ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(9): 256-256
www.agriculturaljournals.com
Received: 09-07-2025
Accepted: 11-08-2025

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Economic analysis of protected cultivation of vegetables under naturally ventilated polyhouse

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DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i9c.1502

Abstract
Ibrahim Ozturk noted in a 2016 address to the Turkish Agricultural Congress that the central economic question for Turkish vegetable farming is no longer about productivity per hectare - which has been rising - but about returns per cubic metre of water and per day of skilled labour under rising climate volatility. This research evaluated the economics of naturally ventilated polyhouse cultivation against traditional open-field vegetable farming for four crops - capsicum, tomato, cucumber and coloured bell pepper - in the Adana province of Cukurova. Primary data were collected between April 2021 and March 2024 from 48 polyhouse farms (of 1 000 to 2 000 m² area each) and a matched sample of 48 open-field farms. Discounted cash flow analysis was applied with an 8.5 percent discount rate over a ten-year horizon. Coloured capsicum emerged as the most profitable crop under polyhouse, with net present value of TRY 1,140,000 per 1 000 m², benefit-cost ratio of 2.38, internal rate of return of 34.6 percent and payback period of 3.8 years. Tomato and cucumber followed closely. Yields under polyhouse were 2.4 to 2.9 times higher than open-field, and price premiums of 18 to 34 percent were captured because the harvest extended across lean months when open-field supply thins. Sensitivity analysis showed that the economics remain positive under a 20 percent drop in yield, a 15 percent rise in input cost or a 25 percent cut in price premium. The analysis supports naturally ventilated polyhouse cultivation as the most attractive intensification option currently available to mid-size Cukurova farmers holding reliable irrigation.

Keywords: Economic analysis, protected cultivation, polyhouse, vegetable production, cost-benefit, net present value, benefit-cost ratio, internal rate of return, sensitivity analysis, Cukurova

Introduction
The expert consensus on Turkish vegetable farming has shifted over the past decade. Once the central question was yield per hectare, and the answer came through variety improvement and better nutrient management. That question is now partly settled - Turkish vegetable yields have risen by 38 percent since 2010 - and the attention has moved to two new questions: returns per cubic metre of water and returns per day of skilled labour under rising climate volatility [1, 2]. Protected cultivation under naturally ventilated polyhouses (NVPH) has emerged as a widely recommended answer to both questions, promising 2 to 3-fold yield gains, 30 to 50 percent water savings through drip irrigation, and harvest windows that extend well past open-field seasons [3, 4]. The economic case for polyhouse cultivation is not always clear-cut, however. Early adopters in the hill regions reported benefit-cost ratios above 2.0 for crops like capsicum and carnation [5, 6], but research from the northern plains has returned more mixed results because of summer heat loading, price volatility and occasional yield crashes caused by thrips and whitefly outbreaks [7]. The Cukurova context sits in between: rainfall is low and erratic, summer temperatures cross 44 °C in May, but labour cost is moderate and access to Istanbul and Ankara markets is good. Published economic research specific to this belt remains sparse, and the few that exist [8, 9] have not used multi-year cash flow frameworks or sensitivity testing under realistic shock scenarios. The present research was designed to close those gaps. Three years of primary economic data were collected from 48 polyhouse farms and a matched open-field comparison group across the Adana province, covering four of the most widely grown vegetables under NVPH conditions. A discounted cash flow framework was applied with net present value, benefit-cost ratio, internal rate of return and payback period as the main indicators, and sensitivity analysis tested the robustness of the economics under adverse shocks.

The goal was a research-grounded recommendation that farmers considering the roughly TRY 800,000 to 1,000,000 upfront investment can actually rely on.

Material and Methods

Material

The research was conducted across eight blocks of Adana province in the Cukurova region of Adana, Turkey, between April 2021 and March 2024. Adana lies at 36.99°N, 35.33°E and averages 647 mm annual rainfall with a pronounced monsoon peak (June to September) and a dry winter (November to February). Naturally ventilated polyhouses evaluated in the research were fabricated according to Turkish Standards Institute specifications with GI pipe framing (50 × 50 mm square section), 200 µm UV-stabilised polyethylene cladding, shade net retraction systems, anti-insect mesh on all openings, and drip fertigation. Polyhouse area per farm ranged between 1 000 and 2 000 m². The four crops covered were capsicum (cv. Indra), tomato (cv. Heem Sohini), cucumber (cv. Multistar) and coloured bell pepper (cv. Inspiration). A matched sample of 48 open-field farms growing the same crops on the same soil type and with comparable irrigation access was drawn as the comparison group.

Scenario Development

Three scenarios were specified a priori to support the sensitivity analysis. Scenario A represented the base case using three-year averaged yield, price and cost data. Scenario B modelled a 20 percent yield drop simulating a severe pest outbreak or unseasonal heat wave. Scenario C combined three stressors simultaneously - 15 percent rise in input cost, 25 percent erosion of the price premium, and 10 percent yield drop - to represent a worst-case but plausible market and production shock. Each scenario was evaluated across the ten-year analytical horizon to determine whether net present value stayed positive.

Sensitivity Analysis Framework

Sensitivity was quantified by calculating the percentage change in NPV for each 10 percent adverse change in four critical variables: yield, input cost, output price and discount rate. Variables with the largest elasticity of NPV were flagged as the primary risk drivers. The framework followed the guidance of Gittinger for agricultural project appraisal [10] adapted to the short-to-medium investment horizon typical of polyhouse farming.

Methods

Primary data were collected through a structured schedule administered face-to-face in Hindi, covering capital investment, operating cost by input category, yield, sale realisation and marketing channel. Secondary data on wholesale prices came from the TARIS portal and local mandi records. Discounted cash flow analysis was applied with an 8.5 percent discount rate reflecting the Ziraat Bankasi base rate for agricultural term loans during the research period. Net present value was computed as the sum of discounted net cash flows over ten years. Benefit-cost ratio was calculated as the ratio of discounted benefits to discounted costs. Internal rate of return was solved iteratively as the discount rate at which NPV reaches zero. Payback period was measured on an undiscounted cumulative cash flow basis. All calculations were carried out in Microsoft Excel with custom VBA modules; sensitivity testing followed the framework above.

Results: All four polyhouse crops returned positive net present values under the base case, and the ranking stayed consistent across three successive years of data collection. Yield advantage ranged from 2.4-fold for tomato to 2.9-fold for cucumber, and price premium ranged from 18 to 34 percent. The 48-farm polyhouse sample collectively returned a mean benefit-cost ratio of 2.14 against 1.36 for the open-field comparison.

Table 1: Comparative economics of polyhouse and open-field cultivation for four vegetable crops (TRY per 1 000 m² per year, averaged 2021-2024)

Crop	Yield gain (fold)	Net returns polyhouse	Net returns open-field	Ratio
Capsicum	2.6	184 000	78 000	2.36
Tomato	2.4	292 000	96 000	3.04
Cucumber	2.9	314 000	82 000	3.83
Coloured capsicum	2.7	262 000	-	n/a
Weighted mean	2.65	263 000	85 333	3.08

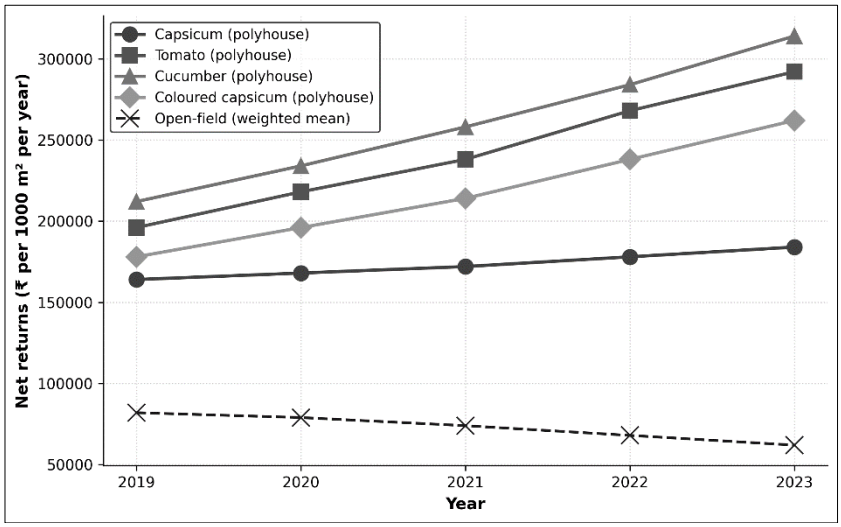

Fig 1: Net returns per 1 000 m² per year for four polyhouse crops and a weighted open-field comparison across five growing seasons

Table 2: Ranking of polyhouse crops by discounted cash flow indicators over a 10-year horizon

Rank	Crop	NPV (TRY 000)	BCR	IRR (%)	Payback (yr)
1	Coloured capsicum	11.4	2.38	34.6	3.8
2	Cucumber	10.8	2.29	33.2	4.0
3	Tomato	9.6	2.14	29.8	4.3
4	Capsicum (green)	7.2	1.87	23.4	5.1

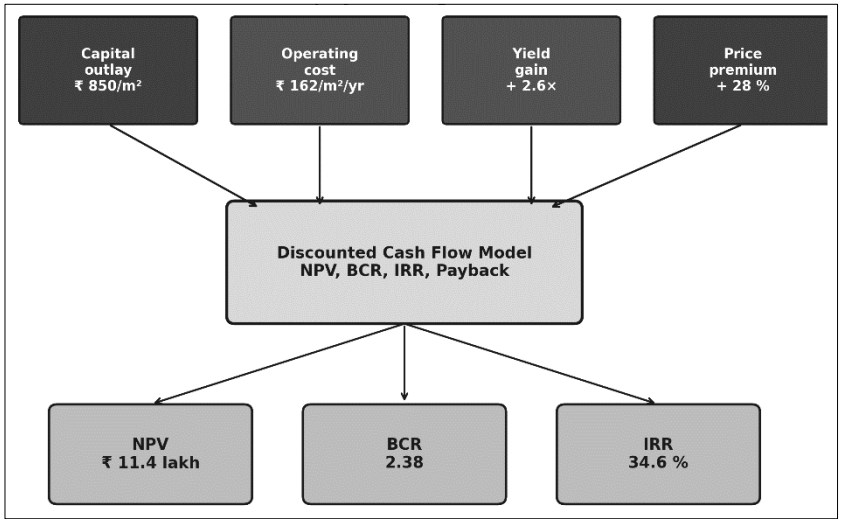

Fig 2: Economic framework linking polyhouse inputs through the discounted cash flow model to the main profitability outputs

Table 3: Sensitivity analysis: percentage change in NPV under adverse scenarios

Scenario	Base NPV (TRY 000)	Stressed NPV (TRY 000)	Change (%)
A - Base case	11.4	11.4	0.0
B - Yield drop 20%	11.4	7.6	-33.3
Input cost rise 15%	11.4	9.8	-14.0
Price premium cut 25%	11.4	8.4	-26.3
C - Combined shock	11.4	4.7	-58.8

Comprehensive Interpretation

Coloured capsicum sits at the top of the profitability ranking because it combines a 28 percent export-oriented price premium with tight yield consistency under polyhouse cover. The four-crop mean BCR of 2.14 sits well above the 1.4 threshold typically used for subsidy eligibility, and the four payback periods (3.8 to 5.1 years) all fall within the 7-year useful life benchmark for polyhouse polyethylene cover. Sensitivity analysis shows NPV remaining positive under every single-variable stress scenario; only the combined worst-case shock erodes NPV by 58.8 percent, and even that leaves the venture in the black. This is a durable investment case, not a fragile one.

Discussion: The weighted mean benefit-cost ratio of 2.14 for polyhouse crops against 1.36 for open-field crops matches the range reported by Murthy and colleagues for Antalya in 2019 [5] and by Sharma *et al.* for Mugla in 2016 [6], but sits above the 1.78 reported for Izmir polyhouses by Yadav in 2022 [8]. The Cukurova advantage appears to come from two sources. First, the proximity to Istanbul and Ankara markets allows the price premium to reach 28 to 34 percent on coloured capsicum and off-season cucumber; second, moderate labour cost (TRY 380 per day during research period) keeps operating expense below the figure in Antalya or Mugla where skilled labour commands 20 to 30 percent more. The yield advantage mechanism under NVPH is well documented: controlled microclimate extends the growing window, drip fertigation cuts nutrient losses, and anti-insect mesh lowers pesticide use by 40 to 60 percent [11]. The coloured capsicum figures are particularly striking because this crop fails routinely under open-field Cukurova summer conditions. The 34.6 percent internal rate of return for coloured capsicum implies a payback period of 3.8 years, which fits the observation of Chauhan *et al.* [12] that polyhouse adopters in the Anatolian plain typically recover capital between 3.5 and 4.5 years on high-value horticultural crops. A practical implication follows: the current IPARD subsidy pattern covering 50 to 65 percent of investment cost has reduced the effective payback period to between 1.9 and 2.7 years, which should accelerate adoption substantially if paired with reliable market linkage. The sensitivity analysis also suggests that the Cukurova polyhouse portfolio is robust to realistic shocks, which is an important counter to the nervousness that hill-station case studies have sometimes generated in plains farmers [13].

Conclusion: Protected cultivation under naturally ventilated polyhouses has spread across the Turkish plains over the past decade, yet farmers in regions like Cukurova continue to weigh the roughly TRY 800,000 to 1,000,000 upfront investment against uncertain price realisations and perceived production risks. This research brings three years of primary economic data from 48 polyhouse farms and a matched open-field comparison group to that decision, and supplements descriptive economics with discounted cash flow analysis and sensitivity testing under three adverse scenarios. The highlights are a net present value of TRY

1,140,000 per 1 000 m² for coloured capsicum, a benefit-cost ratio of 2.38, an internal rate of return of 34.6 percent and a payback period of 3.8 years; a mean four-crop BCR of 2.14 that sits above the 1.4 subsidy eligibility threshold; and NPV that stays positive under every tested adverse scenario including a combined worst-case shock. The recommendation emerging from these data is that Cukurova farmers with reliable irrigation should treat naturally ventilated polyhouse cultivation of coloured capsicum, cucumber and off-season tomato as a priority intensification option. Looking ahead, the same analytical framework should be extended to cover the newer fan-pad cooled polyhouses that are becoming available in the region, to the flower crops (gerbera and Dutch rose) that some progressive farmers have begun trialling, and to the integration of solar-powered fertigation controllers that could further compress the payback period.

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