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Classification of beekeeping provinces in Türkiye using data mining methods and research into production trends. Technical note

Clasificación de provincias apícolas en Turquía usando método de minería de datos e investigación en las tendencias de producción. Nota técnica

Hakan Serin[1]*, Alperen Varalan[2]

[1]Selcuk University, Faculty of Veterinary, Department of Biostatistics. Konya, Türkiye.
[2]Atatürk University, Faculty of Veterinary, Department of Animal Health Economics and Management. Erzurum, Türkiye.
**Corresponding author: hakan.461995@gmail.com*

ABSTRACT

Beekeeping holds significant importance both in human nutrition and economically worldwide. The objective of this study is to classify provinces in Türkiye based on beekeeping production indicators using K–Means clustering method. Furthermore, by utilizing national data related to production indicators, ascending and descending trends were identified. Five production indicators (number of enterprises, number of colonies, total honey production, beeswax production, and honey yield per colony) from the years 1991 to 2022 were analyzed. For an objective and accurate classification of the provinces, the K–Means clustering method, as a data mining technique, was employed. To identify trends, the Sen Trend and Modified Mann–Kendall test were used. As a result of the K–Means clustering method, a structure with three clusters, comprising 4, 11, and 66 provinces, was obtained. Ordu, Muğla, Adana, and Sivas were grouped in cluster 1, which is the top cluster with the highest productivity (P<0.001). These provinces stand out with their different aspects. In Adana, which is categorised in cluster 1 in the Mediterranean Region, colony production continues in the winter months also. In Ordu, the most active city in the Black Sea region, the implementation of modern training programs plays a significant role in achieving high honey yield per colony. On the other hand, the Sen trend analysis results revealed a negative trend in honey yield per colony but positive trends in the remaining indicators (all P<0.001). In conclusion, it was determined that implementing practices aimed at supporting beekeeping productivity in provinces within Cluster 2 and 3 is essential. Accordingly, by ensuring ascending trends in all production indicators, a contribution to global beekeeping activities can be achieved.

Key words: Beekeping; classification; cluster analysis; data mining; trend analysis

RESUMEN

La apicultura ocupa un lugar importante tanto en la alimentación humana como económicamente en todo el mundo. El objetivo de este estudio es clasificar las provincias de Turquía según los indicadores de producción apícola utilizando el método de agrupación de K–Means. Además, utilizando datos nacionales sobre indicadores de producción, se determinaron las tendencias de aumento y disminución a lo largo del tiempo. En el estudio se analizaron cinco indicadores de producción (número de empresas, número de colonias, producción total de miel, producción de cera de abejas, rendimiento de la miel) para los años 1991–2022. Para clasificar las ciudades de forma más objetiva y realista se utilizó el método de agrupación K–Means, que es un método de minería de datos, y para determinar las tendencias se emplearon las pruebas Sen Trend y Mann–Kendall modificada. Como resultado del método de agrupación K–Means, se obtuvo una estructura de tres clusters formada por 4, 11 y 66 ciudades. En el clúster 1, el de mayor productividad, se incluyeron las ciudades de Ordu, Muğla, Adana y Sivas (P<0,001). Estas ciudades destacan por diferentes aspectos. En Adana, que se encuentra en la región mediterránea, la producción de colonias continúa en los meses de invierno. En Ordu, que destaca en la Región del Mar Negro, la aplicación de modernos programas de formación desempeña un papel importante en la consecución de un alto rendimiento de miel por colonia. Por otra parte, cuando se analizaron los resultados del análisis de tendencias Sen, se encontró una tendencia negativa en el rendimiento de miel por colonia, mientras que en otros indicadores se encontró una tendencia positiva (todos P<0,001). Como resultado, se ha determinado que es esencial implementar prácticas de apoyo a la productividad apícola en las provincias de los Clusters 2 y 3 para aumentar la productividad. En este sentido, se puede contribuir a las actividades apícolas globales garantizando tendencias al alza en todos los indicadores de producción.

Palabras clave: Apicultura; clasificación; análisis de conglomerados; minería de datos; análisis de tendencias

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INTRODUCTION

In addition to producing honey and other beekeeping products, beekeeping is an advantageous activity that supports plant production through pollination and also requires less labor and capital compared to other livestock sub–sectors [1, 2]. Moreover, beekeeping is a sector that can be pursued without harming nature or polluting the environment [3].

Considering the dependence of the beekeeping sector on nature, Türkiye is in an advantageous position due to its geographical location and natural resources [4, 5]. This advantage enables the production of a wide variety of honey types due to the diverse floral and plant nectar found in different regions of Türkiye, which in turn enhances the economic potential of beekeeping [6]. Consequently, beekeeping is an important source of income for many Turkish families and contributes significantly to the national economy [7].

The scale of this contribution is evident in the sector's substantial growth over the past three decades. From 1992 to 2023, the number of bee colonies in Türkiye increased dramatically from approximately 3.5 million to over 9.2 million. This expansion was accompanied by significant, albeit more variable, growth in production, with annual honey output rising from around 60,000 tons to nearly 115,000 tons and beeswax production increasing from 2,916 to 3,971 tons in the same period [8].

The variability in honey and beeswax production in Türkiye during the years under review can be attributed to various risk factors and challenges in the beekeeping sector, particularly global warming and climate change. However, the observed fluctuations in production in the beekeeping sector cannot be attributed solely to these factors. The intensive use of pesticides, the prevalence of bee diseases, challenges associated with migratory beekeeping, inadequacies in marketing strategies, and sectoral organizational issues have also been identified as contributing factors [9, 10, 11, 12, 13].

According to the 2023 province–based beekeeping data of Türkiye, the provinces with the highest number of colonies are Muğla, Ordu, and Adana, respectively. However, in terms of honey production, Ordu ranked first, followed by Adana and Muğla, respectively [8]. It is noteworthy that these provinces are from different regions of Türkiye. Furthermore, while some provinces stand out with high honey production, others excel in wax production and the number of colonies. According to the evaluation of all data together, it is of interest to examine the similarities and differences among these provinces in various aspects of beekeeping. Accordingly, exploring the reasons behind these results is important.

Various academic studies focusing on the beekeeping sector in Türkiye are present in the literature. For instance, studies investigating the socioeconomic structure of beekeeping enterprises have been conducted in the provinces of Çanakkale [14], Malatya [5], Yozgat [15], Uşak [16], and Iğdır [17]. In addition to these studies on socioeconomic structures, Çelik [18], has modeled honey production in Türkiye using time series analysis. In another study, Burucu and Bal [19], predicted honey production for the next 7 years (2017–2023) using the ARIMA model from time series analysis. Saner *et al.* [20], projected honey supply and demand for the period 2016–2023 using the Box–Jenkins forecasting model. When the classification studies on this subject are examined, Dinler [21], comparatively analysed the livestock potential of 81 provinces in Türkiye using seven cluster analysis methods (average, centroid, complete, mcquitty, median, single, and ward). Koday and Karadağ [22], analysed the beekeeping activities in Türkiye between 2007 and 2018 according to geographical regions. Güler [23], classified Türkiye and the European Union countries according to the number of beekeepers and the amount of honey produced using the average linkage method.

Although there are many studies in the literature that examine the socioeconomic structure, time series modeling, data envelopment, and regional distribution of beekeeping in Türkiye, there is no comprehensive study utilizing data mining methods to classify provinces based on beekeeping–related variables and to examine production indicators using various trend methods. Accordingly, this study aimed to classify provinces in Türkiye based on production indicators using the K–Means clustering method. Moreover, significant upward or downward trends in beekeeping production indicators between 1991 and 2022 were examined using trend tests.

MATERIAL AND METHODS

Study sites

Variables were selected based on criteria that directly reflect beekeeping production and enable objective classification. In addition, other studies in the field of beekeeping were reviewed and criteria that were considered important were also incorporated [24, 25]. Beekeeping production indicators include number of enterprises (pcs), number of colonies (pcs), total honey production (ton), beeswax production (ton), and honey yield per colony (kg/colony). These indicators represent activity, production capacity, and productivity in the beekeeping sector. Consequently, these indicators are used to evaluate the potential, performance, and sectoral position of provinces in terms of beekeeping. The cluster analysis in this study is based on beekeeping data from the Turkish Statistical Institute (TÜİK or TurkStat), spanning the years 1991–2022 [8] Beekeeping production indicators of cities grouped according to Turkiye's Nomenclature of Territorial Units for Statistics (NUTS – level 3) were utilized (TABLE I). In addition, FIG. 1 shows the change in the number of colonies in Türkiye enterprises over the years.

TABLE I
Provinces analysed using cluster analysis

Region	Provinces
Marmara Region	Istanbul, Edirne, Kirklareli, Tekirdag, Canakkale, Kocaeli, Yalova, Sakarya, Bilecik, Bursa, Balikesir
Aegean Region	Izmir, Manisa, Aydin, Denizli, Mugla, Afyonkarahisar, Kutahya, Usak
Black Sea Region	Bolu, Duzce, Zonguldak, Karabuk, Bartin, Kastamonu, Sinop, Samsun, Ordu, Giresun, Trabzon, Rize, Artvin, Corum, Amasya, Tokat, Gumushane, Bayburt
Central Anatolia Region	Ankara, Konya, Kayseri, Eskisehir, Sivas, Kirikkale, Aksaray, Karaman, Kirsehir, Nigde, Nevsehir, Yozgat, Cankiri
Mediterranean Region	Antalya, Adana, Mersin, Hatay, Isparta, Burdur, Osmaniye, Kahramanmaras, Kilis
Eastern Anatolia Region	Malatya, Erzincan, Elazig, Tunceli, Bingol, Erzurum, Mus, Bitlis, Van, Agri, Kars, Igdir, Ardahan, Hakkari
Southeastern Anatolia Region	Gaziantep, Sanliurfa, Diyarbakir, Mardin, Batman, Siirt, Sirnak, Adiyaman

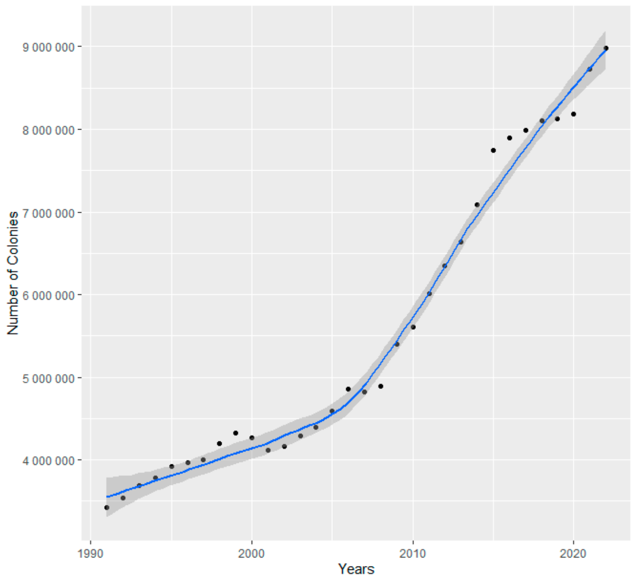

FIGURE 1. The change in the number of colonies by year. Province: Adana, Adiyaman, Afyonkarahisar, Agri, Aksaray, Amasya, Ankara, Antalya, Ardahan, Artvin, Aydin, Balikesir, Bartin, Batman, Bayburt, Bilecik, Bingol, Bitlis, Bolu, Burdur, Bursa, Canakkale, Cankiri, Corum, Denizli, Diyarbakir, Duzce, Edirne, Elazig, Erzincan, Erzurum, Eskisehir, Gaziantep, Giresun, Gumushane, Hakkari, Hatay, Igdir, Isparta, Istanbul, Izmir, Kahramanmaras, Karabuk, Karaman, Kars, Kastamonu, Kayseri, Kilis, Kirikkale, Kirklareli, Kirsehir, Kocaeli, Konya, Kutahya, Malatya, Manisa, Mardin, Mersin, Mugla, Mus, Nevsehir, Nigde, Ordu, Osmaniye, Rize, Sakarya, Samsun, Sanliurfa, Siirt, Sinop, Sivas, Sirnak, Tekirdag, Tokat, Trabzon, Tunceli, Usak, Van, Yalova, Yozgat, Zonguldak

Statistical analysis

K–Means technique was used as the clustering method. The data were standardized before analysis. The optimum number of clusters was calculated using the Elbow technique, which is a mathematical measurement [26]. In the Elbow method, the value on the y–axis, which shows the sum of squares within a cluster, drops significantly and starts to flatten when the cluster forms an elbow. This point indicates the optimum number of clusters. In this way, the point at which the sum of squares within the cluster rapidly decreases and then smooths out but can also be visually identified [27]. Moreover, resources related to beekeeping activities in the provinces and the geographical characteristics (such as climate, altitude and vegetation) of the provinces were also considered. Considering the geographical characteristics of the provinces and the amount of honey produced, it was decided that the number of clusters defined as 3 was appropriate.

One–way analysis of variance (One–way ANOVA) was performed to determine whether a statistically significant difference exists between the cluster structures obtained. Subsequently, Tukey's HSD multiple comparison tests were conducted. Shapiro Wilk's normality test and Q–Q plots were used to assess the normality of the data. In groups where normal distribution was not observed, the Kruskal–Wallis H test was conducted, followed by multiple comparisons assessed using Dunn's test with Bonferroni correction.

Furthermore, trend analysis was conducted to determine the increasing and decreasing trends in production quantities (number of enterprises, number of colonies, total honey production, beeswax production, and honey yield per colony) related to beekeeping indicators in Türkiye between 1991 and 2022. All statistical analyses were performed using R statistical language (version 4.2.1; The R Foundation for Statistical Computing, Vienna, Austria; https://www.r–project.org) [28]. The results were obtained using the "factoextra", "stats" "dplyr", "ggpubr" and "ggplot2" packages in the R statistical programming language. The process of selecting the numerical variables to be used in the dataset was performed using the select function in the "dplyr" package. The "factoextra"package was used to determine and visualise the optimal number of clusters using the Elbow method. For this, the fviz nbclust function in the "factoextra" package was used. In addition, a graphical representation of the cluster structure was obtained using the fviz cluster function. K–Means clustering was performed on the data matrix using the kmeans function in the "stats" package. The ggpar function in the "ggpubr" package has been used to add text to the cluster image.

Clustering method

Data mining is a method of extracting valuable information from large amounts of data collected in a computer environment. Cluster analysis, one of the unsupervised learning methods, is a sub–branch of data mining. Cluster analysis involves grouping a heterogeneous dataset based on their similarities [29, 30].

The K–Means technique is a non–hierarchical clustering method. In K–Means, a researcher can specify the number of clusters based on their understanding of the subject or by employing methods (Elbow method and Silhouette analysis) for determining the optimal number of clusters. Variables should be quantitative at the interval or ratio level in the K–Means technique. Objects are assigned to their nearest centroid. Typically, the Euclidean distance matrix is used to calculate the distance between units in this technique. Equation (1) shows the formula for the calculation of Euclidean distance based on x and y values [31, 32, 33].

$$d_{Euclidean}\left(x, y\right) = \sqrt{\sum_{i=1}^{n}\left(x_i - y_i\right)^2} \qquad \text{(Eq. 1)}$$

Trend analysis

Trend refers to the upward or downward movement in any independent variable over a time series. Analysing whether this trend in the time series is statistically significant is known as trend analysis [34]. Sen Trend (ST) and Modified Mann–Kendall (MMK) tests were used for trend analysis.

The MMK and ST trend analysis results are presented as test statistics values, critical values at the 95% confidence level, and p–values. When evaluating the results, a test statistic value above the critical values indicates a significant trend in the time series of the given production indicator. The direction of the trend is determined by the sign of the test statistic value. A positive sign indicates an ascending trend, whereas a negative sign indicates a descending trend.

Sen Trend (ST) test

In this method, the time series data is divided into two equal parts. The dataset containing the years 1991–2022 is split into two, 1991–2006 and 2007–2022. Each sub–series is sorted separately in ascending order. The first half of the time series is plotted on the X–axis, and the second half is plotted on the Y–axis. As shown in FIG. 2, if the data points closely around the 1:1 straight line, it was concluded that there is no discernible trend in the time series. However, if the data points fall predominantly in the upper triangle along the 1:1 (45°) line, it indicates an ascending trend in the time series. Conversely, if the data points in the lower triangle along the same line, it suggests a descending trend in the time series [35, 36].

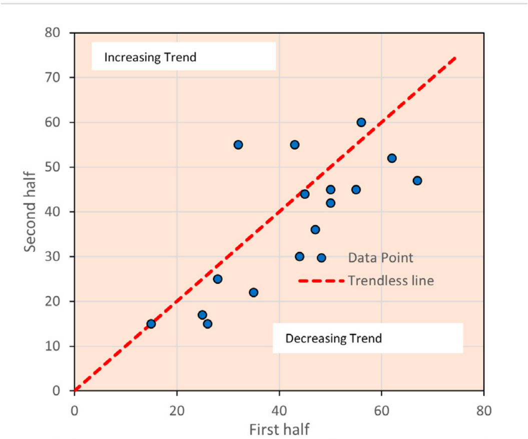

FIGURE 2. The illustration of ascending, descending, and no trend using the ST method

Modified Mann–Kendall (MMK) trend test

MMK is a nonparametric test conducted to determine any trend in a given time series. In this method, -1 (+1) is added to the Mann–Kendall statistics (S) if the subsequent data point is larger (smaller) than the current one as given in Equation (2), where variable (i) changes from 1 to n-1 and variable (j) varies from I+1 to the data length n. This process is repeated for the entire dataset. Then, S statistics are calculated and summed as shown in Equation (3).

$$sign\left(z_j - z_i\right) = \begin{cases} 1 & if \quad z_j > z_i \\ 0 & if \quad z_j = z_i \\ -1 & if \quad z_j < z_i \end{cases} \qquad \text{(Eq. 2)}$$

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(z_j - z_i\right) \qquad \text{(Eq. 3)}$$

S is assumed to have a normal probability density function with zero mean and a certain variance as shown in Equations (4) and (5). Furthermore, as a H_0 null hypothesis, it is assumed that the time series does not show any trend initially. If H_0 is rejected, the alternative hypothesis H_1 would be valid which means that the examined time series has a trend. This acceptance is concluded based on the standardized test statistic z and a specific significance as shown in Equation (6). If the calculated z value, z_cal is higher than a normal distribution value, z_tab tabulated according to the significance level of α, the trend in the time series is deemed as significant [37, 38].

$$E(S) = 0 \qquad \text{(Eq. 4)}$$

$$Var\left(S\right) = \frac{n(n+1)(2n+5)}{18} \qquad \text{(Eq. 5)}$$

$$z = \begin{cases} \frac{S-1}{Var(S)} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{Var(S)} & if\ S < 0 \end{cases} \qquad \text{(Eq. 6)}$$

RESULTS AND DISCUSSION

As mentioned in the Introduction, from 1992 to 2023 the number of colonies showed a continuous increase, while honey and wax production decreased in certain years.

The graph used in the Elbow method is shown in FIG. 3. The graph shows that the line forms an elbow at K=3 and then continues in a straighter line. Therefore, the optimum number of clusters was determined as 3.

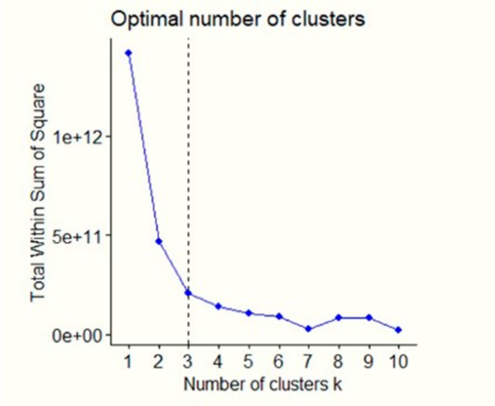

FIGURE 3. Determination of the optimal number of clusters using the Elbow methods

According to the Elbow graph, the intra–cluster sum–of–squares gradually decreases after three clusters, indicating that the appropriate number of clusters is three. The number of observations in the clusters are 4, 11, and 66, respectively. The cluster structure is given in FIG. 4. Accordingly, the provinces Ordu, Adana, Sivas, and Muğla were grouped into Cluster 1. İzmir, Mersin, Aydın, Erzurum, Balıkesir, Kocaeli, Van, Antalya, Trabzon, Rize, and Çanakkale comprised Cluster 2. The remaining 66 provinces are categorized into Cluster 3. An examination of the results across the country indicated that Cluster 1 comprises provinces from different regions of Türkiye. Finally, all provinces from the Central Anatolia, Western Black Sea, and Southeastern Anatolia regions are in Cluster 3 (FIG. 5).

The comparison of the clusters based on the production indicators is shown in TABLE II. There was a statistically significant difference in the number of enterprises (F[2, 78]=62.50, P<0.001, *partial* ε^2=0.61), number of colonies (χ^2[2]=28.54, P<0.001, ε^2=0.35), total honey production (χ^2[2]=35.41, P<0.001, ε^2=0.44), beeswax production (χ^2[2]=29.59, P<0.001, ε^2=0.37) and honey yield per colony (χ^2[2]=16.80, P<0.001, ε^2=0.21) among clusters. According to the multiple comparisons, the number of enterprises in Cluster 1 is significantly higher than in Cluster 2, which is also

FIGURE 4. Cluster structure obtained with K–Means clustering technique

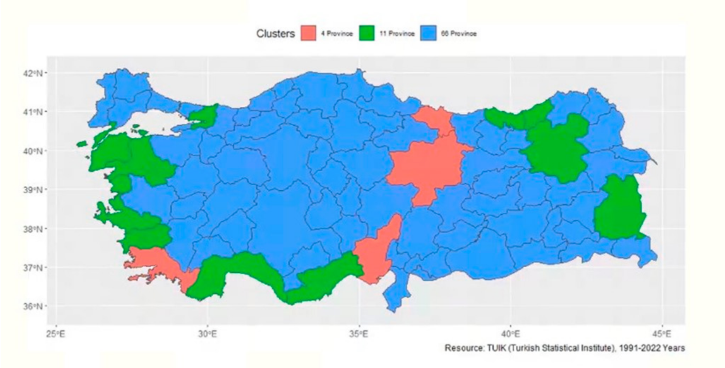

FIGURE 5. Clustering of provinces in Türkiye due to beekeeping production indicators

significantly higher than in Cluster 3. The number of colonies in Cluster 1 and Cluster 2 (adjusted $P<0.001$) is significantly higher than in Cluster 3. Similarly, total honey production in Cluster 1 and Cluster 2 is significantly higher than in Cluster 3. Beeswax production in Cluster 1 (adjusted $P=0.001$) and Cluster 2 is also significantly higher than in Cluster 3. Furthermore, in terms of honey yield per colony, Cluster 1 and Cluster 2 displayed significantly higher means compared to Cluster 3.

The results of the trend analysis are valid for the whole of Türkiye. Beekeeping–related production indicators were examined using ST and MMK trend analyses and the obtained results are given in TABLE III.

According to the MMK test results, significant ascending trends were identified for the number of colonies, total honey production, and beeswax production. Conversely, a significant descending trend was observed in honey yield per colony. On the other hand, no significant ascending or descending trend was observed for the number of enterprises over the examined 31–year period ($P>0.05$).

According to the ST graphs given in FIG. 6, the number of enterprises, number of colonies, total honey production, and beeswax production data were accumulated upper section of the 1:1 line. Furthermore, the ST results indicate that the ascending trends in the time series for these indicators were significant. However, a descending trend was observed in the honey yield per colony graph. This descending trend was found to be significant in the ST results.

TABLE II
The comparison of the clusters based on the production indicators

Production Indicator	Cluster 1 (n=4)	Cluster 2 (n=11)	Cluster 3 (n=66)	*P*–value
Number of Enterprises	3520 ± 1002[a]	2172 ± 813[b]	869 ± 476[c]	<0.001[1]
Number of Colonies	551929 [442600 – 678094][a]	177460 [148622 – 245298][a]	62011 [30975 – 94197][b]	<0.001[2]
Total Honey Production	9612 [6453 – 14259][a]	2629 [2218 – 3219][a]	526 [262 – 908][b]	<0.001[2]
Beeswax Production	378 [347 – 398][a]	87 [58 – 104][a]	21 [9 – 32][b]	<0.001[2]
Honey Yield Per Colony	23 [17 – 27][a]	12 [12 – 16][a]	9 [6 – 11][b]	<0.001[2]

[1]One–Way Analysis of Variance, [2]Kruskal Wallis H test. Data are presented as mean ± standard deviation or median [quartiles, Q1–Q3]. [a, b]; the difference between means with different letters in the same row is significant

TABLE III
Trend analysis results of the production indicators for the time series (Türkiye)

Production Indicator	MMK Z Value	Z Critical Value	*P*–value	MMK Trend	ST s value	± CL	*P*–value	ST Trend
Number of Enterprises	1.63	±1.96	0.102	No	3.32	±1.96	**<0.001**	+
Number of Colonies	6.37	±1.96	**<0.001**	+	7.73	±1.96	**<0.001**	+
Total Honey Production	10.88	±1.96	**<0.001**	+	6.40	±1.96	**<0.001**	+
Beeswax Production	5.98	±1.96	**<0.001**	+	3.55	±1.96	**<0.001**	+
Honey Yield Per Colony	-5.46	±1.96	**<0.001**	-	-4.39	±1.96	**<0.001**	-

Statistically significant trends are indicated in bold

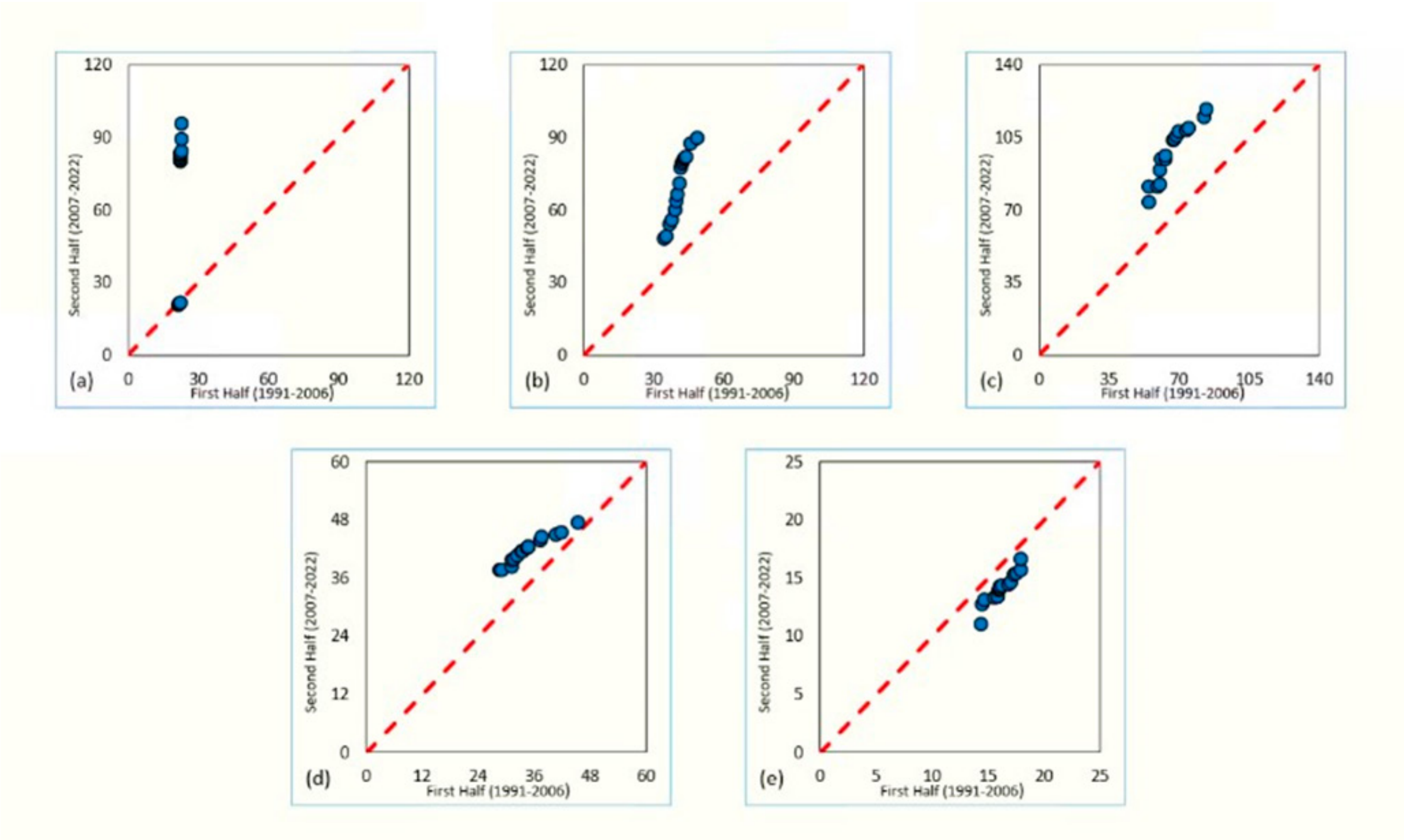

FIGURE 6. ST graphs for Number of enterprises (a)×1000, Number of colonies (b)×100000, Honey production (c)×1000, Beeswax production (d)×100, and Honey yield (e)

The results of the analysis indicated that Cluster 1 comprises four provinces (FIG 3). A notable observation is that these provinces are geographically distant from each other, indicating that regional differences do not directly affect the observed clustering patterns. The analysis revealed that beekeeping activities are widespread in the provinces belonging to Cluster 1 and that honey and beeswax production in these provinces is higher than in other provinces. This observation led to the classification of these provinces under the same cluster. In another study using cluster analysis, the provinces of Adana, Muğla, and Ordu emerged as notable units [21]. This result is consistent with this study. Previous studies have highlighted the scientific significance of beekeeping activities in various regions of Türkiye, and the findings of the current study are consistent with those of prominent provinces in the literature [39, 40, 41, 42, 43]. For instance, a study conducted in Ordu province identified that beekeeping has been practiced for many years, with producers transitioning to modern techniques, significantly contributing to the local economy. Additionally, it was noted that Ordu ranks second in Türkiye in terms of the number of beehives, following Muğla [42]. Studies conducted in Sivas province show that, while beekeeping activities are carried out across most regions of Türkiye, provinces such as Muğla, Adana, Ordu, and Sivas stand out in terms of honey production and beekeeping [39, 41]. Similarly, research in Adana province emphasized that favorable climatic conditions and suitable technological infrastructure offer substantial potential for beekeeping [40]. The differences among the provinces of Ordu, Adana, Sivas, and Muğla can be attributed to their geographical locations and climate characteristics. Ordu, located in the Black Sea Region, experiences a humid climate. In contrast, Adana features a warm Mediterranean climate. Sivas is influenced by a continental climate, while Muğla, situated in the Aegean Region, is notable for its production of flower honey [44]. These climatic differences contribute to the production of various types of honey (flower honey, citrus honey, etc.) distinguishing these provinces within their respective regions. Furthermore, the beekeeping research institutes and centers in the provinces of Cluster 1 provided significant support to producers and fostered sustainable production practices. For instance, in Ordu, producers achieved high–quality honey with high productivity and consequently, adopted beekeeping as their primary livelihood [45]. Additionally, during the flowering season, beekeepers in this region transport their hives to various provinces with abundant blossoms, and therefore, increase their honey production [46].

Abacı *et al.* [47], classified the provinces in the Black Sea region for the beekeeping sector using the Ward clustering method. They found that Ordu province alone comprised a single cluster. Consistently, in the current study, Ordu province was grouped under Cluster 1 with the highest productivity. However, since the clustering analysis covers all provinces in Türkiye, the results are more generalizable. Guler [48], assessed the overall activity value of the provinces and identified the most influential provinces as Ordu and Aydın. Similarly, in the current study, Ordu and Aydın are grouped into the first two clusters.

A total of eleven provinces were identified in Cluster 2. The cities in Cluster 2 were Antalya, Aydın, Balıkesir, Çanakkale, Erzurum, İzmir, Kocaeli, Mersin, Rize, Trabzon, and Van. The cities in Cluster 2 are distributed across a wide geographical range spanning from west to east and from north to south of Türkiye. Consequently, it can be argued that not only geographical location but also socio–economic or demographic factors might be influential in this clustering. Erzurum, Van, Trabzon, and Rize offer high–quality honey production thanks to their rich vegetation and favorable climatic conditions [49, 50, 51, 52, 53, 54, 55], whereas Antalya, Mersin, and Aydın contribute to beekeeping activities with their early spring and long vegetation seasons [56, 57, 58]. The provinces of Çanakkale and Balıkesir provide ideal conditions for beekeeping, with a variety of flower species and expansive pastures [59, 60]. Furthermore, industrial regions like İzmir and Kocaeli are considered pivotal in the processing and marketing of beekeeping products. These provinces have robust infrastructure for processing and marketing beekeeping products and they hold an important position in the beekeeping sector due to their rich vegetation, favorable climatic conditions, and industrial capacity.

Among the provinces examined under the NUTS–3 classification, the remaining 66 provinces cities out of 15 are grouped into Cluster 3. This cluster includes all cities in Central Anatolia, Western Black Sea, and Southeastern Anatolia, indicating distinct economic, social, and demographic characteristics compared to other regions. It is believed that in these regions, beekeeping is generally practiced as a sideline, and producers often lack sufficient knowledge and equipment [61]. Consequently, it can be argued that provinces in Cluster 3 do not meet the criteria present in the first two clusters.

Koday and Karadağ [22], conducted a research of regional colony numbers and honey production and identified that the top 4 regions in Türkiye with the highest production were Black Sea, Aegean, Mediterranean, and East Anatolia. The findings of the current study are consistent with the results reported by Koday and Karadağ [22]. Studies have identified the Black Sea, Aegean, Mediterranean, and East Anatolia regions as the foremost areas in Türkiye for beekeeping.

In the MMK and ST tests, Türkiye displayed increasing trends in the beekeeping production indicators, except for honey yield per colony. Only the number of enterprises was not found to be significant in the MMK method. The calculation of test statistics for the ST and MMK methods differs. Therefore, the results of both methods may differ. This result may be attributed to changes in the beekeeping support system implemented after 2008. Because before 2008, a support system incentivizing yield was in place, whereas after 2008, a support system based solely on the number of colonies, regardless of production, was implemented. Consequently, honey producers across Türkiye chose to increase the number of colonies and the number of beekeeping enterprises rather than focusing on increasing yield [63]. Other studies conducted within the beekeeping sector in Türkiye are also consistent with this situation. In their time series analysis, Erdal and Tipi [63] found that although there has been an increase in honey production in Türkiye, there has been a decline in honey yield per hive. Similarly, Abacı *et al.* [64], in their time series study, emphasized that despite the increase in the number of colonies, the yield per hive has increased at a slower rate, which aligns with the findings of this study.

CONCLUSIONS

The findings offer valuable insights into the clustering structure of provinces across the entire Türkiye. Specifically, the provinces included in Cluster 1 suggest that geographical and developmental differences across regions did not appear in the clustering analysis. Conversely, the aggregation of entire parts of certain regions under Cluster 3 indicates that provinces within these regions have similar characteristics. These results constitute important findings that should be considered when preparing regional policies and development strategies. Consequently, the obtained findings highlight the importance of targeted regional development policies and strategic planning.

In the trend analysis, positive trends were observed in the production indicators except for honey yield. To obtain a positive trend also in honey yield and further strengthen positive trends in other indicators, the implementation of policies that support beekeeping is important. Additionally, practices aimed at enhancing the beekeeping productivity of enterprises in provinces within Cluster 1 should be implemented. The results obtained from these practices should then be considered in efforts to enhance beekeeping productivity in other provinces as well.

The statistically significant differences observed among the clusters indicate that the classification made in this study has been successful. The findings presented in this study are believed to make a valuable contribution to the beekeeping literature by classifying provinces across Türkiye based on various production indicators. In future studies, it is recommended to explore various clustering algorithms and trend analysis methods while incorporating different variables obtained from reliable institutions.

Conflict of interest

Authors declare that they have no conflict of interest.

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