TECHNICAL AND ECONOMIC EFFICIENCY OF BEEKEEPING PROJECTS IN WASIT GOVERNORATE IN 2025: A CASE STUDY OF AL-KUT DISTRICT

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Abstract. This study evaluates the technical, allocative, and economic efficiency of beekeeping projects in Al-Kut District, Wasit Governorate, Iraq, in 2025. It also examines the current status of beekeeping and the use of economic resources in the study area. Primary data were collected from 32 licensed apiaries selected from approximately 81 licensed and unlicensed apiaries operating in Al-Kut District. The selected apiaries had sufficiently complete records on production, costs, profits, and hive-level characteristics, while secondary data were obtained from the Wasit Directorate of Agriculture. Technical and economic performance was assessed using output-oriented Data Envelopment Analysis (DEA) under constant and variable returns to scale, with the analysis conducted using DEAP software. The results showed that average technical efficiency was approximately 80% under the CRS specification, with six apiaries achieving full technical efficiency, and approximately 87% under the VRS specification, with 16 apiaries achieving full technical efficiency. Average allocative efficiency was 67%, with seven apiaries achieving full allocative efficiency, while average economic efficiency was 59%, with seven apiaries achieving full economic efficiency. These findings indicate considerable scope for improving resource allocation and overall economic performance among the sampled apiaries. The study also found substantial variation in efficiency across apiaries of different sizes. The results highlight the importance of improving resource management, strengthening technical support for beekeepers, and enhancing production and marketing practices in order to improve the economic sustainability of beekeeping projects in the study area.

Keywords: Technical Efficiency; Allocative Efficiency; Economic Efficiency; Data Envelopment Analysis (DEA); Beekeeping; Wasit Governorate; Iraq.

ТЕХНИЧЕСКАЯ И ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ПРОЕКТОВ ПЧЕЛОВОДСТВА В ПРОВИНЦИИ ВАСИТ В 2025 ГОДУ: НА ПРИМЕРЕ РАЙОНА ЭЛЬ-КУТ

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Аннотация. В исследовании оценивается техническая, аллокативная и экономическая эффективность пчеловодческих хозяйств района Эль-Кут провинции Васит, Ирак, в 2025 году. Также рассматриваются современное состояние пчеловодства и особенности использования экономических ресурсов в исследуемой территории. Первичные данные были собраны по 32 лицензированным пасекам, отобранным из примерно 81 лицензированной и нелицензированной пасеки, действующей в районе Эль-Кут. В выборку были включены пасеки, по которым имелись достаточно полные данные о производстве, затратах, прибыли и характеристиках ульев. Вторичные данные были получены из Управления сельского хозяйства провинции Васит.

Техническая и экономическая эффективность оценивалась с использованием ориентированного на выпуск метода анализа среды функционирования (Data Envelopment Analysis, DEA) при постоянной и переменной отдаче от масштаба. Расчёты выполнялись с использованием программного обеспечения DEAP.

Результаты показали, что средняя техническая эффективность при постоянной отдаче от масштаба (CRS) составила приблизительно 80%, при этом 6 пасек достигли полной технической эффективности. При переменной отдаче от масштаба (VRS) средняя техническая эффективность составила приблизительно 87%, а полной технической эффективности достигли 16 пасек. Средняя аллокативная эффективность составила 67%, при этом 7 пасек достигли полной аллокативной эффективности. Средняя экономическая эффективность составила 59%, при этом 7 пасек достигли полной экономической эффективности.

Полученные результаты указывают на наличие значительных возможностей для улучшения распределения ресурсов и повышения общей экономической эффективности исследованных пасек. Также были выявлены различия в уровнях эффективности между пасеками различного размера. Результаты подчёркивают важность совершенствования управления ресурсами, развития технической поддержки пчеловодов, а также повышения эффективности производственной и маркетинговой деятельности для улучшения экономической устойчивости пчеловодства в исследуемом районе.

Ключевые слова: техническая эффективность; аллокативная эффективность; экономическая эффективность; анализ среды функционирования (DEA); пчеловодство; провинция Васит; Ирак.

Introduction

Humans have practiced beekeeping since approximately 2400 BCE. Although human management has influenced the genetic composition of honey bee populations, the species has not been fully domesticated because queens continue to mate freely with drones outside the hive (Du et al., 2024).

Beekeeping provides numerous economic and agricultural benefits through the production of honey, pollen, propolis, royal jelly, bee venom, beeswax, and other products. Historically, honey bees were not intensively managed; instead, people often provided simple shelters in which wild colonies could establish themselves. Over time, major technological developments substantially improved the management and control of honey bee colonies. These developments included the discovery of “bee space,” the introduction of the movable-frame Langstroth hive in 1851, the queen excluder in 1849, and the honey extractor in 1867. The discovery that queens and drones mate in flight outside the hive also had important implications for honey bee breeding (Oxley & Oldroyd, 2010).

Consequently, beekeeping is considered one of the oldest agricultural and economic activities. It is a relatively accessible agricultural enterprise that generally requires less initial capital than many other productive activities. In addition, beekeeping can be integrated with other agricultural activities and provides opportunities for individuals to develop practical skills in hive management, production, and small-scale enterprise management (Khalil et al., 2025).

Honey bees live in highly organized social colonies within structures known as hives. Their colonies consist of individuals that perform specialized and cooperative functions essential for colony survival. In addition to producing honey and other bee products, honey bees provide substantial nutritional, economic, and ecological benefits.

One of the most important roles of honey bees is pollination. While collecting nectar and pollen, honey bees contribute to the pollination of numerous cultivated and wild plant species, thereby supporting agricultural productivity and ecosystem functioning (Al-Dulaimi, 2025). In addition to their pollination services, colony health is an important determinant of sustainable beekeeping. Breeding for hygienic behavior has been associated with reduced Varroa infestation and lower viral loads, which may contribute to improved colony health and resilience (Erez et al., 2022).

Beekeeping contributes not only to the production of food and other valuable bee products but also to the conservation of biodiversity and the maintenance of ecological balance. Through their

pollination activity, honey bees support the reproduction of both cultivated and wild plant species and thereby contribute to the stability of natural and agricultural ecosystems.

However, modern beekeeping faces several challenges that can adversely affect colony health, productivity, and survival. These include agricultural intensification, climate change, pesticide exposure, habitat degradation, and various diseases and parasites (Palacio et al., 2024).

One of the most important honey bee species used in beekeeping is the Western honey bee (*Apis mellifera* L.), which is native to Eurasia and Africa. Friedrich Ruttner, a pioneer in honey bee taxonomy, identified 24 subspecies based on 36 morphological traits, including hair density, pigmentation, the length of various body parts, wing venation, and other characteristics (Rodrigues et al., 2022; Meixner et al., 2010).

Honey bee health and genetic resistance to parasites are increasingly important considerations in sustainable beekeeping and breeding programs. In particular, resistance to *Varroa destructor* has been shown to have a complex polygenic architecture, highlighting the importance of genetic factors in the development of more resilient honey bee populations (Eynard et al., 2025). At the same time, effective hive management and breeding practices remain important for maintaining productive and sustainable colonies (Qu et al., 2025; De Iorio et al., 2026).

Beekeeping success and the rate of colony proliferation depend on the ability to create optimal conditions within the hive under both cold and hot conditions, as well as on the ability of honey bee colonies, as social organisms, to maintain internal thermal balance, thereby supporting rapid and steady colony growth (Stabentheiner et al., 2021).

Honey bee breeding programs are relatively recent in most countries and vary among diverse, small-scale breeding groups; beekeepers themselves exhibit a wide range of motivations and management practices. Nevertheless, little is known about the breeding objectives that beekeepers prioritize when designing these programs (Kistler et al., 2026).

For beekeepers, the success of a honey bee colony is often measured by the amount of honey produced during the flowering season, a yield that depends on numerous factors, including the colony's location and environmental conditions, the availability of forage, weather conditions during pollen and nectar foraging flights, and the colony's health status. Furthermore, the genetic makeup of the queen bee is of critical importance in this regard, as she is the only reproductive female in the colony and lays the eggs that develop into worker bees (Meyer-Rochow & Jung, 2019; Uzunov et al., 2017).

Beekeeping is subject to strong natural selection pressures driven by climate change, pesticide exposure, and habitat fragmentation. These factors can cause colony losses, resulting in economic damage and reduced genetic diversity, thereby increasing interest in honey bee breeding and conservation programs (Obšteter et al., 2023). In recent years, honey bee breeding has attracted significant scientific attention, as reflected in numerous theoretical and practical advances. In particular, the selection of high-quality drones is crucial for the success of breeding programs in the medium and long term (Du et al., 2021a, 2021b).

Beekeeping is an agricultural activity aimed at producing honey and other bee products; it also provides benefits such as improved seed production and environmental protection and can be practiced by both men and women. It is considered a successful agricultural activity in rural areas of developing countries because of its numerous economic benefits (Gakenia et al., 2024). It serves as a significant source of income and an important economic activity for the livelihoods of many people. At the same time, market dynamics and traditional beekeeping practices influence beekeepers' management methods and the demand for high-quality queen bees (Dimitrov et al., 2024).

Honey bees play a pivotal role in maintaining ecological balance and can serve as environmental indicators, while also supporting the global agricultural economy through pollination services and the production of bee products. Approximately one-third of the global food supply depends, directly or indirectly, on pollination services provided by bees and other insects, underscoring their considerable economic and ecological value. Therefore, a decline in bee populations may pose a serious threat to food security, biodiversity, and, ultimately, human well-being (Lin et al., 2025; Kaskinova et al., 2023).

Importance of the Research: The significance of this research lies in assessing the economic and technical efficiency of beekeeping operations, as well as the economic, nutritional, and medicinal value of honey bees. Beekeeping has attracted considerable interest among producers, particularly in rural areas, due to the suitability of the Iraqi environment for this economic activity. It plays a major role in promoting economic and social development by providing various products and creating employment opportunities. In recent years, beekeeping has expanded significantly, driven by factors such as rising honey prices and growing demand in both global and local markets, which has facilitated the marketing of honey and other bee products. Honey is used for various nutritional and medicinal purposes, which contributes to its significant economic value and high demand. Investment in this sector and encouraging individuals to establish apiaries can contribute to reducing youth unemployment, particularly among graduates of agricultural colleges, institutes, and schools. Beekeeping is a profitable small-scale agricultural activity that requires relatively limited capital.

The selection of Al-Kut District as the study area was justified by the active presence of beekeeping in the district, where approximately 81 licensed and unlicensed apiaries were identified during the study period.

Research Problem: The main research problem is to determine the extent to which the sampled beekeeping projects use their available production resources efficiently and whether differences exist between technical, allocative, and economic efficiency. The study therefore focuses on identifying the degree of inefficiency in the sampled apiaries and assessing their production costs, output, and economic returns.

Research Hypothesis: The technical and economic efficiency of the beekeeping apiaries included in the study sample is below full efficiency.

Research Objectives

The research aims to:

1) Measure the technical, allocative, and economic efficiency of the beekeeping projects included in the study sample.

2) Examine the current structure of beekeeping in Al-Kut District and evaluate the use of the principal economic resources employed in honey production.

3) Estimate annual production costs, production value, and net profit per hive.

Scientific Novelty and Contribution

The scientific contribution of this study lies in the application of an output-oriented Data Envelopment Analysis framework to farm-level data from beekeeping projects in Al-Kut District, Wasit Governorate. The study jointly evaluates technical, allocative, and economic efficiency and complements the DEA results with a detailed assessment of production costs, seasonal honey output, production value, and net profit per hive. This integrated approach provides locally specific evidence on the efficiency and economic performance of beekeeping projects under the production and market conditions prevailing in the study area in 2025. In addition, the distinction between efficiency estimates under constant and variable returns to scale makes it possible to identify the potential contribution of scale-related factors to the observed differences in performance among the sampled apiaries.

Data Sources and Sample Selection

The study was based primarily on cross-sectional data collected from apiary owners in Al-Kut District, Wasit Governorate, during 2025. Approximately 81 licensed and unlicensed apiaries were operating in the study area. The final sample consisted of 32 licensed apiaries for which sufficiently complete records were available on the number of hives, labor use, production, production costs, input-related expenditures, honey prices, and revenues. Apiaries for which the required production and cost information was unavailable or could not be reliably obtained were excluded from the analytical sample. Primary data were collected through a structured questionnaire administered through personal interviews and telephone contact with apiary owners. Secondary information was obtained from the Wasit Directorate of Agriculture.

The sampled apiaries varied considerably in size, ranging from approximately 10 to 112 hives, thereby allowing efficiency comparisons across production units of different scales.

DEA Model Specification

Technical, allocative, and economic efficiency were estimated using Data Envelopment Analysis (DEA) with DEAP software. Each apiary was treated as a separate decision-making unit (DMU). The analysis adopted an **output-oriented specification**, reflecting the objective of assessing the extent to which honey output could be increased using the resources available to each apiary.

The principal production inputs considered in the analysis were **capital-related production resources** and **labor**, while total honey production represented the production output. Labor use was recorded in working hours, honey output was measured in kilograms, and monetary variables and input-price information were expressed in Iraqi dinars (IQD). Cost information was derived from the questionnaire records on hive and equipment costs, their useful lives, labor and other operating expenditures, while honey production and prices were recorded separately for the summer and autumn production seasons.

Resource-price and cost information was obtained directly from the questionnaire records of the sampled apiaries rather than from an external market-price database. The sample-average reported purchase prices were 22,031.25 IQD for a wooden hive, 8,468.75 IQD for a honey super box, 56,875.00 IQD for a set of twenty frames, 118,437.50 IQD for a bee package or colony, 186,093.75 IQD for a honey extractor, and 19,031.25 IQD for apiary tools. Their corresponding average reported useful lives were 14.781, 15.438, 4.531, 2.844, 19.625, and 4.500 years, respectively. These price and useful-life data were used to derive annualized production-resource costs. Labor wages and other operating expenditures were recorded in the questionnaire as a combined annual cost category; therefore, a separate hourly market wage was not available. The recorded monetary cost information, expressed in Iraqi dinars (IQD), was used together with the observed input quantities in the assessment of allocative and economic efficiency.

Technical efficiency was evaluated under both constant returns to scale (CRS) and variable returns to scale (VRS). CRS efficiency reflects overall technical efficiency, whereas the VRS specification separates managerial or pure technical efficiency from scale effects. Scale efficiency was assessed through the relationship between CRS and VRS technical-efficiency scores. For the estimation of allocative and economic efficiency, observed input quantities and the corresponding cost information were incorporated into the DEA model. Efficiency scores range from 0 to 1, with a score of 1 indicating an efficient apiary located on the estimated efficiency frontier.

For transparency and reproducibility, the principal apiary-level input and output data underlying the DEA analysis are presented in Table 3 for all 32 decision-making units (DMUs).

Table 1. Variables Used in the DEA Analysis

Variable	Role in the Model	Measurement
Capital-related production resources	Input	Iraqi dinars (IQD)
Labor	Input	Working hours per apiary
Honey production	Output	Kilograms per apiary
Input cost/price information	Used for allocative and economic efficiency	Iraqi dinars (IQD)

Note: Cost information was obtained from the questionnaire and included annualized hive and equipment costs together with labor and other production-related expenditures. Honey output represents the combined production recorded for the summer and autumn seasons.

Source: Authors' calculations based on the 2025 field survey.

Economic Importance of Beekeeping: Honey bees have economic, nutritional, and medicinal importance. Honey bee colonies are highly organized social systems in which individuals work for the benefit of the colony, and the colony consists of one queen, several thousand female workers, and a few dozen males.

Beekeeping is an important source of income and an essential economic activity for the livelihoods of many people. However, there is still a lack of knowledge and research related to its economic aspects; therefore, this sector requires greater attention in order to improve its efficiency and development.

One of the most important bee products is honey, and current economic analyses have focused mainly on this product. Other bee products, including pollen, propolis, royal jelly, bee venom, and beeswax, have also become increasingly important because of their high economic value and pharmacological properties. Living materials such as bee colonies, bee packages, and queen bees are additional products of the hive, and their economic importance should not be overlooked.

In view of the current difficulties associated with honey production and marketing, economic research has increasingly focused on the value of the ecosystem services provided by beekeeping to agriculture and biodiversity, in addition to the profitability of beekeeping itself. Honey bees are globally recognized as pollinators of great economic importance for both crops and wild plants, and beekeeping can have a significant social and economic impact on household income. Therefore, losses of honey bee colonies caused by factors such as land management, pesticide use, and queen-related problems, including poor health and advanced age, may have serious economic consequences.

The Reality of Bee Honey Production in Wasit Governorate (Al-Kut Center)

Wasit Governorate is one of the most important honey-producing governorates because of its vast agricultural lands, good vegetation cover, and the large areas cultivated with jut and alfalfa crops, which provide abundant nectar and pollen preferred by bees. The governorate also contains large orchards with various types of citrus trees and Sidr trees (buckthorn). The number of licensed and unlicensed apiaries in Al-Kut Center reached approximately 81 apiaries, including both large and small operations. The number of hives in a single apiary ranges from 10 to 112 or more.

Theoretical Framework: The study and analysis of production costs, revenues, and returns obtained from honey production are of great importance in identifying the strengths and weaknesses of this agricultural activity. Such analysis helps in taking measures to improve production and the economic efficiency of the use of beekeeping resources, including colonies, hives, nutrition, and labor. This may encourage current producers to expand their activities and motivate others to enter this field.

The Concept of Efficiency

Efficiency has been defined in the management literature in several ways. In general, it reflects the extent to which available resources (inputs) are converted into results (outputs) in an economical manner. In other words, efficiency represents the relationship between available resources and the outputs achieved, either by maximizing output from a given amount of inputs or by minimizing the inputs required to achieve a given level of output.

Efficiency can also be understood as the ability to perform the required activity with the least possible use of resources and costs. Thus, efficiency is related to how a production unit uses its available resources in relation to the outputs achieved. It is clear from these definitions that resources should be used rationally and effectively; therefore, efficiency can be understood as doing things correctly.

Types of Efficiency

A. Technical Efficiency (TE): Technical efficiency refers to the ability of a farm to use the optimal combination of available inputs to obtain the maximum possible level of production (Al-Hajami & Al-Aqili, 2015). It is a measure of the ability of a production unit to achieve the maximum possible output from a given amount of resources. The value of technical efficiency ranges between 0 and 1. A production unit achieves full technical efficiency when its technical efficiency score is equal to 1. It can also be defined as the operational position of a production unit in relation to the production frontier, where a unit operating on the frontier is considered technically efficient (Moaz & Ahmed, 2020).

B. Allocative Efficiency (AE): Allocative efficiency refers to the ability of a production unit to use inputs in optimal proportions, given their respective prices and the available production technology.

C. Economic Efficiency (EE): Economic efficiency refers to the use of combinations of production resources, under prevailing relative prices, in a way that maximizes profit (Zeidan et al., 2014). It can also be defined as the use of production resources in such a way that a greater level of output can be achieved at the same production cost, or the same level of output can be achieved at a lower cost.

D. Scale Efficiency (SE): Scale efficiency is determined by comparing technical efficiency under constant returns to scale (CRS) with technical efficiency under variable returns to scale (VRS). It is calculated as the ratio of technical efficiency under CRS to technical efficiency under VRS (Moaz & Ahmed, 2020).

Results and Discussion

The output-oriented DEA model was applied under both constant returns to scale (CRS) and variable returns to scale (VRS). Efficiency scores range from 0 to 1, with a score of 1 indicating that an apiary operates on the estimated efficiency frontier. Under the CRS specification, the average technical efficiency of the sampled apiaries was approximately 80%, and 6 of the 32 apiaries achieved full technical efficiency. This result indicates that a substantial proportion of the sampled apiaries operated below the overall CRS efficiency frontier.

Under the VRS specification, average technical efficiency increased to approximately 87%, with 16 apiaries achieving a technical-efficiency score of 1.00. Ten apiaries recorded efficiency scores between 75% and 99%, while six apiaries recorded scores between 50% and 74%. No apiary recorded a VRS technical-efficiency score below 50%. The difference between the CRS and VRS results indicates that part of the observed inefficiency may be associated with scale effects rather than purely with resource-management performance. Capital and labor were also examined as principal production inputs. The results indicated that capital was used efficiently in approximately 11 apiaries, while labor reached the corresponding efficient level in approximately 28 apiaries. When input quantities and their associated cost information were incorporated into the analysis, allocative and economic efficiency were estimated as presented in Table 2.

Table 2. Distribution of Apiaries by VRS Technical, Allocative, and Economic Efficiency Levels

Efficiency Level	**Technical Efficiency (TE)**	**Allocative Efficiency (AE)**	**Economic Efficiency (EE)**
100%	16	7	7
75–99%	10	5	4
50–74%	6	10	4
Less than 50%	0	10	17
Total	**32**	**32**	**32**

Source: Authors' calculations based on the results obtained using DEAP software.

The VRS results showed that the average technical efficiency was approximately 87%, with 16 apiaries achieving full technical efficiency. The average allocative efficiency was approximately 67%, with seven apiaries achieving full allocative efficiency, while the average economic efficiency was approximately 59%, with seven apiaries achieving full economic efficiency. Apiaries No. 3, 6, 8, 17, 19, 22, and 25 achieved 100% efficiency across all three efficiency measures reported in Table 2.

The difference between average technical efficiency under CRS (approximately 80%) and VRS (approximately 87%) suggests that scale-related factors contributed to the overall inefficiency observed in the sample. However, the present study did not estimate a single optimal number of hives applicable to all apiaries.

To improve the transparency of the efficiency analysis, Table 3 presents the apiary-level input and output data for all 32 decision-making units (DMUs) included in the study.

Table 3. Apiary-Level Input and Output Data for the 32 Decision-Making Units (DMUs)

Apiary No.	Number of Hives	Labor Input (hours)	Capital-Related Production Resources (IQD)	Total Honey Output (kg)
1	17	102	1,256,633.333	131.75
2	35	210	2,079,500.000	332.50
3	112	672	5,838,596.491	1,372.00
4	15	90	1,141,000.000	153.75
5	20	120	1,557,500.000	285.00
6	11	66	796,533.333	101.75
7	26	156	1,697,811.111	208.00
8	13	78	1,000,666.667	130.00
9	35	210	3,474,637.255	393.75
10	20	120	1,497,833.333	240.00
11	11	66	858,033.333	99.00
12	10	60	861,583.333	65.00
13	15	90	1,395,000.000	123.75
14	18	108	1,233,600.000	180.00
15	65	390	5,946,666.667	910.00
16	45	270	3,375,000.000	540.00
17	25	150	1,608,624.359	312.50
18	12	72	946,900.000	102.00
19	95	570	5,813,666.667	1,353.75
20	10	60	794,833.333	75.00
21	12	72	984,500.000	105.00
22	40	240	3,531,861.111	520.00
23	10	60	725,166.667	55.00
24	10	60	748,350.000	95.00
25	75	450	4,305,000.000	1,143.75
26	18	108	1,255,700.000	211.50
27	12	72	767,150.000	90.00
28	67	402	3,583,366.667	552.75
29	85	510	4,886,333.333	1,020.00
30	13	78	867,766.667	182.00
31	10	60	835,083.333	85.00
32	30	180	1,626,500.000	307.50

Note: Each apiary was treated as an individual decision-making unit (DMU). The number of hives is reported as a descriptive indicator of apiary size and was not included as a separate DEA input. Labor input is expressed as the total number of working hours recorded for each apiary. Capital-related production resources are expressed in Iraqi dinars (IQD), while total honey output represents the combined quantity of honey produced during the summer and autumn production seasons.

Source: Authors' calculations based on the 2025 field survey and questionnaire data.

Table 3 shows considerable variation in the production scale of the sampled apiaries. The number of hives ranged from 10 to 112, labor input ranged from 60 to 672 working hours, and total honey output ranged from 55.00 to 1,372.00 kg per apiary. These observations provide the principal apiary-level input and output data used in the DEA analysis. The number of hives is presented for descriptive comparison of apiary size, whereas labor, capital-related production resources, and honey output correspond to the variables specified in the DEA model.

Table 4. Average Annualized Production Costs per Hive

Item	Useful Life (Years)	Annualized Cost per Hive (IQD)
Wooden hive (box, bottom board, cover, and stand)	14.781	1,490.511

Item	Useful Life (Years)	Annualized Cost per Hive (IQD)
Honey super box	15.440	548.494
Set of twenty frames	4.531	627.621
Bee package / colony	2.844	41,644.691
Honey extractor	19.625	9,482.497
Apiary tools	4.500	4,229.167
Labor and other operating costs per hive	—	11,819.556
Total Annual Cost	—	**69,842.537**

Note: Annualized costs for depreciable hive and equipment items were calculated on the basis of their recorded purchase prices and reported useful lives. The corresponding annual costs were then expressed on a per-hive basis. No separate salvage-value information was available in the source records used for these calculations.

Labor wages and other operating expenditures were recorded in the questionnaire as an aggregated cost category. Therefore, individual components such as supplemental feeding, veterinary treatments, transportation, fuel, maintenance, and other operating expenses could not be reported separately where they were not independently identified in the original records.

Source: Authors' calculations based on data collected through the 2025 questionnaire.

Table 4 shows the average annualized cost structure per hive. The largest cost component was the bee package or colony, while labor and other operating expenditures also represented an important part of annual production costs. The annualization of durable assets reflects differences in their reported useful lives and avoids treating the full purchase price of long-lived equipment as a one-year production expense.

Table 5. Average Honey Production, Price, and Production Value per Hive by Season

Season	Average Honey Production (kg/hive)	Average Price (IQD/kg)	Average Production Value (IQD/hive)
Summer	9.656	24,046.875	232,196.625
Autumn	0.695	51,000.000	35,445.000
Total	**10.351**	—	**267,641.625**

Note: The quantities and prices presented in Table 5 are sample averages calculated from apiary-level observations for the summer and autumn production seasons. The reported production values were calculated from the individual apiary records. Therefore, because the table presents rounded averages, the multiplication of the average quantity by the average price may differ slightly from the reported average production value. The difference between summer and autumn prices reflects the seasonal prices reported by the sampled beekeepers. The present study does not attempt to estimate the determinants of seasonal price variation.

Source: Authors' calculations based on data collected through the 2025 questionnaire.

The results indicate clear seasonal differences in both honey production and market prices. Average honey production was substantially higher during the summer season, reaching 9.656 kg per hive, compared with 0.695 kg per hive during the autumn season. In contrast, the average reported price of autumn honey was considerably higher than the summer price, reaching 51,000 IQD/kg compared with 24,046.875 IQD/kg. The combined average production value from the two seasons amounted to 267,641.625 IQD per hive.

Table 6. Average Net Profit per Hive

Description	Value (IQD/hive)
Total Production Value	267,641.625

Description	Value (IQD/hive)
Total Annual Cost	69,842.537
Net Profit	**197,799.088**

Source: Authors' calculations based on data collected through the 2025 questionnaire.

The average total production value per hive was 267,641.625 IQD, while the average annual production cost amounted to 69,842.537 IQD. Accordingly, the estimated average net profit was 197,799.088 IQD per hive.

Net Profit = Total Production Value − Total Annual Cost

Net Profit = 267,641.625 − 69,842.537 = 197,799.088 IQD per hive

A descriptive comparison of the sampled apiaries suggests that apiaries with higher efficiency scores generally tended to have larger numbers of hives and higher honey output. However, the present study did not formally test the statistical relationship between apiary size and efficiency. Therefore, this pattern should be interpreted as descriptive rather than causal. Labor also represented an important component of production costs, particularly in smaller apiaries.

The empirical results indicate several key economic and management constraints affecting the sampled apiaries. First, allocative and economic efficiency were substantially lower than technical efficiency, indicating that resource allocation remains an important source of inefficiency. Second, the bee package or colony represented the largest annualized cost component per hive. Third, substantial seasonal differences were observed in both honey production and selling prices. These findings suggest that the main problems identified in the sampled apiaries were related primarily to resource allocation, production costs, and seasonal market conditions.

Discussion in Relation to Previous Studies

The findings of the present study can be considered in relation to previous economic research on beekeeping and agricultural production efficiency. Khalil et al. (2025) examined honey-production projects of different production capacities and emphasized the importance of production scale and resource use for financial performance. Similarly, the present study revealed substantial differences among the sampled apiaries in production scale, costs, honey output, and efficiency.

Previous research in Iraq has also examined production costs and economies of scale in honey production. Zeidan et al. (2014) analyzed cost functions and economies of scale in Diyala Governorate. The present study complements this earlier work by using Data Envelopment Analysis to evaluate technical, allocative, and economic efficiency at the individual-apiary level.

An important result of the present study is the difference between technical and economic performance. Average VRS technical efficiency was approximately 87%, whereas average allocative efficiency was 67% and average economic efficiency was 59%. This indicates that relatively high technical efficiency does not necessarily mean that production resources are being allocated in the most economically efficient manner. The distinction between technical, allocative, and scale efficiency has also been applied in previous agricultural DEA research, including Moaz and Ahmed (2020).

Direct numerical comparisons between the present study and previous studies should be interpreted cautiously because of differences in geographical location, sample size, production conditions, study period, and analytical methodology.

Conclusions

1. Under the CRS specification, the average technical efficiency of the sampled apiaries was approximately 80%, with six apiaries achieving full technical efficiency. Under the VRS specification, average technical efficiency increased to approximately 87%, with 16 apiaries achieving full technical efficiency.
2. The average allocative efficiency was approximately 67%, while the average economic efficiency was approximately 59%. Seven apiaries achieved full allocative efficiency and

seven achieved full economic efficiency. Apiaries No. 3, 6, 8, 17, 19, 22, and 25 achieved 100% efficiency across all three efficiency measures reported in the study.

3. The difference between technical and economic efficiency indicates that the main opportunities for improving performance are related not only to production technology, but also to the allocation and cost-effective use of available resources.
4. The average annual production cost was estimated at 69,842.537 IQD per hive, while the average production value was 267,641.625 IQD per hive. Consequently, the estimated average net profit amounted to 197,799.088 IQD per hive.
5. A descriptive comparison indicated that apiaries with higher efficiency scores generally tended to have larger numbers of hives and higher honey output. However, because this relationship was not formally tested statistically, the findings should not be interpreted as evidence of a causal relationship or as identifying a specific optimal apiary size.

Recommendations

Beekeepers should improve the management and allocation of available production resources, particularly labor and capital, in order to reduce inefficiencies and improve overall economic performance.

Owners of smaller apiaries may consider expanding the number of hives where such expansion is economically and technically feasible. However, because the present study did not estimate a specific optimal apiary size, expansion decisions should be based on the individual cost structure, management capacity, and production conditions of each apiary.

Governmental and agricultural institutions should support beekeeping projects through technical assistance, extension services, specialized training programs, and access to appropriate financing, particularly for small-scale beekeepers seeking to improve production efficiency.

Greater attention should be given to honey marketing and pricing mechanisms. Improved market information, organized marketing channels, and better coordination between producers and buyers may help reduce uncertainty and improve the economic returns of beekeeping projects.

Agricultural extension centers should provide regular training on hive management, disease and parasite control, feeding practices, cost management, and efficient use of production resources.

Future studies should use larger and more geographically diverse samples, include multi-year data, and formally examine the relationship between apiary size and efficiency in order to determine whether economies of scale exist and to identify economically justified production scales.

Study Limitations

This study has several limitations that should be considered when interpreting the results. First, the analysis was based on a cross-sectional sample of 32 licensed apiaries in Al-Kut District selected primarily on the basis of the availability and completeness of production and cost records. Therefore, the sample should not be considered statistically representative of all apiaries in Wasit Governorate or Iraq.

Second, the study covers a single production year, 2025. Consequently, the estimated efficiency levels, production costs, honey output, and prices may have been influenced by year-specific climatic, production, and market conditions.

Third, part of the production and cost information was obtained directly from apiary owners through questionnaires, personal interviews, and telephone contacts. Therefore, some observations may be affected by differences in record-keeping accuracy or reporting.

Fourth, labor wages and other operating expenditures were recorded as an aggregated cost category. Consequently, individual components such as supplemental feeding, veterinary treatments, transportation, fuel, maintenance, and other miscellaneous operating expenses could not be separately evaluated where they were not independently identified in the original records.

Finally, although descriptive differences in efficiency were observed among apiaries of different sizes, the study did not formally test the statistical relationship between the number of hives and efficiency and did not estimate a specific optimal apiary size. Future research should

address these issues using larger and more geographically diverse samples, multi-year observations, and more detailed apiary-level production and cost records.

References

1. Al-Hajami, Issa Sawadi, & Al-Aqili, Osama Kazem. (2015). A study to measure the technical and economic efficiency of approved varieties of wheat crop in irrigated areas in Iraq for the 2012–2013 season. *Iraqi Journal of Agricultural Sciences, 46*(4), 569–583.
2. Khalil, Yahya Mohamed Metwally, Abdel Gawad, Mona Shehata Al-Sayed, & Mahmoud, Nermeen Mohamed. (2025). Financial evaluation of different production capacities of bee honey production projects in Fayoum Governorate. *Egyptian Journal of Agricultural Economics, 35*(2), 648–667.
3. Al-Dulaimi, Sabah Nouri Mohamed. (2025). The deterioration of honey beekeeping and apiary management in Al-Rashidiya District and the factors affecting it. *Madad Al-Adab, 15*(41), 1023–1070.
4. Zeidan, Ali Ghaidan, et al. (2014). An economic study to estimate the cost functions and economies of scale of bee honey production in Diyala Governorate. *Diyala Journal of Agricultural Sciences, 6*(1), 239–250.
5. Moaz, Saeed Hassan Ali, & Ahmed, Fawzy Abdel Hamid. (2020). Technical and economic efficiency of date processing in New Valley Governorate. *Egyptian Journal of Agricultural Economics, 30*(3), 777–791.
6. De Iorio, M. G., Lazzari, B., Cozzi, M. C. S., Polli, M., & Minozzi, G. (2026). Variability and number of circulating *csd* alleles in a honey bee breeding population after four years of single-drone insemination. *Genes, 17*(1), 86. https://doi.org/10.3390/genes17010086
7. Dimitrov, L., Uzunov, A., Andonov, S., Costa, C., Meixner, M. D., Le Conte, Y., Mondet, F., Kovacic, M., Carreck, N. L., Basso, B., Bienkowska, M., Dall'Olio, R., Charistos, L., Hatjina, F., Wirtz, U., & Büchler, R. (2024). Economic aspects of honey bee queen breeding: Insights from a European study. *Journal of Apicultural Research, 63*(4), 813–821. https://doi.org/10.1080/00218839.2024.2361944
8. Du, M., Bernstein, R., & Hoppe, A. (2024). The number of drones to inseminate a queen with has little potential for optimization of honeybee breeding programs. *Hereditas, 161*, 28. https://doi.org/10.1186/s41065-024-00332-0
9. Gakenia, N. M., Mbavha, B. T., Oh, D., Akongte, P. N., Lee, C., Choi, Y. S., & Kim, D. (2024). Case studies for honey bee breeding research: Beekeeping status in Kenya. *Journal of Apiculture, 39*(3), 151–162.
10. Du, M., Bernstein, R., Hoppe, A., & Bienefeld, K. (2021a). A theoretical derivation of response to selection with and without controlled mating in honeybees. *Genetics Selection Evolution, 53*, 17. https://doi.org/10.1186/s12711-021-00606-5
11. Du, M., Bernstein, R., Hoppe, A., & Bienefeld, K. (2021b). Short-term effects of controlled mating and selection on the genetic variance of honeybee populations. *Heredity, 126*(5), 733–747. https://doi.org/10.1038/s41437-021-00411-2
12. Erez, T., Bonda, E., Kahanov, P., Rueppell, O., Wagoner, K., Chejanovsky, N., & Soroker, V. (2022). Multiple benefits of breeding honey bees for hygienic behavior. *Journal of Invertebrate Pathology, 193*, 107788. https://doi.org/10.1016/j.jip.2022.107788
13. Eynard, S. E., Mondet, F., Basso, B., Bouchez, O., Le Conte, Y., Dainat, B., Decourtye, A., Genestout, L., Guichard, M., Guillaume, F., Labarthe, E., Locke, B., Mahla, R., de Miranda, J., Neuditschko, M., Phocas, F., Canale-Tabet, K., Vignal, A., & Servin, B. (2025). Sequence-based multi-ancestry association study reveals the polygenic architecture of *Varroa destructor* resistance in the honeybee *Apis mellifera*. *Molecular Ecology, 34*(3), e17637. https://doi.org/10.1111/mec.17637
14. Kaskinova, M. D., Salikhova, A. M., Gaifullina, L. R., & Saltykova, E. S. (2023). Genetic methods in honey bee breeding. *Vavilov Journal of Genetics and Breeding, 27*(4), 366–372. https://doi.org/10.18699/VJGB-23-44

15. Kistler, T., Basso, B., Lauvie, A., & Phocas, F. (2026). Beekeepers' preferences for honeybee breeding goals: A French case study. *bioRxiv*. https://doi.org/10.64898/2026.01.28.701934
16. Lin, Z., Yang, L., Wang, Z., Wang, K., Niu, Q., & Ji, T. (2025). Honey bee breeding and breed: Advancements, challenges, and prospects. *Animal Research and One Health, 3*(4), 350–357. https://doi.org/10.1002/aro2.70003
17. Meixner, M. D., Costa, C., Kryger, P., Hatjina, F., Bouga, M., Ivanova, E., & Büchler, R. (2010). Conserving diversity and vitality for honey bee breeding. *Journal of Apicultural Research, 49*(1), 85–92. https://doi.org/10.3896/IBRA.1.49.1.12
18. Meyer-Rochow, V. B., & Jung, C. (2019). Remote honey bee breeding centre: A case study of Heligoland Island in Germany. *Journal of Apiculture, 34*(4), 285–293. https://doi.org/10.17519/apiculture.2019.11.34.4.285
19. Obšteter, J., Strachan, L. K., Bubnič, J., Prešern, J., & Gorjanc, G. (2023). SIMplyBee: An R package to simulate honeybee populations and breeding programs. *Genetics Selection Evolution, 55*, 31. https://doi.org/10.1186/s12711-023-00798-y
20. Oxley, P. R., & Oldroyd, B. P. (2010). The genetic architecture of honeybee breeding. In *Advances in Insect Physiology* (Vol. 39, pp. 83–118). Academic Press. https://doi.org/10.1016/B978-0-12-381387-9.00003-8
21. Palacio, M. A., Guzman-Novoa, E., Scannapieco, A. C., Giacobino, A., & Mondet, F. (2024). Editorial: Current status of honey bee genetic and breeding programs: Progress and perspectives. *Frontiers in Insect Science, 4*, 1365665. https://doi.org/10.3389/finsc.2024.1365665
22. Qu, X., Zhang, X., Zhang, G., Qin, H., Zhang, H., Tian, H., & Chen, X. (2025). Investigations on beekeeping and breeding of *Apis cerana* in China. *Life, 15*(1), 9. https://doi.org/10.3390/life15010009
23. Rodrigues, P. J., Gomes, W., & Pinto, M. A. (2022). DeepWings©: Automatic wing geometric morphometrics classification of honey bee (*Apis mellifera*) subspecies using deep learning for detecting landmarks. *Big Data and Cognitive Computing, 6*(3), 70. https://doi.org/10.3390/bdcc6030070
24. Stabentheiner, A., Kovac, H., Mandl, M., & Käfer, H. (2021). Coping with the cold and fighting the heat: Thermal homeostasis of a superorganism, the honeybee colony. *Journal of Comparative Physiology A, 207*(3), 337–351. https://doi.org/10.1007/s00359-021-01464-8
25. Uzunov, A., Brascamp, E. W., & Büchler, R. (2017). The basic concept of honey bee breeding programs. *Bee World, 94*(3), 84–87. https://doi.org/10.1080/0005772X.2017.1345427