

Exploring Two Decades of Change in Turkish Apiculture through Spatiotemporal Data Analysis

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Received: 12.09.2025

Accepted: 28.10.2025

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Abstract: This study examines the apiculture sector in Türkiye between 2004 and 2024 using data from the Turkish Statistical Institute, focusing on temporal, spatial, and relational dimensions. Time-series analyses, spatial visualizations, productivity comparisons, and correlation assessments were applied to reveal the structural transformation of the sector. The findings indicate a steady increase in modern hive numbers alongside a gradual decline in traditional hives. While overall honey production has grown, per-hive productivity has not improved significantly, suggesting that modernization alone is insufficient. Spatial analyses revealed that provinces such as Ordu, Muğla, and Adana remain dominant in production, yet substantial regional inequalities persist. Comparative and relational analyses highlighted a strong positive relationship between modern hive adoption and honey output, whereas traditional hives contributed little. The study concludes that Turkish apiculture is undergoing a modernization-driven transformation of hive structures and production practices, but efficiency stagnation and regional disparities necessitate complementary policies and practices to ensure sustainable development.

Keywords: Apiculture, honey production, modern hives, traditional hives, productivity, spatial analysis

1. Introduction

Beekeeping in Türkiye is regarded as a strategic component of agricultural production due to its dual economic and ecological functions. In addition to producing honey, beeswax, propolis, pollen, and royal jelly, beekeeping plays a crucial role in sustaining plant production through pollination services. Owing to its biodiversity, favorable climatic conditions, and unique local ecotypes, Türkiye ranks second globally in honey production and third in terms of colony numbers (Abacı et al., 2020). Similarly, the general situation of Türkiye's beekeeping over the last twenty years was analyzed within the scope of the current literature review study (Şahinler and Toy, 2022).

Nevertheless, the literature emphasizes that Turkish beekeeping faces multiple structural challenges. Low productivity, colony losses, diseases and pests, pesticide exposure, and hive theft are among the factors negatively affecting the

sector (Çevrimli and Sakarya, 2018; Varalan and Çevrimli, 2023). Furthermore, shortcomings in beekeeper training, limited adoption of modern hive technologies, insufficient use of improved queen bees, and weaknesses in record-keeping systems contribute to declining yields (Dodoloğlu and Erdoğan, 2022; Cengiz and Arslan, 2023). Migratory beekeeping represents both an opportunity and a risk: while it enables the efficient use of seasonal floral resources, it also creates pressures such as uncontrolled hybridization and ecological stress (Aksoy et al., 2022; Küçüktekin and Mencet Yelboğa, 2022; Sıralı and Cımbırtoğlu, 2022). Another study in the current literature examined the negative impacts of climate change indicators such as temperature increases, precipitation changes, and carbon dioxide (CO₂) emissions on honeybees, which play a critical role in agricultural production through pollination as well as honey production (Duru and Parlakay, 2021).

Regional disparities are another recurring theme in the literature. Provinces such as Ordu, Muğla, and Adana consistently lead in honey production and colony numbers, while others remain relatively underrepresented (Koç et al., 2020; Koday and Karadağ, 2020). These differences illustrate significant inequalities in the spatial distribution of apicultural capacity. Similarly, while some provinces stand out in beeswax production and colony stocks, in others, beekeeping is maintained largely as a supplementary activity. A recent spatial study aimed to reveal the spatial distribution of honey yield outputs in Türkiye using exploratory spatial data analyses (Bayir et al., 2025).

Alternative production models and innovative practices are also discussed in national studies. Organic beekeeping is gaining increasing importance, largely driven by consumer demand for safe and high-quality products (Demir et al., 2023). Moreover, the economic value of non-honey bee products such as propolis, pollen, and royal jelly has been highlighted, underscoring the importance of diversification in the sector (Çevrimli and Aral, 2020). In this context, Kılıçin et al. (2021) examined the structure and production activities of organic beekeeping enterprises in Türkiye, revealing the relationships between bee breed preferences, queen bee production methods, colony losses, and production styles.

From a productivity perspective, a common finding across the literature is the persistent decline in honey yield per hive. Addressing this trend requires the modernization and broader adoption of scientific practices (Dodoloğlu and Erdoğan, 2022; Cengiz and Arslan, 2023). In a related quantitative study, it was aimed to determine the efficiency levels of beekeeping activities across 81 provinces of Türkiye by employing data on honey and beeswax production, beekeeping enterprises, and the number of hives through data envelopment analysis (Güler, 2021). Improved queen breeding, better colony nutrition, effective pest and disease management, and systematic record-keeping have been identified as prerequisites for efficiency gains. Furthermore, Türkiye's share in foreign trade remains limited compared to its production capacity, underscoring the need for increased competitiveness and export diversification (Çukur and Çukur, 2021). Moreover, conducted field surveys within the scope of current literature reveal that beekeeping enterprises identify marketing, accommodation, diseases and pests, security, transportation, and pesticide exposure as the most important concerns of the sector (Şahin et al., 2021). A complementary study reveals Türkiye's honey export structure and competitiveness in international markets during the 2002-2021 period,

reflecting the advantages provided by its rich vegetation, diverse climate zones, and honeybee genetic resources (Akdeniz and Kantar, 2022).

Despite these valuable insights, most existing studies focus on specific regions or short timeframes. Comprehensive, long-term analyses that examine temporal trends, spatial distributions, and productivity dynamics across the entire country remain scarce. This study seeks to fill this gap by analyzing Türkiye's beekeeping sector from 2004 to 2024 using data from the Turkish Statistical Institute (TÜİK). Employing time-series analyses, spatial visualizations, productivity comparisons, and correlation assessments the study explores the impact of hive type transformation on honey production, inter-provincial disparities, and efficiency trends. In doing so, it aims to provide a multidimensional picture of the sector and contribute to the literature by offering insights that may inform both policy and practice.

2. Materials and Methods

The dataset analyzed in this study was obtained from the TÜİK and covers the period 2004-2024. It provides annual, province-level data on key apicultural indicators, including honey production (tons), beeswax production (tons), the number of traditional (old-type) hives, and the number of modern (new-type) hives. From these primary indicators, additional variables were derived, most importantly the total number of hives (sum of traditional and modern hives) and honey yield per hive (kg hive^{-1}). These derived indicators allowed the analysis to incorporate both capacity and efficiency dimensions of Turkish apiculture. The dataset thus offers a comprehensive longitudinal and spatial framework that enables the exploration of temporal trends, regional variations, productivity levels, and structural transformations in beekeeping over two decades.

The analysis was organized into four categories. First, temporal trends were reviewed. Hive types, honey production levels, and the link between hive transformation and production growth were traced over time. Time-series analysis and trend plots were supported with correlation checks between hive numbers and production outcomes.

Second, spatial distribution was examined. Regional differences in production and hive prevalence were identified. Leading provinces and areas of concentration were highlighted using ranking tables, bar charts, and GIS-based maps. Third, productivity and efficiency were studied. Honey yield per hive, the effect of modern hives on efficiency, and provincial differences were compared. Ratio calculations, comparative charts,

and correlations between modern hive use and yield were applied. Finally, relational analyses were conducted. The balance between traditional and modern hives, the link between hive numbers and honey production, and the effect of hive composition on production fluctuations were tested. Correlation matrices, scatter plots, and regression models were used. All statistical analyses and visualizations were conducted using Python (version 3.x). Data handling and preprocessing were performed with the pandas and numpy libraries. For statistical modeling, scikit-learn was employed. Visualization of trends, comparisons, and scatter plots was carried out using matplotlib and seaborn, and geospatial analyses were implemented with the geopandas library in combination with provincial boundary data in GeoJSON format. This combination of tools enabled both quantitative and spatial exploration of the data and ensured reproducibility of the results.

The study used descriptive, comparative, and relational methods in a structured framework. This allowed both structural patterns and temporal changes to be captured. As a result, the sector was assessed in a comprehensive way. Based on this framework, the next section reports the findings. Results are grouped into four categories: temporal trends, spatial distribution, productivity and efficiency, and comparative-relational analysis. Each category directly addresses the research questions. Tables and figures are used to show both

descriptive patterns and analytical outcomes. This clear organization forms the basis for the discussion of Türkiye's apiculture.

3. Results

3.1. Temporal trends

In this section, the analysis focuses on the temporal dynamics of Türkiye's apicultural indicators between 2004 and 2024. Specifically, three key research questions are addressed: (i) how the numbers of traditional and modern hives have evolved over time, (ii) whether honey production exhibits notable increasing or decreasing trends across the years, and (iii) whether the transformation from traditional to modern hive types has proceeded in parallel with the trajectory of honey production. These questions provide the foundation for examining long-term developments in beekeeping practices and production outcomes within the national context.

Figure 1 illustrates the national totals of traditional and modern hives in Türkiye between 2004 and 2024. The figure shows two distinct trajectories: while the number of traditional hives remains at relatively low levels with limited fluctuations, modern hives dominate the apicultural landscape and exhibit a steady upward trend over the entire period. The graphical evidence clearly highlights the overwhelming share of modern hives compared to traditional hives throughout the observed timeframe.

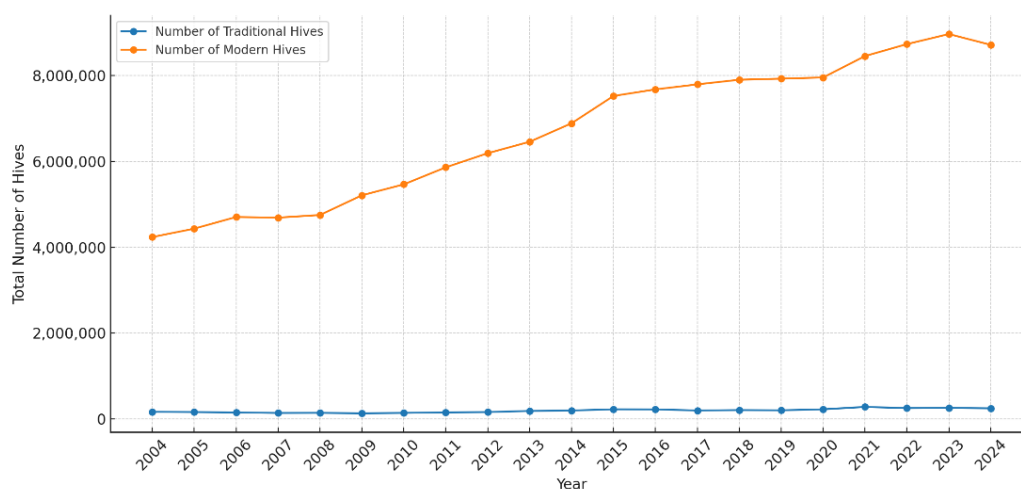


Figure 1. Traditional vs. modern hives in Türkiye (2004-2024)

Table 1 provides a comparative summary of traditional and modern hive counts in 2004 and 2024. In 2004, the total number of hives was 4,399,725, of which 162,660 (3.70%) were traditional and 4,237,065 (96.30%) were modern. By 2024, the total reached 8,961,975, with 244,813

traditional hives (2.73%) and 8,717,162 modern hives (97.27%). This corresponds to an absolute increase of 82,153 traditional hives (+50.51%) and 4,480,097 modern hives (+105.74%), resulting in an overall hive population growth of 4,562,250 (+103.69%) (Table 1).

Table 1. Traditional vs modern hives 2004 comparison

Metric	2004	2024	Absolute change	Percent change
Traditional hives	162.660	244.813	+82.153	+50.51%
Modern hives	4.237.065	8.717.162	+4.480.097	+105.74%
Total hives	4.399.725	8.961.975	+4.562.250	+103.69%
Share of traditional hives	3.70%	2.73%	-0.97 pp	—
Share of modern hives	96.30%	97.27%	+0.97 pp	—

Figure 2 presents the national honey production in Türkiye between 2004 and 2024. The graph shows annual fluctuations but highlights the overall increase across the observed period. Honey production amounted to 73.929 tons in 2004 and reached 95.492 tons in 2024 (Figure 2).

Table 2 provides a comparative summary of honey production at the beginning and end of the period. The results indicate an absolute increase of 21.563 tons, corresponding to a 29.17% growth in total national honey production over two decades (Table 2).

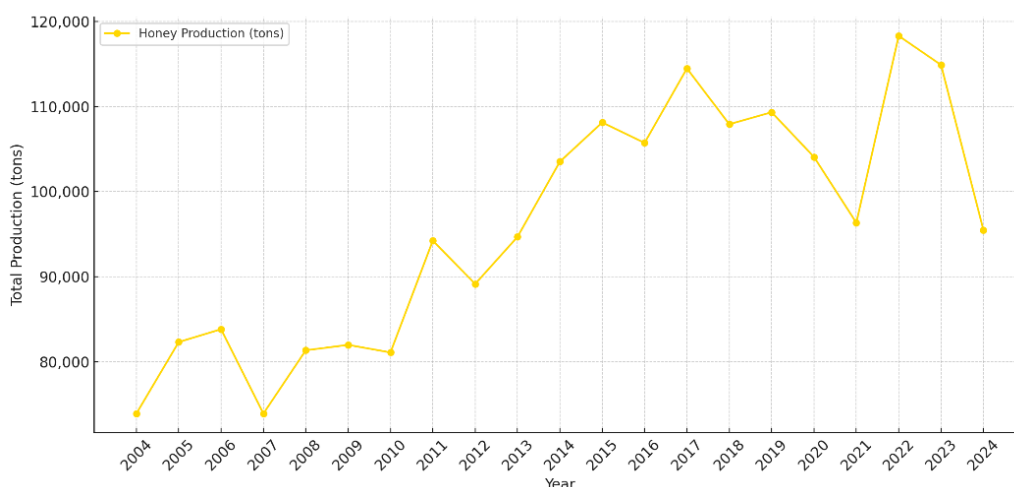


Figure 2. Honey production in Türkiye (2004-2024)

Table 2. Honey production in Türkiye (2004 vs. 2024)

Metric	2004	2024	Absolute change	Percent change
Honey production (tons)	73.929	95.492	+21.563	+29.17%

Figure 3 illustrates the annual totals of traditional hives, modern hives, and honey production in Türkiye between 2004 and 2024. The figure shows that traditional hives remain at relatively low levels with fluctuations, while modern hives increase consistently across the observed period. Honey production displays year-to-year variations but follows an overall increasing trajectory in parallel with the rise in modern hives.

Table 3 presents the correlation coefficients among hive types and honey production. Honey production is strongly correlated with modern hives ($r=0.89$) and moderately correlated with traditional hives ($r=0.75$). In addition, modern and traditional hives exhibit a strong positive correlation ($r=0.91$) (Table 3). These coefficients provide evidence of a close alignment between modern hive expansion and honey production growth during the period.

The temporal analysis highlights clear distinctions in Türkiye’s beekeeping indicators between 2004 and 2024. While the number of modern hives more than doubled over the period, traditional hives remained at comparatively low levels despite a modest increase in absolute terms. Honey production grew by nearly one-third, and correlation analysis revealed that its trajectory aligns more closely with the expansion of modern hives than with traditional hives. Taken together, these findings demonstrate that long-term trends in national honey production are closely associated with the structural shift toward modern hive types.

3.2. Spatial distribution

This section investigates the spatial dimension of Türkiye’s apicultural sector across provinces between 2004 and 2024. The analysis seeks to address three central questions: (i) which provinces

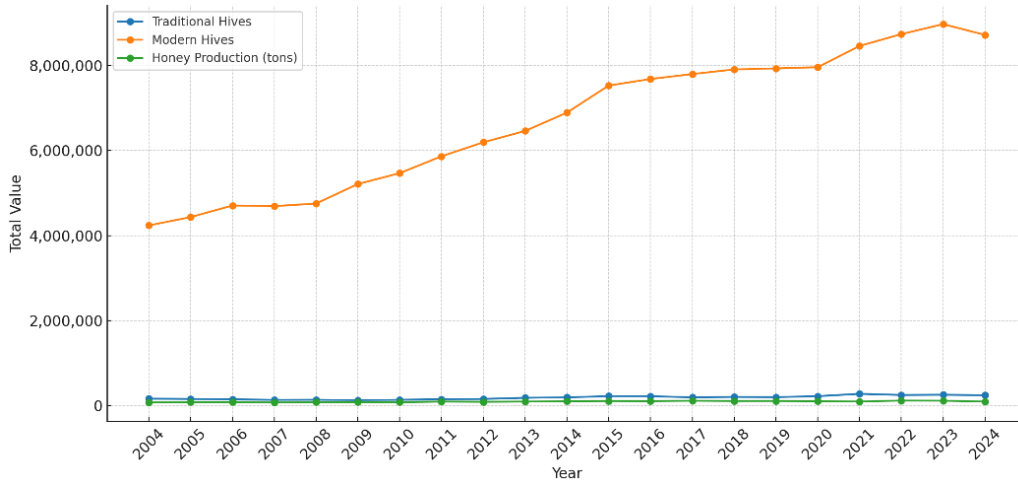


Figure 3. Hive types and honey production in Türkiye (2004-2024)

Table 3. Correlation coefficients among hive types and honey production (2004-2024)

Variables	Honey production	Traditional hives	Modern hives
Honey production	1.00	0.75	0.89
Traditional hives	0.75	1.00	0.91
Modern hives	0.89	0.91	1.00

have emerged as leading centers of beekeeping activity and how their positions have shifted over time, (ii) where the primary geographic clusters of hive populations and production are concentrated, and (iii) whether regional differences in honey production are statistically significant. These questions aim to provide a comprehensive overview of the geographic distribution of beekeeping practices and production performance, thereby complementing the temporal trends presented in the previous section.

Figure 4 displays the top ten provinces in honey production for the years 2004 and 2024. In 2004, the leading provinces were Ordu (10.196 tons) and Muğla (9.878 tons), followed by Mersin, Adana, and Sivas. By 2024, Ordu maintained its leading position with 13.001 tons, while Adana rose to second place with 11.582 tons, and Muğla ranked third with 7.031 tons. The 2024 list also included provinces such as Diyarbakır, Şanlıurfa, and Çanakkale, which were not among the top producers in 2004 (Figure 4).

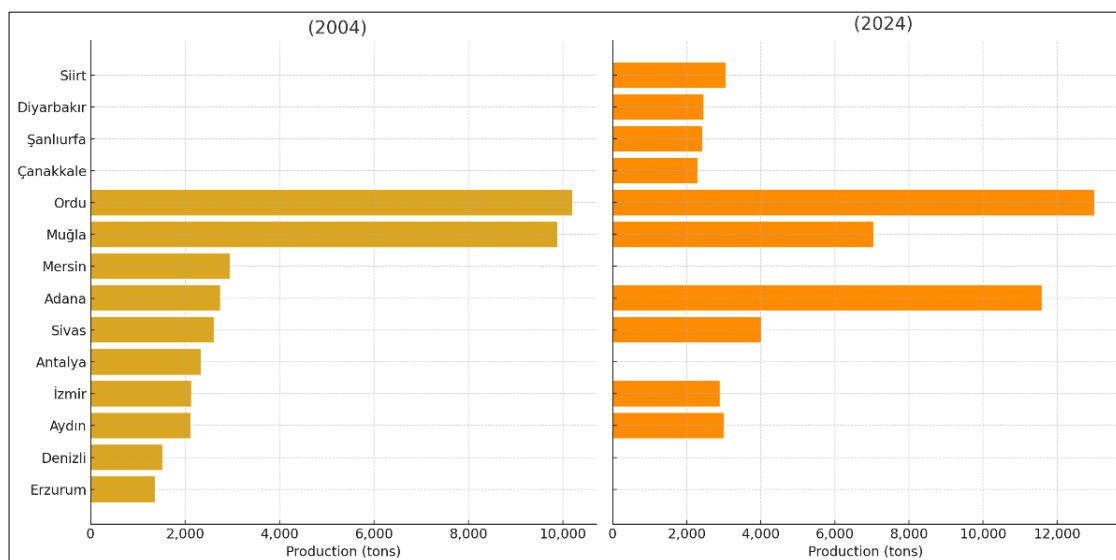


Figure 4. Top 10 provinces in honey production (2004-2024)

Table 4 summarizes the comparative ranking of the top ten provinces in 2004 and 2024. The table shows that while certain provinces like Ordu and Muğla remained consistently among the leading producers, others such as Mersin, Antalya, Denizli, and Erzurum dropped out of the top ten by 2024. Conversely, provinces including Siirt, Diyarbakır, Şanlıurfa, and Çanakkale entered the top tier of production during this period (Table 4).

Table 4. Top 10 provinces in honey production (2004 vs. 2024)

Rank	Province (2004)	Production (tons)	Province (2024)	Production (tons)
1	Ordu	10.196	Ordu	13.001
2	Muğla	9.878	Adana	11.582
3	Mersin	2.949	Muğla	7.031
4	Adana	2.742	Sivas	4.003
5	Sivas	2.608	Siirt	3.048
6	Antalya	2.328	Aydın	2.998
7	İzmir	2.130	İzmir	2.884
8	Aydın	2.112	Diyarbakır	2.459
9	Denizli	1.520	Şanlıurfa	2.420
10	Erzurum	1.364	Çanakkale	2.291

Figure 5 illustrates the spatial distribution of honey production across provinces in Türkiye in 2004. The map shows that production was relatively concentrated in specific provinces such as Ordu and Muğla, while the majority of provinces displayed comparatively lower production levels. The figure highlights a clear spatial clustering, particularly in the Black Sea and southwestern regions (Figure 5).

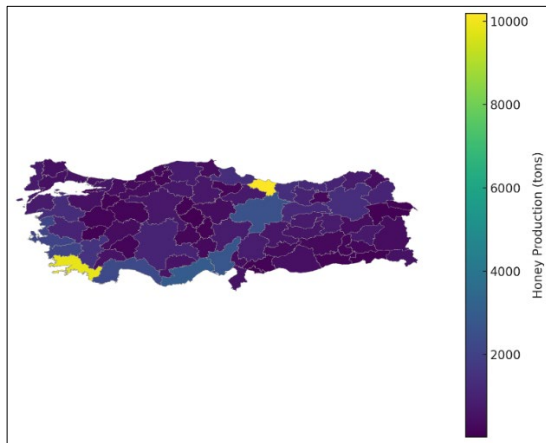


Figure 5. Honey production by province (2004)

Figure 6 presents the corresponding distribution for 2024. Compared to 2004, the map indicates an expansion of production in several provinces, with Adana and Sivas emerging as prominent contributors alongside Ordu and Muğla. Additionally, southeastern provinces such as Diyarbakır and Şanlıurfa entered the group of high-producing areas, suggesting a diversification in the

geographic concentration of honey production (Figure 6).

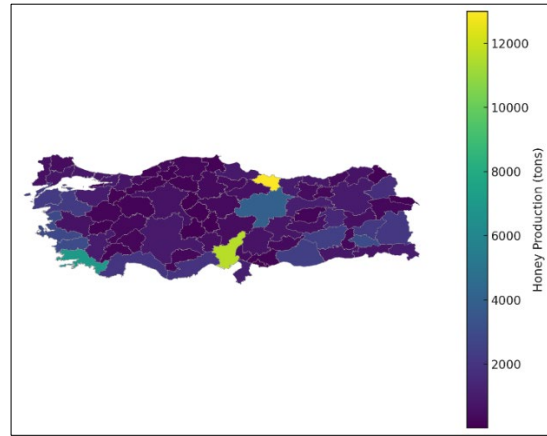


Figure 6. Honey production by province (2024)

Figure 7 displays the distribution of provincial honey production in Türkiye for the years 2004 and 2024 using boxplots. The figure highlights the substantial variability among provinces in both years, with a wide interquartile range and the presence of several extreme outliers. While the median production level increased slightly from 2004 to 2024, the persistence of high outliers—such as Ordu and Adana—demonstrates that production continues to be concentrated in a limited number of provinces. Overall, the boxplots emphasize that the inter-provincial disparities have remained pronounced across the two decades (Figure 7).

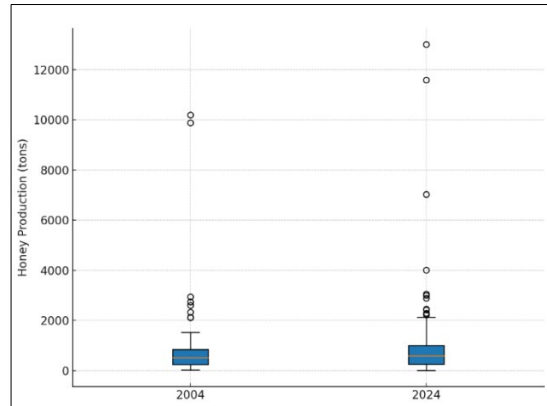


Figure 7. Distribution of provincial honey production (2004 vs 2024)

Table 5 summarizes the descriptive statistics and the results of the Kruskal-Wallis test for provincial honey production in 2004 and 2024. The mean and median values indicate moderate increases over the period, while the high standard deviations and skewness coefficients confirm the strongly uneven distribution of production. The

Kruskal-Wallis test statistic (0.386) with a p-value of 0.534 suggests that the differences in provincial distributions between 2004 and 2024 are not statistically significant (Table 5). This result implies that, despite an overall rise in production, the structural inequality in provincial honey output has remained largely unchanged.

Table 5. Descriptive statistics of provincial honey production in 2004 and 2024, and Kruskal-Wallis test results

	2004	2024
Mean	912.71	1178.92
Median	516.32	581.58
Standard deviation	1591.71	2084.65
Minimum	28.6	13.34
Maximum	10195.94	13000.68
Skewness	4.78	4.16
Kruskal-Wallis statistic	-	0.386
p-value	-	0.534

The spatial analysis of honey production in Türkiye between 2004 and 2024 reveals a persistent pattern of geographical concentration. Certain provinces, notably Ordu and Muğla, consistently maintained their leading positions, while new contributors such as Adana, Diyarbakır, and Şanlıurfa emerged as significant production centers over time. Choropleth maps highlighted a diversification of production across regions, although the Lorenz curve and associated concentration metrics indicated a continuing imbalance, with a small number of provinces accounting for a disproportionately large share of national output. Statistical tests confirmed that inter-provincial disparities remained structurally stable over the two decades, underscoring that growth in production did not substantially reduce

inequalities in regional contributions.

3.3. Productivity and efficiency

The analysis of productivity and efficiency provides critical insights into the performance of Türkiye's apiculture sector beyond aggregate production levels. While overall honey output and hive numbers have increased substantially over the past two decades, it is essential to assess whether these changes have translated into proportional efficiency gains at the hive level. In this section, three interrelated questions are addressed: (i) how honey productivity per hive has evolved nationally over time, (ii) whether the expansion of modern hive usage has been accompanied by measurable improvements in productivity, and (iii) whether provinces characterized by high shares of traditional hives exhibit different efficiency levels compared to those dominated by modern hives. By examining these questions, the section seeks to disentangle the relationship between structural modernization and actual productivity outcomes in Turkish beekeeping.

Figure 8 presents the evolution of honey productivity per hive in Türkiye between 2004 and 2024. The figure indicates that national productivity levels fluctuated throughout the period, with no sustained upward trend despite the growth in overall honey production. Productivity levels started around 18-19 kg hive⁻¹ in 2004, peaked at certain points, and declined in recent years to approximately 14-15 kg hive⁻¹ by 2024 (Figure 8). These findings suggest that while modernization and expansion of hive numbers have supported production growth, they have not translated into proportional efficiency gains at the hive level.

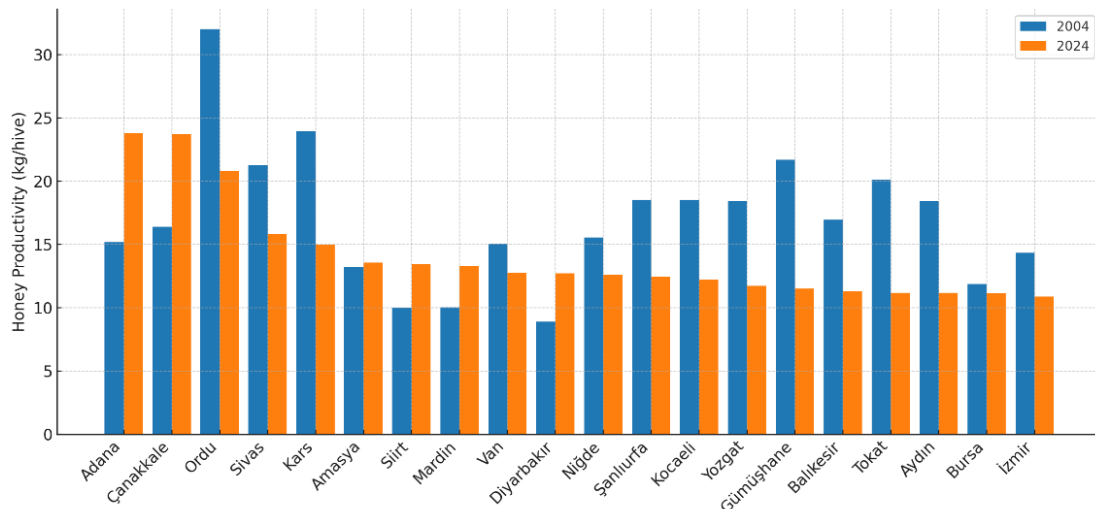


Figure 8. Honey productivity per hive (Top 20 provinces, 2004 vs 2024)

Table 6 compares honey productivity per hive across the top 20 provinces in 2024 relative to their values in 2004. The results reveal heterogeneous trajectories: some provinces such as Adana and Çanakkale recorded notable improvements in productivity, while others including Ordu, Kars, and Gümüşhane experienced significant declines. In several provinces, such as Amasya and Bursa, productivity levels remained relatively stable over the two decades (Table 6). This variation underscores the uneven impact of modernization and management practices across provinces, highlighting that regional ecological and socio-economic conditions play a decisive role in shaping productivity outcomes.

Table 6. Honey productivity per hive (kg) for the top 20 provinces in 2024, with comparison to 2004

Province	2024 (kg hive ⁻¹)	2004 (kg hive ⁻¹)
Adana	23.78	15.18
Çanakkale	23.69	16.38
Ordu	20.80	32.00
Sivas	15.84	21.28
Kars	15.00	23.90
Amasya	13.57	13.19
Siirt	13.42	10.00
Mardin	13.31	10.04
Van	12.75	15.07
Diyarbakır	12.70	8.87
Niğde	12.58	15.55
Şanlıurfa	12.45	18.51
Kocaeli	12.19	18.51
Yozgat	11.71	18.39
Gümüşhane	11.49	21.67
Balıkesir	11.30	16.94
Tokat	11.18	20.10
Aydın	11.17	18.41
Bursa	11.13	11.88
İzmir	10.86	14.33

Figure 9 illustrates the national evolution of modern hive adoption and honey productivity per hive in Türkiye between 2004 and 2024. The results reveal that the proportion of modern hives has been consistently high, exceeding 96% from the very beginning of the study period and reaching 97.3% in 2024. This indicates that the modernization of hive structures was largely achieved prior to 2004, leaving little room for further increases. In contrast, honey productivity per hive shows a clear downward trend: average productivity declined from approximately 16.8 kg per hive in 2004 to about 10.7 kg per hive by 2024 (Figure 9). Taken together, these results demonstrate that the near-universal adoption of modern hives has not translated into proportional improvements in per-hive efficiency, suggesting that other ecological, managerial, and climatic factors play a more decisive role in determining productivity outcomes.

Figure 10 graphically illustrates the productivity gap between provinces dominated by traditional hives and those dominated by modern hives. The comparison highlights that modern-heavy provinces consistently outperform traditional-heavy ones in terms of per-hive productivity. While the differences are not uniform—since local ecological conditions, beekeeper practices, and regional management capacities also influence outcomes—the overall pattern reinforces the conclusion that modernization has contributed positively to productivity (Figure 10).

Table 7 compares the five provinces with the highest relative shares of traditional hives to the five provinces where modern hives account for nearly the entire stock in 2024. The results demonstrate that provinces with larger traditional hive proportions, such as Bitlis, Siirt, and Kilis, generally record lower productivity levels, ranging between 3 and 13 kg per hive. By contrast, provinces fully dominated by modern hives, including Kars, Denizli, and Ağrı, tend to display higher productivity values, often exceeding 10-15 kg per hive (Table 7). These results underscore the efficiency advantage of modern hive systems in supporting higher per-hive yields.

Overall, the comparison between provinces with higher shares of traditional hives and those dominated by modern hives indicates a consistent productivity gap in favor of modernization. In 2004, several provinces still relied heavily on traditional hive types and consequently recorded lower yields per hive, whereas modern-dominated provinces achieved substantially higher efficiency. By 2024, the near disappearance of traditional-dominant provinces underscores the rapid and almost complete transition to modern beekeeping practices. Nevertheless, the national trend of declining productivity suggests that modernization alone has not been sufficient to sustain efficiency gains. Instead, modernization has primarily contributed to reducing regional disparities and establishing a more uniform baseline of productivity across Türkiye's apiculture sector, while ecological conditions, management practices, and climate-related challenges continue to shape efficiency outcomes.

3.4. Comparative and relational analyses

This section examines the interconnections between hive types, hive numbers, and honey production outcomes in Türkiye over the 2004-2024 period. While earlier sections have focused on temporal and spatial patterns as well as productivity indicators, the present analysis aims to uncover whether structural dynamics within the beekeeping

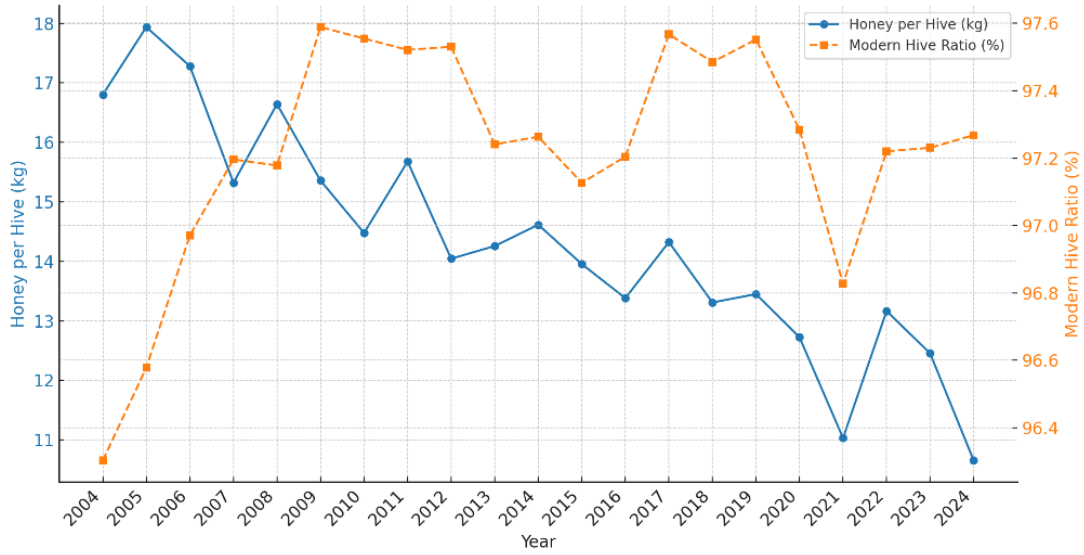


Figure 9. National trends in modern hive ratio and honey productivity per hive (2004-2024)

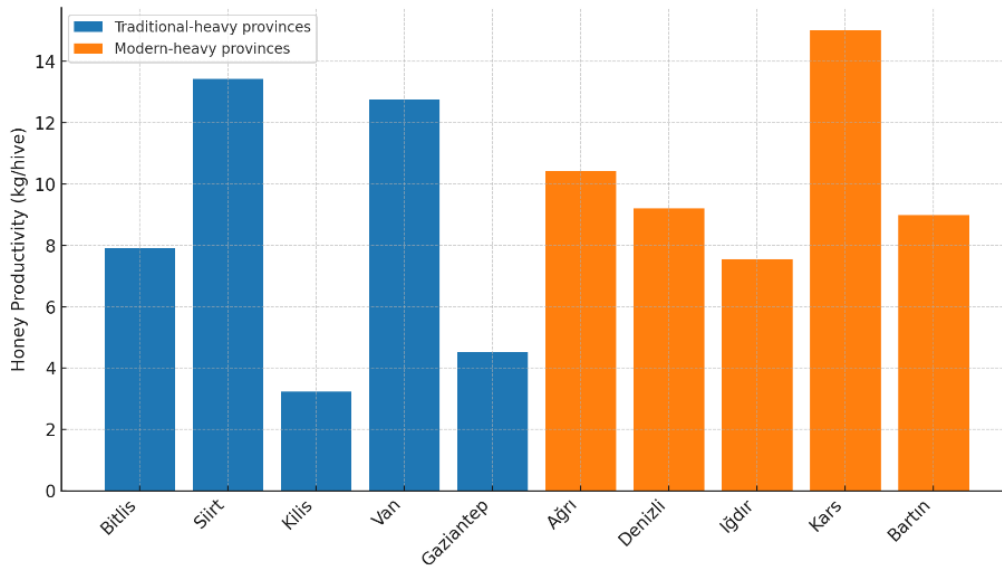


Figure 10. Honey productivity per hive in provinces with high traditional vs modern hive shares (2024)

Table 7. Provinces with the highest share of traditional hives vs. modern hives in 2024

Province	Traditional hives	Modern hives	Total hives	Traditional share (%)	Modern share (%)	Productivity (kg hive ⁻¹)
Bitlis	86.824	194.376	281.200	30.9	69.1	7.91
Siirt	58.536	168.561	227.097	25.8	74.2	13.42
Kilis	1.013	3.120	4.133	24.5	75.5	3.23
Van	25.822	141.115	166.937	15.5	84.5	12.75
Gaziantep	3.025	31.019	34.044	8.9	91.1	4.53
Ağrı	0	26.944	26.944	0.0	100.0	10.41
Denizli	0	106.871	106.871	0.0	100.0	9.20
Iğdır	0	17.747	17.747	0.0	100.0	7.56
Kars	0	116.035	116.035	0.0	100.0	15.00
Bartın	0	38.736	38.736	0.0	100.0	8.99

sector are relational in nature. Specifically, we ask whether the adoption of modern hives has directly substituted traditional hives or whether both have increased simultaneously; to what extent the number of hives correlates with honey production across provinces and years; and whether fluctuations in annual production performance at the provincial level can be attributed to underlying shifts in hive composition. By addressing these questions, this section provides a comparative and relational perspective, highlighting systemic patterns that go beyond simple temporal or spatial descriptions.

Figure 11 illustrates the evolution of traditional and modern hives in Türkiye between 2004 and 2024. The results reveal a clear divergence between

the two hive types. Modern hives dominated the apicultural landscape throughout the period, increasing steadily from approximately 4.2 million in 2004 to 8.7 million in 2024. By contrast, traditional hives declined from around 163.000 in 2004 to approximately 245.000 in 2024, with minor fluctuations in the last decade (Figure 11). These findings indicate that growth in hive numbers has been almost entirely driven by modern hives, while traditional hives have gradually diminished but not completely disappeared. Taken together, the results suggest that modernization has expanded the structural foundation of beekeeping without fully eliminating traditional practices, pointing to a process of substitution combined with persistence of small-scale traditional systems.

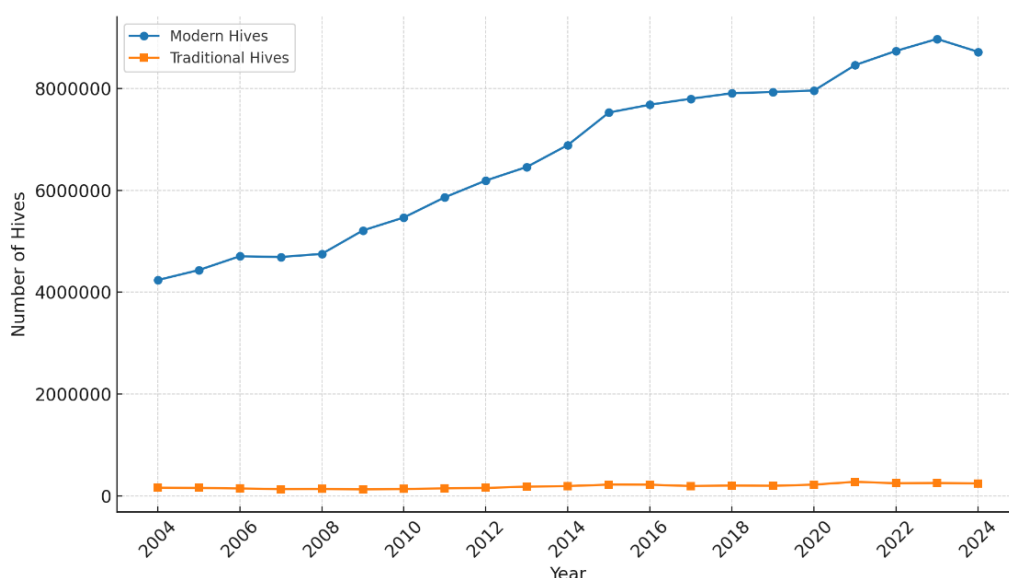


Figure 11. Modern vs traditional hives in Türkiye (2004-2024)

Table 8 provides the national totals of traditional and modern hives in Türkiye between 2004 and 2024. The results indicate that the expansion of hive numbers has been driven almost entirely by modern hives, which increased from approximately 4.2 million in 2004 to 8.7 million in 2024. By contrast, traditional hives decreased from about 163.000 in 2004 to 245.000 in 2024, with fluctuations in the intervening years. Total hive numbers nearly doubled over the two decades, reflecting the sector's structural transformation (Table 8). These results confirm that modernization has been the dominant force shaping hive dynamics in Türkiye, while traditional hives have persisted only marginally without contributing substantially to national growth.

Figure 12 illustrates the relationship between the total number of hives and honey production across all provinces and years during the 2004-2024 period. Each point represents a province-year observation, while the red line denotes the fitted regression trend. The results reveal a strong positive correlation ($r \approx 0.90$) between hive numbers and honey production, indicating that provinces with larger hive stocks tend to achieve higher production levels (Figure 12). Nevertheless, the dispersion of observations around the regression line suggests that hive numbers alone do not fully account for production outcomes, with ecological variability, management practices, and climatic conditions playing additional roles in shaping productivity differences across provinces.

Table 8. National totals of modern and traditional hives in Türkiye (2004-2024).

Year	Traditional hives	Modern hives	Total hives
2004	162.660	4.237.065	4.399.725
2005	157.059	4.432.954	4.590.013
2006	146.950	4.704.733	4.851.683
2007	135.318	4.690.278	4.825.596
2008	137.963	4.750.998	4.888.961
2009	128.743	5.210.481	5.339.224
2010	137.000	5.465.669	5.602.669
2011	149.020	5.862.312	6.011.332
2012	156.777	6.191.232	6.348.009
2013	183.265	6.458.083	6.641.348
2014	193.825	6.888.907	7.082.732
2015	222.635	7.525.652	7.748.287
2016	220.882	7.679.482	7.900.364
2017	194.406	7.796.666	7.991.072
2018	203.922	7.904.502	8.108.424
2019	198.992	7.929.368	8.128.360
2020	222.152	7.956.933	8.179.085
2021	277.089	8.456.305	8.733.394
2022	249.738	8.734.938	8.984.676
2023	255.494	8.969.387	9.224.881
2024	244.813	8.717.162	8.961.975

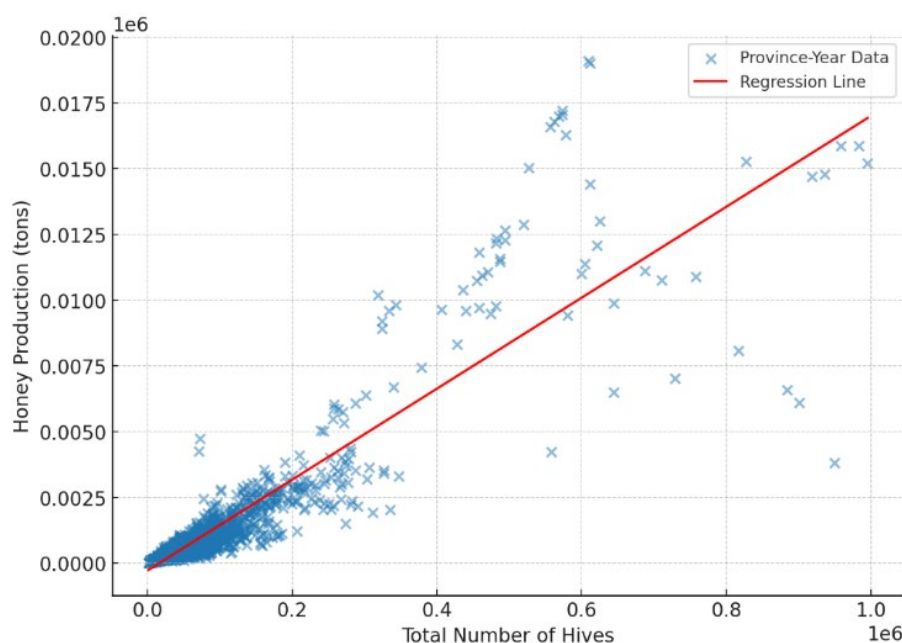
**Figure 12.** Relationship between hive numbers and honey production (2004-2024)

Table 9 presents the results of an ordinary least squares (OLS) regression model examining the relationship between total hive numbers and honey production across provinces between 2004 and 2024. The coefficient for total hive numbers is positive (0.0173) and highly significant ($p < 0.001$), indicating that increases in hive stocks are strongly associated with higher honey output. The model explains approximately 80% of the variance in honey production ($R^2 = 0.802$), underscoring the strength of this relationship (Table 9). The negative

intercept suggests limitations in the linear specification at very low hive counts, but overall the model confirms that hive expansion has been the primary driver of increased honey production in Türkiye during the study period.

Figure 13 presents the national relationship between honey production and the share of modern hives during the period 2004-2024. The results reveal that while honey production exhibits notable annual fluctuations, ranging from approximately 70.000 to over 115.000 tons, the share of modern

Table 9. Regression summary for the relationship between total hive numbers and honey production (2004-2024)

Variable	Coefficient	Standard error	t-Statistic	p-Value
Constant	-285.331	29.706	-9.605	0.000
Total number of hives	0.017297	0.000209	82.916	0.000

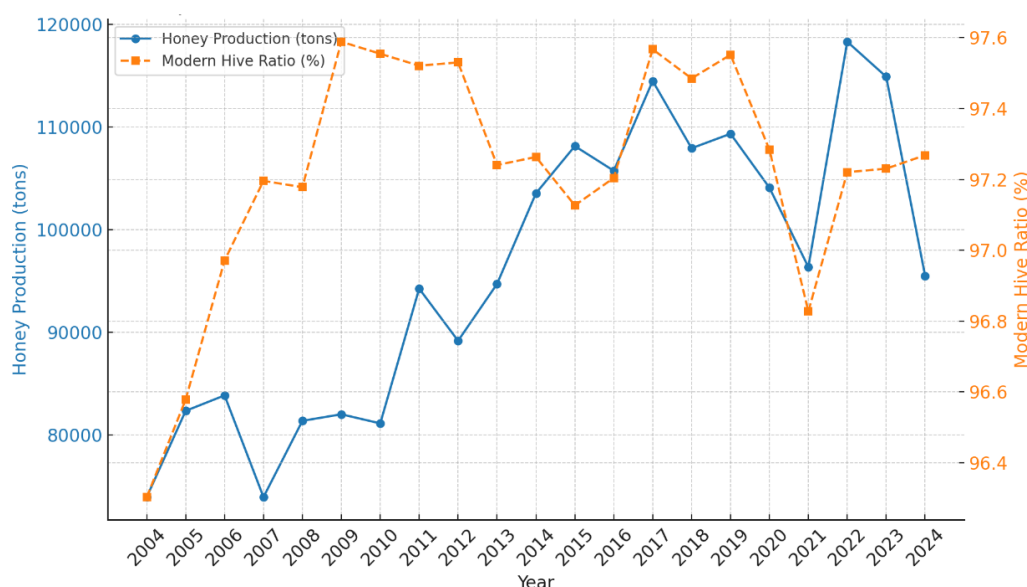


Figure 13. Relationship between hive modernization and production fluctuations (2004-2024)

hives remains almost constant, exceeding 96% throughout the entire timeframe (Figure 13). This pattern indicates that the observed variations in honey output cannot be explained by changes in hive composition, as modernization had already reached near-completion at the beginning of the study period. Instead, production fluctuations are more likely attributable to external factors such as climatic variability, ecological conditions, and regional management practices.

Table 10 presents Türkiye’s annual honey production alongside the share of modern hives between 2004 and 2024. The results show clear fluctuations in honey output, ranging from approximately 74,000 tons in 2004 to peaks exceeding 118,000 tons in 2022, before declining again to about 95,500 tons in 2024. By contrast, the share of modern hives remains remarkably stable, fluctuating only slightly between 96.3% and 97.6% over the entire period (Table 10). These findings confirm that annual variations in production are not driven by changes in hive composition, as modernization was already virtually complete at the beginning of the study period. Instead, external factors such as ecological dynamics, climatic variability, and disease pressures likely play a more decisive role in shaping the observed fluctuations.

Table 10. National honey production and modern hive ratio in Türkiye (2004-2024)

Year	Honey production (tons)	Modern hive ratio (%)
2004	73.929	96.30
2005	82.336	96.58
2006	83.842	96.97
2007	73.935	97.20
2008	81.364	97.18
2009	82.003	97.59
2010	81.115	97.55
2011	94.245	97.52
2012	89.162	97.53
2013	94.694	97.24
2014	103.525	97.26
2015	108.128	97.13
2016	105.727	97.20
2017	114.471	97.57
2018	107.920	97.49
2019	109.330	97.55
2020	104.077	97.28
2021	96.344	96.83
2022	118.297	97.22
2023	114.886	97.23
2024	95.492	97.27

Overall, the comparative and relational analyses reveal distinct patterns in the structural dynamics of Turkish apiculture. The steady replacement of traditional hives by modern ones demonstrates a

clear substitution process rather than parallel growth. The strong correlation between hive numbers and honey production underscores the central role of hive quantity in driving aggregate output, yet the analysis of interannual performance fluctuations indicates that modernization alone does not account for variability in provincial productivity. Taken together, these findings suggest that while modernization has been a defining structural shift, its direct effect on stabilizing or amplifying production efficiency is limited. Instead, broader ecological, climatic, and management factors likely play a greater role in shaping year-to-year performance outcomes.

4. Discussion and Conclusion

This study offers a broad assessment of Turkish apiculture between 2004 and 2024. The analysis combined official statistics with several methods, including time-series techniques, spatial mapping, productivity comparisons, correlation checks, and regression models. In doing so, it revealed not only temporal shifts and regional differences but also the structural dynamics that link hive types, production, and efficiency. Over time, the number of modern hives expanded steadily, while traditional hives declined. Honey production followed an upward path in parallel with this modernization. Yet, the data also showed short-term fluctuations, pointing to the continuing influence of climate variability, disease, and management shortcomings. These findings resonate with earlier work by Çevrimli and Sakarya (2018), who underscored the structural and managerial challenges facing Turkish apiculture. Regional patterns added another layer of insight. Ordu, Muğla, and Adana emerged as dominant producers, while many other provinces contributed only marginally. Modern hive use was most visible in western and coastal areas, whereas traditional hives still held a stronger presence in parts of the east. Similar patterns were reported by Koday and Karadağ (2020) and Koç et al. (2020), who also identified these provinces as leading production centers. Such disparities point to the necessity of regionally tailored development policies.

Productivity and efficiency analyses suggested that although modernization increased total output, per-hive efficiency gains remained limited. Provinces with higher shares of modern hives achieved better yields, yet the stagnation of per-hive productivity demonstrates that modernization alone is insufficient. Improvements in colony management, nutrition, pest and disease control, and queen breeding are essential to achieve sustainable efficiency gains. Dodoloğlu and Erdoğan (2022) and Cengiz and Arslan (2023) similarly highlighted the need for improved queen

breeding and management practices to enhance productivity.

Comparative and relational analyses confirmed a strong positive relationship between modern hive adoption and honey production, while the role of traditional hives was weak or even negative. Nonetheless, inter-provincial variations indicated that hive type alone does not determine productivity; ecological, socio-economic, and managerial factors also play decisive roles. This finding resonates with the work of Varalan and Çevrimli (2023), who emphasized climate change as a key risk factor, and with Sıralı and Cınbirtoğlu (2022), who noted the ecological pressures of migratory beekeeping.

In terms of policy and practical implications, the results highlight the importance of expanding training programs to improve beekeepers' knowledge in modern hive management, colony nutrition, and disease control. High-quality queen breeding initiatives should be prioritized to enhance genetic resilience and productivity. Moreover, diversification into bee products beyond honey—including propolis, royal jelly, pollen, and beeswax—should be promoted to strengthen income security and export potential, as emphasized by Çevrimli and Aral (2020) and Demir et al. (2023). Region-specific development policies are needed to support provinces lagging behind in modernization and productivity, while long-term strategies should address climate-related risks and ecological pressures associated with migratory beekeeping (Aksoy et al., 2022; Küçüktekin and Mencec Yelboğa, 2022).

Overall, Turkish apiculture is undergoing a transformation characterized by the predominance of modern hives, an increase in total honey output, and persistent regional inequalities. While modernization has positively influenced production, efficiency gains remain constrained, underscoring the importance of complementary measures in management, education, and policy support. By integrating temporal, spatial, and relational perspectives, this study provides a multidimensional evaluation of the sector and delivers evidence-based insights for researchers and policymakers. Strengthening resilience, improving efficiency, and diversifying production are crucial to ensure the long-term sustainability and global competitiveness of Turkish beekeeping.

Ethical Statement

This research does not require ethical approval.

Funding

This research received no external funding.

Declaration of Conflicts of Interest

No conflict of interest has been declared by the author.

References

- Abacı, N.İ., Abacı, S.H., Bıyık, S., 2020. Forecast for the number of colonies and honey yield in Turkey. *Turkish Journal of Agriculture - Food Science and Technology*, 8(2): 464-470. (In Turkish).
- Akdeniz, G., Kantar, A., 2022. Analysis of honey export potential and competitiveness of Türkiye. *Bee Studies*, 14(2): 55-61.
- Aksoy, A., Özbek, E., Özdemir, F., 2022. An economic review of migratory beekeeping sector in Turkey. *Turkish Journal of Agricultural and Natural Sciences*, 9(4): 1051-1061. (In Turkish).
- Bayir, T., Arslan, E., Inal, S., 2025. Spatial analysis of honey yield by province based on registered honey production data: Exploring spatial patterns. *Kocatepe Veterinary Journal*, 17(4): 375-385.
- Cengiz, M.M., Arslan, S., 2023. Physical quality criteria of queen bees reared in Türkiye and their importance for Turkish beekeeping. *Uludağ Bee Journal*, 23(2): 296-306.
- Çevrimli, M.B., Aral, Y., 2020. Bee products production and trade in beekeeping sector in the world and Turkey. In: Ö. Küplülü (Ed.), *Arı Ürünleri*, 1st Edition, Ankara: Türkiye Klinikleri, pp. 59-66. (In Turkish).
- Çevrimli, M.B., Sakarya, E., 2018. Current situation, problems and solutions for beekeeping sector in Turkey. *Journal of Faculty of Veterinary Medicine, Erciyes University*, 15(1): 58-67. (In Turkish).
- Çukur, T., Çukur, F., 2021. Turkey honey production forecast with Arima model. *The Journal of Agricultural Economics Researches*, 7(1): 31-39. (In Turkish).
- Demir, F., Sandalcıoğlu, Z.S., Erkan, C., 2023. Organic beekeeping in Türkiye. *Journal of Animal Science and Products*, 6(1): 64-71. (In Turkish).
- Dodoloğlu, A., Erdoğan, Y., 2022. Reasons for low yield in Turkish beekeeping. *Arı ve Arıcılık Teknolojileri Dergisi*, 1(1): 29-36. (In Turkish).
- Duru, S., Parlakay, O., 2021. The effect of climate change in Turkey on honey production: ARDL limit testing approach. *Mustafa Kemal University Journal of Agricultural Sciences*, 26(3): 791-800. (In Turkish).
- Güler, D., 2021. Determination of beekeeping activity by province in Türkiye using data envelopment analysis. *Uludağ Bee Journal*, 21(2): 146-156. (In Turkish).
- Kılıçın, T., Akdeniz, G., Aktürk, S., Kabakcı, D., Karataş, Ü., Çankaya, S., 2021. A research on the breeding activities of organic beekeeping enterprises. *Bee Studies*, 13(1): 9-16.
- Koç, H., Ergün, A., Kartal, F., 2020. Problems and solution suggestions of honey producers in Sivas province. *Journal of International Social Science Education*, 6(2): 327-362. (In Turkish).
- Koday, Z., Karadağ, H., 2020. Regional distribution of annual beekeeping and honey production in Turkey (2007-2018). *Journal of Graduate School of Social Sciences*, 24(1): 495-510. (In Turkish).
- Küçüktekin, M.Ö., Mencet Yelboğa, M.N., 2022. Examining the problem areas of wandering beekeeping activities: A case of Antalya province. *Eurasian Journal of Agricultural Economics*, 2(2): 1-12. (In Turkish).
- Sıralı, R., Cımbırtoğlu, Ş., 2022. Risk factors encountered in the sustainability of honeybee races and ecotypes in Türkiye. *International Journal of Anatolia Agricultural Engineering Sciences*, 4(4): 106-114. (In Turkish).
- Şahin, A.E., Akdeniz, G., Şahin, P., Alparslan, S., 2021. An online survey to determine breeding activities and main issues in Turkey's beekeeping enterprises. *Bee Studies*, 13(2): 63-72.
- Şahinler, N., Toy, N.Ö., 2022. Evaluation of Turkish beekeeping from 2000 years to the present. *Turkish Journal of Agriculture - Food Science and Technology*, 10 (1): 86-91. (In Turkish).
- Varalan, A., Çevrimli, M.B., 2023. Investigation of risk factors in the beekeeping sector. *Journal of The Turkish Veterinary Medical Society*, 94(2): 188-201. (In Turkish).