The environment is controlled and artificial so the place makes does not affect agricultural production.
Benefit-cost ratio	Less of	High
Quality	Weak because open field breeders do not control the quality of the settings	The breeder can influence quality parameters like pH adjustments etc.
Market value	Less because of the worst and more variable quality	Because of the homogeneity in size, shape, color, and weight, the market value is great.
Consistency one production	Since manufacturing is dependent on weather conditions, there is little or no regularity.	More regular production because production does not depend on climatic conditions.
Profitability ratio	Low	High
Production	10 tones	166 tones
Cost per kilo	Rs. 17.5	Case 17.3

Hydroponic systems offer economic advantages by reducing cultivation costs, increasing revenues, and promoting sustainable practices, eliminating risks of land and water pollution. Soil-free cultivation minimizes disease risks, reduces labor and time demands, and allows control over plant density and humidity. Similar financial analysis by Hampl (2020) underscores the benefits of increasing ITR in organic farming.

CONCLUSION

This paper delved into a comparative analysis of the financial efficiencies of tomato farms in Bahawalpur district, focusing on three distinct farming systems: progressive, hydroponic, and soil based. The findings underscored a significant association between hydroponic farming efficiency and the need for operational expertise due to its complexity. Financial metrics indicated that hydroponic farming outperforms soil-based counterparts in terms of efficiency, while progressive farming optimizes resource utilization for productive outcomes. However, challenges exist within soil-free agriculture, stemming from high initial costs related to knowledge and irrigation systems, along with factors like water scarcity, energy supply, and system-related risks.

Progressive farmers demonstrated enhanced profitability, reflecting a more competitive economic stance. Conversely, soil-based farmers showcased better resource utilization efficiency for generating profits or sales, as evident through return on sales (ROS) and input to revenue (ITR) ratios. Operational costs were notably higher for soil-based farming, exceeding double that of hydroponic counterparts, compounded by increased labor expenses. Economies of scale were observed across all farming types, with progressive farming emerging as the most financially viable option for tomatoes. For land-limited or low-fertility soil situations, hydroponics emerged as a resource-efficient choice.

The cost-benefit analysis highlighted the economic advantages of hydroponic farming, yielding 25% higher costs and profits compared to soil-based systems. Within soil-based farming, progressive farmers exhibited substantially superior profit margins compared to tenant farmers employing traditional methods.

Despite the valuable insights provided, this study has limitations. The data sample primarily focused on the Bahawalpur district, omitting natural farms from other regions of Pakistan. Challenges included the exclusion of units due to inadequate hydroponic data, incomplete records, and the need for manual validation. However, considering the recent adoption of hydroponic practices in the district, this research offers timely and reliable information to guide farmer decision-making. Future investigations should broaden their scope to encompass various farming systems across Pakistan, providing a comprehensive understanding of the country's agricultural landscape.

Policy recommendations: To conclude based on the discussed comparisons and studies, it becomes evident that traditional soil-based tomato cultivation is falling short of satisfying Pakistan's consumer demand. However, despite its substantial energy requirements, hydroponics emerges as a promising technology. Enhancing water use efficiency in crop yield is crucial, particularly in regions with limited water access. Hydroponics offers water-efficient advantages, time savings, and significantly higher production yields. Given its potential and the World Bank's warnings of imminent severe food shortages due to rapid population growth, it is imperative for Pakistan to adopt this forward-looking technology.

It's important to note that opting for indoor cultivation and avoiding soil-toxic pesticides is not the sole reason for crop protection. Rather, hydroponics stands out as a water-efficient solution, making it especially appealing as urban planners grapple with land and water scarcity. This observation holds particular significance in the context of tomato production and demand within the country.

Evidently, tomato production has hit a plateau over the past five decades while Pakistan's land area remains limited and its population continues to grow. Conventional soil-based tomato cultivation falls short of meeting local demand. In light of these challenges, the introduction of modern technologies stands as a viable option to boost productivity. Hydroponic technology has proven effective in increasing yields within Pakistan. Its benefits ripple both at the micro and macro levels of the economy.

At the micro level, farmers stand to benefit substantially as the horticultural sector undergoes a transformation towards technical and capital-intensive methods. On the macro scale, local tomato supply would rise, improving per capita consumption and public health. Increased production would also shift Pakistan from being a tomato importer to an exporter, thereby bolstering foreign exchange reserves.

For hydroponics to gain traction, governmental support is pivotal. Encouraging the adoption of more advanced control devices can reduce system costs and make it financially accessible to average investors. Administrative and local backing are equally essential to maximize the potential of hydroponic systems within the economy and ensure their profitability for progressive farmers. In this way, hydroponics can contribute to the country's agricultural sustainability and economic growth.

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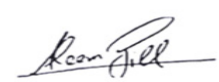
1.	Azeem Sardar	Writeup, Data Analysis, Review, Policy Recommendations	
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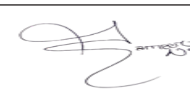
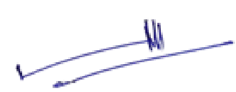
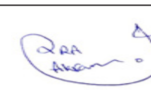
3.	Rameen Shahid	Writeup, Data Analysis, Review, Policy Recommendations	
4.	Khurram Afzal Malik	Writeup, Review, Policy Recommendations	
5.	Iqra Akram	Writeup, Policy Recommendations	
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