

Expansion Without Efficiency: A 16-Year Analysis of Beekeeping Productivity in Bingöl, Türkiye

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Abstract

This study aimed to examine long-term trends in beekeeping productivity and the relationship between support mechanisms and honey yield in Bingöl, Türkiye, between 2009 and 2024. A retrospective ecological time-series design was used based on secondary data obtained from official national and regional sources. Honey yield (kg/hive) was calculated as the primary outcome, and its associations with beekeeping indicators were analyzed using correlation and regression methods. Despite substantial increases in the number of beehives, supported beekeepers, supported hives, and financial support over time, honey production showed fluctuations and honey yield did not exhibit a consistent increasing trend (mean: 11.12±2.54 kg/hive). Pearson correlation analysis revealed significant negative associations between honey yield and number of beehives ($r=-0.597$), supported hives ($r=-0.597$), supported beekeepers ($r=-0.562$), and honey production ($r=-0.549$) ($p<0.05$). Simple linear regression analyses confirmed that these variables were significant predictors of decreased yield, whereas support amount was not statistically significant ($p=0.072$). Overall, the findings indicate that expansion in beekeeping capacity is not associated with improvements in productivity. These results highlight the need to shift from quantity-oriented support strategies toward efficiency-focused approaches to ensure sustainable apiculture systems.

Keywords

Beekeeping,
Honey yield,
Hive productivity,
Agricultural support,
Apiculture efficiency

Verimlilik Olmadan Genişleme: Türkiye'nin Bingöl İlinde Arıcılık Verimliliğinin 16 Yıllık Analizi

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Özet

Bu çalışma, 2009-2024 yılları arasında Bingöl'de arıcılık verimliliğindeki uzun dönemli eğilimleri ve destek mekanizmaları ile bal verimi arasındaki ilişkiyi incelemeyi amaçlamıştır. Çalışma, resmi ulusal ve bölgesel kaynaklardan elde edilen ikincil verilere dayalı retrospektif ekolojik zaman serisi tasarımıyla yürütülmüştür. Temel sonuç değişkeni olarak bal verimi (kg/kovan) hesaplanmış ve arıcılık göstergeleri ile ilişkisi korelasyon ve regresyon analizleri kullanılarak değerlendirilmiştir. Zaman içerisinde kovan sayısı, desteklenen arıcı sayısı, desteklenen kovan sayısı ve finansal destek miktarında önemli artışlar gözlenmesine rağmen, toplam bal üretiminde dalgalanmalar görülmüş ve kovan başına bal verimi tutarlı bir artış eğilimi göstermemiştir (ortalama: 11.12 ± 2.54 kg/kovan). Pearson korelasyon analizi sonuçlarına göre bal verimi ile kovan sayısı ($r = -0.597$), desteklenen kovan sayısı ($r = -0.597$), desteklenen arıcı sayısı ($r = -0.562$) ve bal üretimi ($r = -0.549$) arasında anlamlı negatif ilişkiler saptanmıştır ($p < 0.05$). Basit doğrusal regresyon analizleri bu değişkenlerin verimdeki azalış ile anlamlı düzeyde ilişkili olduğunu doğrulamış, ancak destek miktarının istatistiksel olarak anlamlı olmadığı bulunmuştur ($p = 0.072$). Genel olarak bulgular, arıcılık kapasitesindeki artışın verimlilikte iyileşme ile ilişkili olmadığını göstermektedir. Bu sonuçlar, sürdürülebilir arıcılık sistemlerinin sağlanabilmesi için miktar odaklı destek stratejilerinden verimlilik odaklı yaklaşımlara geçilmesi gerektiğini ortaya koymaktadır.

Anahtar kelimeler

Arıcılık,
Bal verimi,
Kovan verimliliği,
Tarımsal destek,
Arıcılık verimliliği

1. INTRODUCTION

Beekeeping plays a critical role in both agricultural sustainability and ecosystem functioning by contributing to pollination services and food production. Honeybees (*Apis mellifera*) are responsible for the pollination of a substantial proportion of global crops, thereby supporting biodiversity and food security [1,2]. In addition to ecological importance, apiculture represents a significant economic activity, particularly in developing and transition economies where it serves as a source of income and rural development [3,4].

Despite its importance, the beekeeping sector has been facing increasing challenges over the past decades. Global reports indicate that honeybee populations and productivity are influenced by multiple stressors, including climate change, habitat loss, pesticide exposure, and disease prevalence [3,5,6]. These pressures have led to growing concerns regarding the sustainability of apiculture systems, particularly in regions where production expansion is not accompanied by improvements in efficiency.

Türkiye is among the leading countries in terms of beehive numbers and honey production; however, productivity per hive remains below the global average [3,7]. This discrepancy suggests that increases in beehive numbers do not necessarily translate into proportional gains in yield efficiency. Previous studies have highlighted that productivity in beekeeping is strongly influenced by factors such as colony management, environmental conditions, floral diversity, and technical knowledge [7–9].

In recent years, government-supported programs aimed at increasing beekeeping capacity have been widely implemented to promote rural development and agricultural production [10]. While such support mechanisms—such as financial incentives, hive distribution, and beekeeper subsidies—have been effective in expanding production capacity, their impact on productivity per hive remains unclear [3,7,10]. In particular, there is limited empirical evidence examining whether increases in support and beehive numbers lead to sustainable improvements in yield efficiency at the regional level.

Bingöl, located in eastern Türkiye, represents a suitable case for examining these dynamics due to its expanding beekeeping sector and increasing policy-driven support mechanisms. However, despite the growth in the number of beehives and financial support, it remains uncertain whether this expansion has translated into improved productivity or has instead resulted in structural inefficiencies.

Therefore, the aim of this study was to analyze temporal trends in beehive numbers, honey production, and honey yield in Bingöl between 2009 and 2024, and to examine the relationships between support mechanisms and yield efficiency. By integrating regional, national, and global data, this study seeks to provide a comprehensive

assessment of whether quantitative expansion in beekeeping is associated with improvements in productivity, thereby contributing to the evidence base on sustainable apiculture systems.

2. MATERIAL AND METHOD

2.1. Study design and data source

This study was designed as a retrospective ecological time-series analysis based on secondary data. Annual data covering the period from 2009 to 2024 were obtained from two primary sources: the Turkish Statistical Institute and the Bingöl Provincial Directorate of Agriculture and Forestry [11].

The dataset included regional beekeeping indicators for Bingöl, such as the number of beehives, total honey production, and government-supported beekeeping activities (number of supported beekeepers, number of supported hives, and financial support amounts). National and global data on beehive numbers and honey production were obtained from TÜİK databases to enable comparative analysis [12].

Permission for the use of regional administrative data was formally obtained from the Bingöl Provincial Directorate of Agriculture and Forestry prior to data collection. As the study was based exclusively on aggregated secondary data and did not involve human participants or identifiable personal information, ethical approval was not required.

2.2. Variables and definitions

The primary outcome variable of the study was honey yield (kg/hive), calculated by dividing total honey production (tons) by the number of beehives and converting the result into kilograms per hive.

Independent variables included: Year (time variable), Number of beehives, Total honey production, Number of supported beekeepers, Number of supported hives, Amount of financial support (TL).

2.3. Data processing and standardization

All data were systematically checked for completeness and consistency prior to analysis. Unit conversions were standardized across datasets (e.g., tons to kilograms), and derived variables such as honey yield were calculated accordingly. Missing or non-numeric entries were excluded from the analysis. The final dataset consisted of annual observations with complete information for all variables of interest.

2.4. Statistical analysis

All statistical analyses were performed using GraphPad Prism version 10.3.1 (GraphPad Software, San Diego, CA, USA). Descriptive statistics, including mean, standard deviation, minimum, and maximum values, were

calculated to summarize temporal trends in honey yield (kg/hive) and other beekeeping indicators.

Associations between honey yield and explanatory variables (number of beehives, honey production, supported beekeepers, supported hives, and financial support amount) were examined using Pearson correlation analysis. Statistical significance was set at $p < 0.05$.

To evaluate predictive relationships, simple linear regression models were constructed with honey yield as the dependent variable. For each model, unstandardized coefficients (B), standardized coefficients (β), t -values, and p -values were reported. Model fit was assessed using R , R^2 , F -statistics, and overall model significance.

3. RESULTS

Temporal trends in beekeeping indicators in Bingöl between 2009 and 2024 are presented in Figures 1 and 2. Over the study period, the number of supported beekeepers and supported hives showed a consistent increasing trend, with a more pronounced rise after 2021. Similarly, the amount of financial support increased

substantially, particularly in the last three years. In contrast, total honey production exhibited fluctuations over time without a clear increasing trend.

Honey yield (kg/hive) showed considerable temporal variability during the study period. The mean honey yield in Bingöl was 10.95 ± 2.81 kg/hive, remaining below both the national average for Türkiye (13.56 ± 1.37 kg/hive) and the worldwide average (19.49 ± 0.92 kg/hive). Compared with the relatively stable and higher worldwide yield trend, Bingöl displayed greater interannual fluctuations and an overall declining pattern. Türkiye also showed a downward trend, although the decline was less variable than that observed in Bingöl. Conversely, beekeeping capacity and support-related indicators in Bingöl increased markedly over time, particularly the number of supported beekeepers, total number of hives, and financial support amount. Despite these increases, honey yield per hive did not improve accordingly. Total honey production also fluctuated across years, indicating that increases in hive numbers and financial support were not consistently reflected in productivity gains. Overall, the findings indicate that the expansion of beekeeping inputs and support mechanisms in Bingöl was not accompanied by a parallel improvement in hive-level honey yield.

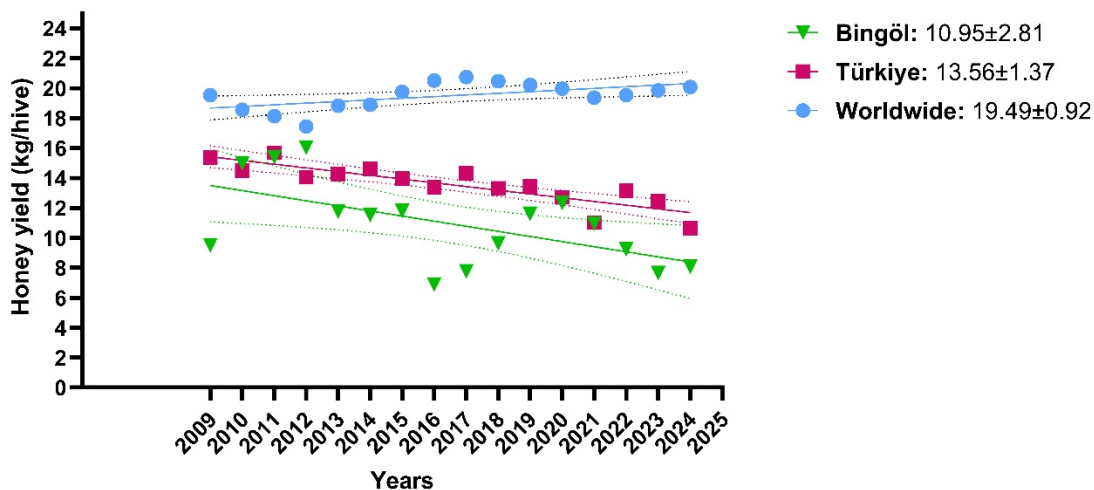


Figure 1. Temporal trends in honey yield (kg/hive), number of beehives, and honey production in Bingöl, Türkiye, and Worldwide (2009-2024)

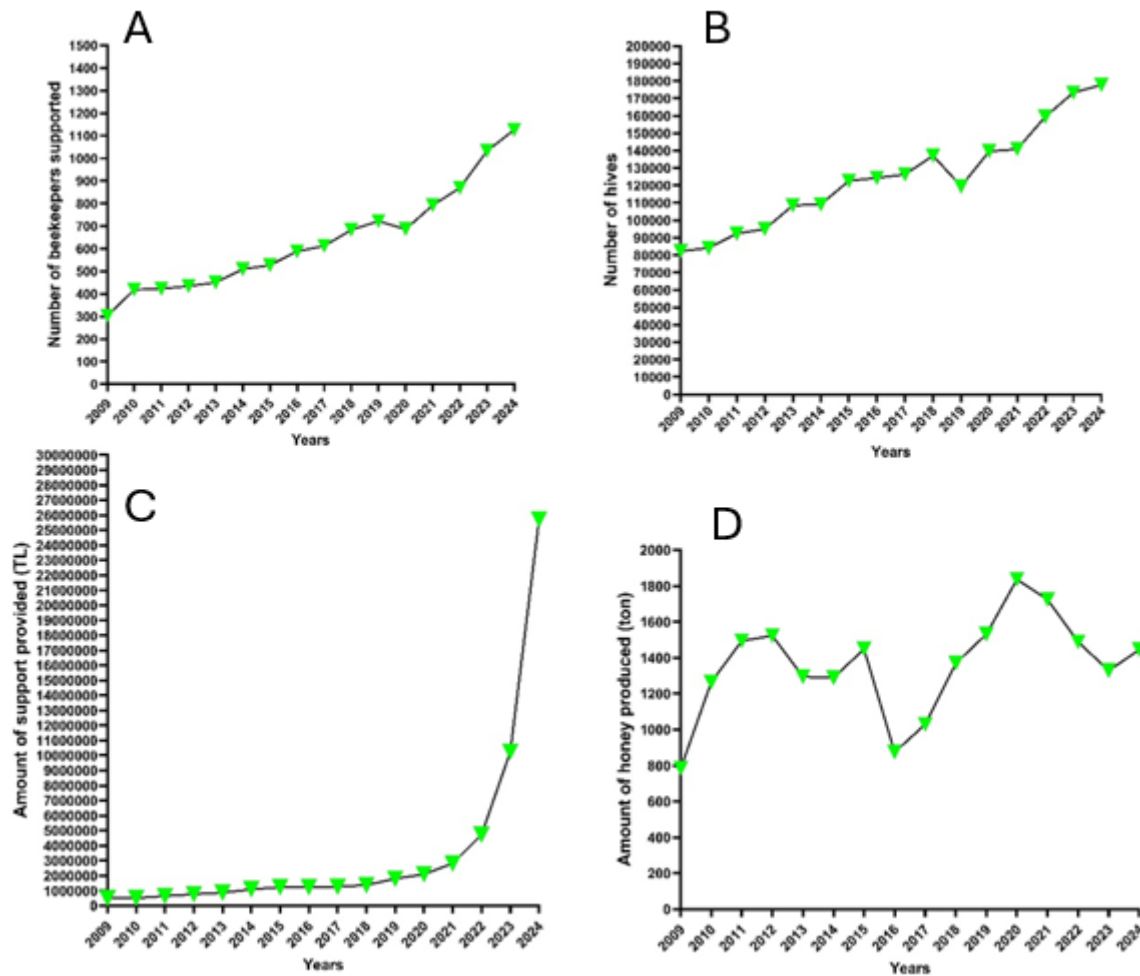


Figure 2. Temporal trends in beekeeping indicators in Bingöl between 2009 and 2024. The figure illustrates annual changes in key beekeeping indicators over the study period. Panel (A) shows the number of supported beekeepers, panel (B) presents the number of supported hives, panel (C) depicts the amount of financial support provided (TL), and panel (D) displays total honey production (tons). All variables are plotted by year to demonstrate temporal trends.

The relationships among study variables are presented in **Table 1**. Pearson correlation analysis revealed that honey yield was significantly negatively correlated with the number of beehives ($r=-0.597$, $p<0.05$), honey production ($r=-0.549$, $p<0.05$), supported beekeepers ($r=-0.562$, $p<0.05$), and supported hives ($r=-0.597$, $p<0.05$). The correlation between honey yield and support amount was negative but not statistically significant ($r=-0.461$, $p>0.05$).

Strong positive correlations were observed among production scale variables. The number of beehives was highly correlated with supported hives ($r=0.999$, $p<0.01$) and supported beekeepers ($r=0.968$, $p<0.01$). Additionally, supported beekeepers were strongly associated with support amount ($r=0.849$, $p<0.01$), indicating that financial support increased in parallel with expansion indicators.

Table 1: Pearson correlation coefficients among study variables

	1.	2.	3.	4	5.	6.
1. Honey Yield	-	-0.597*	-0.549*	-0.562*	-0.597*	-0.461
2. Number of beehives	-	-	0.650*	0.968**	0.999**	0.770**
3. Honey production	-	-	-	0.546*	0.650*	0.163
4. Supported beekeepers	-	-	-	-	0.968**	0.849**
5. Supported hives	-	-	-	-	-	0.770**
6. Support amount (TL)	-	-	-	-	-	-

Pearson correlation coefficients (r) are presented. Values above the diagonal indicate the strength and direction of the relationships between variables. Statistical significance levels are denoted as $p<0.05$ (*) and $p<0.01$ (**).

The results of simple linear regression analyses are presented in Table 2. Supported hives were significantly associated with honey yield ($B=-0.000046$, $\beta=-0.597$, $t=-2.78$, $p=0.015$), explaining approximately 35.7% of the variance ($R^2=0.357$). A similar pattern was observed for the number of beehives, which also showed a significant

negative association with honey yield ($B=-0.000045$, $\beta=-0.597$, $t=-2.78$, $p=0.015$; $R^2=0.357$).

Supported beekeepers were also significantly associated with honey yield ($B=-0.0048$, $\beta=-0.562$, $t=-2.57$, $p=0.023$), accounting for 31.6% of the variance ($R^2=0.316$). In contrast, support amount was not a

statistically significant predictor of honey yield ($B=-0.00000012$, $\beta=-0.461$, $t=-1.92$, $p=0.072$), although it showed a moderate explanatory power ($R^2=0.213$). Overall, the regression analyses consistently indicated that increases in beekeeping scale-related variables were

associated with decreases in honey yield, whereas financial support alone did not demonstrate a statistically significant relationship with yield.

Table 2: Simple linear regression analyses predicting honey yield

Model	Variable	B	β	t	p	R	R^2	F	Model p
1	Constant	16.84	—	6.12	<0.001	0.597	0.357	7.73	0.015
	Supported hives	-0.000046	-0.597	-2.78	0.015				
2	Constant	16.78	—	6.05	<0.001	0.597	0.357	7.73	0.015
	Number of beehives	-0.000045	-0.597	-2.78	0.015				
3	Constant	15.92	—	5.41	<0.001	0.562	0.316	6.61	0.023
	Supported beekeepers	-0.0048	-0.562	-2.57	0.023				
4	Constant	13.74	—	4.02	0.001	0.461	0.213	3.69	0.072
	Support amount (TL)	-0.00000012	-0.461	-1.92	0.072				

Simple linear regression analyses were conducted to examine the associations between honey yield and supported hives, number of beehives, supported beekeepers, and support amount (TL). For each model, unstandardized coefficients (B), standardized coefficients (β), t-statistics, p-values, R, R^2 , F-statistics, and overall model significance values were reported.

4. DISCUSSION AND CONCLUSION

This study examined long-term trends in beekeeping productivity in Bingöl and identified a consistent divergence between expansion indicators and yield efficiency. Despite substantial increases in the number of beehives, supported beekeepers, supported hives, and financial support, honey yield did not improve and demonstrated considerable variability over time. Both correlation and regression analyses consistently showed that increases in production scale variables were associated with decreases in honey yield.

The observed negative associations between beehive numbers and honey yield are consistent with prior evidence suggesting diminishing returns in apiculture systems. Aizen and Harder [8] reported that increases in managed honeybee colonies do not necessarily translate into proportional gains in productivity, largely due to competition for limited floral resources. Similarly, Goulson et al. [5] emphasized that ecological constraints, including reduced forage availability and environmental stressors, may limit per-colony productivity as colony density increases. The findings of the present study align with these observations, suggesting that expansion beyond ecological carrying capacity may reduce efficiency.

However, not all studies report negative relationships between scale and productivity. Some research indicates that productivity gains are possible when expansion is accompanied by improvements in management practices, colony health, and technical knowledge [13–16]. The discrepancy between these findings and the present results may reflect contextual differences. In Bingöl, the absence of detailed data on management practices and environmental conditions suggests that increases in colony numbers may not have been supported by parallel improvements in technical capacity or resource availability.

Another key finding is that financial support was not significantly associated with honey yield. This result is

consistent with agricultural economics literature indicating that subsidy-driven expansion does not necessarily enhance productivity unless accompanied by efficiency-oriented interventions [3,17]. In contrast, some studies report positive effects of targeted support programs, particularly when they include training, extension services, and technological support [18–21]. The lack of such integrated approaches may explain why financial support in this study did not translate into improved yield.

The strong correlations among beekeeping scale indicators suggest that support mechanisms primarily facilitate expansion rather than efficiency. This pattern reinforces the interpretation that policy interventions in the region may be quantity-oriented. Moreover, the variability in honey yield observed over time indicates that productivity is likely influenced by additional unmeasured factors, such as climate variability, floral diversity, disease burden, and colony management practices, which have been widely documented in the literature [9,22–25].

The findings should be interpreted within the limitations of the ecological study design. The use of aggregated annual data precludes individual-level inference and may obscure short-term or seasonal dynamics. Additionally, the absence of key confounding variables limits causal interpretation. Nevertheless, the consistency of results across multiple analytical approaches strengthens the robustness of the observed patterns.

Overall, the findings indicate that expansion in beekeeping capacity alone is insufficient to improve productivity. Instead, improving honey yield likely requires a shift toward efficiency-focused strategies that integrate financial support with technical training, environmental sustainability, and improved management practices.

The findings reveal a clear mismatch between the expansion of beekeeping capacity and productivity outcomes in Bingöl. Despite substantial increases in

beehive numbers and support mechanisms, honey yield per hive declined over time and showed no evidence of efficiency gains. Both contemporaneous and lagged analyses indicate that expansion-oriented strategies are not associated with improved productivity. These results suggest that increasing colony numbers alone is insufficient to enhance yield efficiency. Instead, sustainable productivity requires a shift toward quality-focused interventions, including improved management practices and environmental support. Given the ecological design, causal inferences remain limited; however, the consistent patterns observed highlight the need to reorient beekeeping policies from quantity to efficiency.

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