Assessing the sustainability of beekeeping farms in Turkey: Case of the Aegean region

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Abstract

The aim of this study is to determine the sustainability level of beekeeping farms in the provinces of Aydın, İzmir, and Muğla in the Aegean region of Turkey. The data were collected through a questionnaire from 149 selected beekeeping farms during 2018-2019. The study utilized Principal Components Analysis (PCA) to identify 19 basic sustainability indicators for beekeeping farms, which were categorized into economic, social, environmental and general sustainability indicators. Subsequently, the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) was employed to determine the weight of each indicator, considering expert opinions. The results showed that the economic sustainability index of beekeeping farms was 0.45, social sustainability was 0.36, environmental sustainability was 0.92, and the overall sustainability was 0.58. The study determined that 14.77% of apiaries in the selected farms were unsustainable, while the sustainability of 38.93% was at risk. The results also showed that trans-regional migratory beekeeping harmed sustainable beekeeping due to its negative effect on both bee welfare and cost increase.

Keywords: *Beekeeping Farms, Sustainability, Composite Sustainability Index, Principal Components Analysis, Fuzzy Analytical Hierarchy Process.*

1 Introduction

Beekeeping is an agricultural activity that can be pursued independently of soil conditions and is directly linked to climate, plant diversity, and care. In addition to honey, valuable beekeeping products include beeswax, pollen, propolis, royal jelly, bee bread (perga), and bee venom, which are widely used in traditional and modern medicine (Akçiçek and Yücel, 2015). Furthermore, beekeeping provides living materials such as queen bees, package bees, and artificial swarms to the beekeeping industry (Kouchner *et al.*, 2019). Pollination by bees is also essential for seed and food production. Bee pollination enhances the yield, nutritional value, and quality of many fruits and vegetables, extends their shelf life, and supports reforestation. The production of oilseeds used for biofuels, such as sunflower, rapeseed, and canola, is also improved by bee pollination. The resulting increase in agricultural productivity contributes to the gross domestic product (GDP) of countries. Given the role of beekeeping in pollination, ensuring its economic sustainability is also crucial for food safety (Patel *et al.*, 2021; Apimondia, 2022). In addition to the pollination services provided by honeybees, which have environmental benefits, beehives are considered one of the most reliable

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Table 1 - Impact of beekeeping on SDGs.

No	*Sustainable Development Goals (SDGs)*	*Impact of beekeeping on SDGs*
1	No Poverty	Beekeeping can provide a source of income for people in impoverished areas, as honey and other value-added bee product can be sold for profit.
2	Zero Hunger	Beekeeping can increase food production by improving crop yields through pollination, as well as providing a source of honey and other bee product as nutritious food.
3	Good Health and Well-being	Beekeeping is a therapeutic activity in itself and can provide a source of natural medicine.
4	Quality Education	Beekeeping can be used as an educational tool to teach people about the importance of pollinators, biodiversity, and environmental stewardship.
5	Gender Equality	Beekeeping can provide opportunities for women to participate in economic activities and improve their socio-economic status.
6	Clean Water and Sanitation	Bees play an important role in pollinating plants that help purify water sources.
7	Affordable and Clean Energy	Beeswax can be used as a sustainable and renewable energy source in the production of candles and other products.
8	Decent Work and Economic Growth	Beekeeping can provide opportunities for employment and economic growth in rural areas.
9	Industry, Innovation and Infrastructure	Beekeeping can promote innovation and sustainable practices in agriculture and food production. For example A major trend in beekeeping is the use of electronic information tools for monitoring and teaching.
10	Reduced Inequalities	Beekeeping can provide economic opportunities to marginalized communities, helping to reduce inequality.
11	Sustainable Cities and Communities	Bees can play a vital role in urban agriculture and promoting biodiversity in cities.
12	Responsible Consumption and Production	Beekeeping promotes sustainable agriculture practices and the production of natural, organic products.
13	Climate Action	Bees and other pollinators are essential to maintaining healthy ecosystems and mitigating climate change.
14	Life Below Water	Bees and other pollinators can help maintain the health of aquatic ecosystems by pollinating water-dependent plants.
15	Life on Land	Bees and other pollinators play a critical role in maintaining terrestrial ecosystems and biodiversity.
16	Peace, Justice and Strong Institutions	Beekeeping can promote sustainable agriculture and economic development, contributing to peaceful and just societies.
17	Partnerships for the Goals	Beekeeping requires collaboration and partnerships between various stakeholders, including beekeepers, farmers, and policymakers, to achieve sustainable development.

Source: Prepared based on Apimondia, 2022.

indicators of climate trends and play a crucial role as bioindicators of the ecosystem and environmental degradation (Etxegarai-Legarreta and Sanchez-Famoso, 2022). Beekeeping also supports sustainable income growth for the rural poor. Vocational training in beekeeping creates equal opportunities for employment, education, extension, and entrepreneurship in the local community and beekeeping participation can increase women's opportunities for economic, social, and political decision-making. Apitourism, which supports nature-based tourism initiatives, can also be promoted as sustainable tourism for regional development (Patel *et al.*, 2021; Apimondia, 2022).

The United Nations has issued a universal call to action to improve the lives of future generations through the 17 Sustainable Development Goals (SDGs) since January 2016 (Panta, 2020). Beekeeping is an activity that has the potential to positively impact all 17 SDGs, as it can improve food production systems ranging from traditional methods to highly advanced ones (Apimondia, 2022). The impact of beekeeping on SDGs is shown in Table 1. However, to fulfill the role of beekeeping in sustainable development, it is crucial to ensure the sustainability of beekeeping farms.

Beekeeping is a sector that has made significant progress in recent years, both in Turkey and around the world. The number of apiaries in Turkey increased by 6.74% in 2022 compared to the previous year, reaching 95,386 (Table 2). The number of hives also increased to 8,984,676 in 2022, showing a 2.88% increase compared to the previous year. Honey production in 2022 was 118,297 tons, which represents a significant increase of 22.79% compared to the previous year (TurkStat, 2023).

Turkey exported 17,248 tons of honey, generating 46,275 thousand dollars of foreign exchange revenue in 2022 (TurkStat, 2023). It is seen that the share of honey exports in the country's honey production was low from 2013 to 2020. However, in the last two years, 2021 and 2022, there has been some progress in export volumes (Table 3). Turkey also imports honey from time to time. In 2022, honey imports amounted to 58.24 tons, resulting in an expenditure of 163 thousand dollars of foreign exchange.

In recent years, the importance of crop products based on pollination by bees has increased worldwide. However, at the same time, the losses of bee colonies have also risen. A survey study, which involved 28,629 beekeepers from 35 different countries (31 EU member states), reported a general winter colony loss rate of 16.7% between countries for the 2018-2019 winter season, with the loss rate ranging from 5.8% to 32%. The highest loss rate was recorded in Slovenia with 32.0%, followed by Serbia with 25.4%, Spain, Croatia, Iran, Greece and Portugal with decreasing loss rates between 20% and 25%. The lowest loss rate was observed in Bulgaria, with a rate of 5.8% (Gray *et al.*, 2020). Studies conducted in different regions of Turkey determined that overwintering losses ranged from 9% to 36% (Sıralı and Doğaroğlu, 2005; Öztürk *et al.*, 2015; Emir,

Table 2 - Beekeeping statistics for Turkey (2013-2022).

Years	*Number of Beekeeping Farms*	*Total Number of Hives*	*Index*	*Honey Production (tons)*	*Index*	*Honey Production (kg/hive)*	*Index*
2013	79,934	6,641,348	100.00	94,694	100.00	14.26	100.00
2014	81,108	7,082,732	106.65	103,525	109.33	14.62	102.52
2015	83,475	7,748,287	116.67	108,128	114.19	13.96	97.90
2016	84,047	7,900,364	118.96	105,727	111.65	13.38	93.83
2017	83,210	7,991,072	120.32	114,471	120.89	14.32	100.42
2018	81,830	8,108,424	122.09	107,920	113.97	13.31	93.34
2019	80,675	8,128,360	122.39	109,330	115.46	13.45	94.32
2020	82,862	8,179,085	123.15	104,077	109.91	12.72	89.23
2021	89,361	8,733,394	131.50	96,344	101.74	11.03	77.36
2022	95,386	8,984,676	135.28	118,297	124.93	13.17	92.33
Average Annual Relative Change (%)	1.98	3.41	-	2.50	-	-0.88	-

Source: Calculated based on TURKSTAT, 2023.

Table 3 - Honey export-import in Turkey (2013-2022).

Years	*Amount of Export (ton)*	*Export Value (Thousand $)*	*Export Price ($/kg)*	*Export Amount/ Production Amount (%)*	*Import Value (Thousand $)*
2013	3,574	13,020	3.64	3.77	205
2014	4,972	18,934	3.81	4.80	184
2015	7,196	25,098	3.49	6.66	66
2016	3,628	14,953	4.12	3.43	64
2017	6,455	23,419	3.63	5.64	66
2018	6,418	25,691	4.00	5.95	150
2019	5,548	24,763	4.46	5.07	221
2020	6,038	26,161	4.33	5.80	294
2021	10,046	31,140	3.10	10.43	378
2022	17,248	46,275	2.68	14.58	163
Average Annual Relative Change (%)	19.11	15.13	-3.34	16.20	-2.49

Source: Calculated based on TURKSTAT, 2023.

2015). The decline in the number of bees poses a threat to the sustainability of beekeeping operations, as well as the sustainability of the agricultural system. This decline is likely to affect the production and cost of fruits and vegetables, leading to imbalanced and inadequate nutrition and health problems, particularly some non-communicable diseases (FAO, 2018). In addition to the loss of bee colonies, other factors such as habitat degradation, pollution, agricultural intensification and urbanization, diseases, allergies, pesticide residues, biodiversity decline, climate change, unconscious use of chemicals and antibiotics, and production focused on a single product, have contributed to the need for sustainable beekeeping practices. Sustainability practices on the farm are characterized by concern for environmental protection, respect for social equity, and ensuring the economic viability of the activity (Mokrani *et al.*, 2022).

2. Literature review

Agriculture, in general and beekeeping, in particular, emphasize the environmental, social, and economic pillars, the three dimensions of sustainability (Panta, 2020). Various studies have been conducted on the sustainability of beekeeping operations, examining different aspects of sustainability. Some studies have focused on evaluating one aspect of sustainability, such as cost analysis, carbon footprint, or Life Cycle Analysis (LCA) (Ćejvanović *et al.*, 2011; Kendall *et al.*, 2013; Strano *et al.*, 2015; Mujica *et al.*, 2016; Arzoumanidis *et al.*, 2019; Moreira *et al.*, 2019; Vásquez-Ibarra *et al.*, 2022; Pignagnoli *et al.*, 2021). Others have taken into account all three dimensions of sustainability, i.e., environmental, economic, and social aspects (Pocol *et al.*, 2012; Kouchner *et al.*, 2018; Rahimi *et al.*, 2020).

The indicators used to measure sustainability are directly related to the aspect of sustainability being addressed in each study. Ćejvanović *et al.* (2011) focused on the economic aspect of sustainability and suggested that income and income per hive are appropriate criteria for a sustainable beekeeping model. The economic aspect of sustainability was also highlighted in a study conducted by Strano *et al.* (2015). The results of this study, which evaluated the profitability of investments in apiculture farms in southern Italy using the Life Cycle Costing (LCC) method and economic indicators, showed a positive Net Present Value (NPV), a higher Internal Profitability Ratio (IRR) (5.26%) than the discount rate (r), and a Benefit-Cost ratio (B_0/C_0) of 1.13. These values indicate the profitability of investment projects in beekeeping.

LCA has been widely used in studies of beekeeping sustainability towards the environment (Kendall *et al.*, 2013; Vásquez-Ibarra *et al.*, 2022). In the study by Kendall *et al.* (2013), the carbon footprint of honey production in the U.S. at various company sizes was estimated using LCA. The life-cycle modeling of a complete commercial supply chain (raw honey production, transport to a processor, and processing) showed that total greenhouse gas emissions ranged from 0.67 to 0.92 kg of CO_2 e/kg per kilogram of processed honey. A preliminary estimate of the global warming potential of honey production in Argentina was conducted by Mujica *et al.* (2016), and the carbon footprint of honey was estimated to be 2.5 ± 0.17 kg CO_2 e/kg honey. Moreira *et al.* (2019) conducted a study that evaluated the carbon footprint of honey production, and except for two producers, all achieved lower values than 1.66 kg CO_2 e/kg honey. The study suggests that various measures can be taken to reduce the environmental impacts associated with honey production, such as more efficient transportation, environmentally friendly packaging, and remote pest control systems that allow early detection of invasive wasps.

In the study conducted by Pignagnoli *et al.* (2021), the carbon footprints of migratory and stationary beekeeping were calculated to be 1.40 to 2.20 kg CO_2 e/kg honey and 0.380 to 0.48 kg CO_2 e/kg honey, respectively. In a study conducted in Chile, large-scale beekeepers produced an average of 0.26 kg CO_2 e/kg honey, medium-scale beekeepers 0.31 kg CO_2 e/kg honey, and small-scale beekeepers 0.85 kg CO_2 e/kg honey. The results of this study suggest that the environmental impact of honey production can be reduced through management practices focused mainly on feeding and transport (Vásquez-Ibarra *et al.*, 2022).

The study conducted in the northwestern region of Romania used both quantitative (questionnaire) and qualitative (focus group) research methods to explore several dimensions of beekeeping. The study found that beekeeping can be a profitable business, but its profitability is dependent on climatic conditions. Moreover, there is a lack of a strong system for promoting and marketing bee products in the study region. The study also highlighted the social and environmental benefits of beekeeping. From a social point of view, beekeeping supports rural development by creating job opportunities, while from an environmental perspective; beekeeping plays a critical role in pollination and biodiversity conservation (Pocol *et al.*, 2012).

Several studies have also explored the general framework of sustainability in beekeeping operations. For example, Panta (2020) aimed to identify value-adding activities in beekeeping operations from a sustainability perspective, while Kösoğlu *et al.* (2021) conducted a literature review to explore the concept of sustainability in beekeeping, considering factors such as bee health, environmental issues, climate change, and beekeeping practices. These studies emphasize the importance of strengthening awareness and legal measures to protect natural habitats, reducing environmental pollutants, and promoting the use of natural control methods against diseases and pests to ensure the sustainability of beekeeping and the production of high-quality bee products.

Over 120 agricultural sustainability assessment tools such as MESMIS (Framework for Assessing the Sustainability of Natural Resource Management Systems), RISE (Response-Inducing Sustainability Evaluation), SAFE (Sustainability Assessment of Farming and the Environment), IDEA (Indicateurs de Durabilité des Exploitations Agricoles), and SAFA (Sustainability Assessment of Food and Agriculture systems) are utilized to develop the indicators related to the economic, environmental and social dimensions of sustainability. (Lopez-Ridaura *et al.*, 2002; Hani *et al.*, 2003; Van Cauwenbergh *et al.*, 2007; Zahm *et al.*, 2008; FAO, 2012; Talukder and Blay-Palmer, 2017). For instance, Kouchner *et al.* (2018) developed a sustainability framework based on a participatory approach to suit the specificities of beekeeping in France. The SAFA guide was used as a basis for the study, which resulted in six dimensions and 15 themes that can be used to assess the sustainability of beekeeping operations. These dimensions include the beekeeping sector and society issues, economic viability, environmental impacts, development, and the ability to ensure production and quality of life. In another study conducted in Iran, the Delphi technique was used to determine the sustainability criteria of the beekeeping sector. The opinions of 32 experts were gathered, resulting in the identification of 13 sustainability criteria (Rahimi *et al.*, 2020).

Despite the multitude of methodologies and frameworks for assessing sustainability, there is currently no consensus on the widespread use of one methodology, and various frameworks and indicators are still being utilized (Abdollahzadeh *et al.*, 2015). Given the significant differences in management practices between professional beekeeping and other agricultural activities, it is not appropriate to apply a sustainability assessment tool developed for other agricultural activities directly to beekeeping (Kouchner *et al.*, 2018). Therefore, this study aims to develop an index to measure sustainability in beekeeping at the farm level in Aydın, İzmir, and Muğla provinces in the Aegean region of Turkey and to provide recommendations for future research based on the developed index.

3. Materials and method

3.1. *Research area*

This study was conducted in the provinces of Aydın, İzmir, and Muğla, located in the Aegean region of Turkey (Figure 1). These provinces have a Mediterranean climate, with hot and dry summers and warm and rainy winters (MGM, 2022a). According to long-term data from 1941 to 2021, the average temperatures in these provinces are 17.7°C, 17.9°C, and 15.1°C, respectively. The annual average number of rainy days is 81.9, 84.2, and 108.9, respectively, and the average annual precipitation is 661.7 mm/year, 713.8 mm/year, and 1209.1 mm/year, respectively (MGM, 2022b).

3.2. *Sampling method*

The data for this study were collected through questionnaires from 149 apiaries located in the provinces of Aydın, İzmir, and Muğla in the Aegean region. The main population of the survey consisted of 8,508 apiaries registered in the Apiculture Registration System (AKS) in these provinces. The sample size of 149 producers

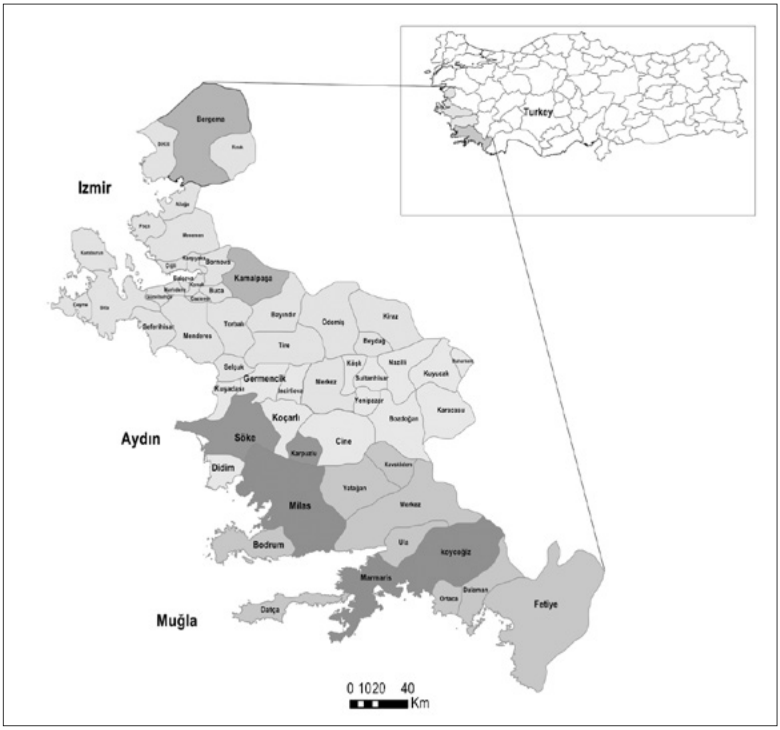
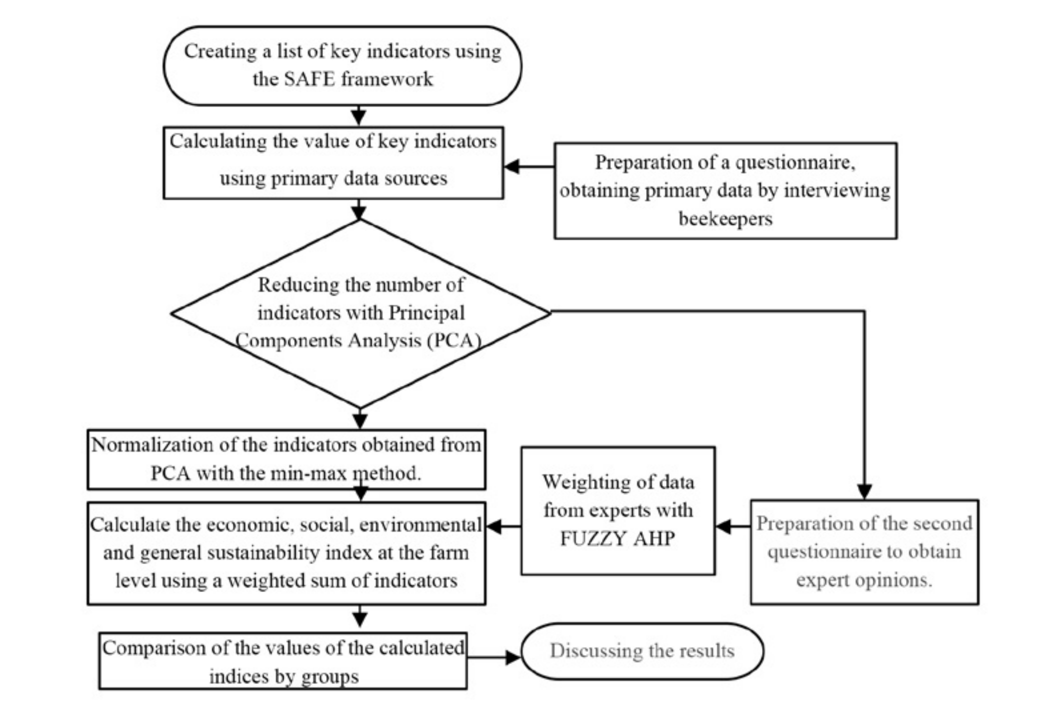


Figure 1 - Location map of the studied area constructing by ArcGIS.

Figure 2 - The methodology used in the research.



was determined using the proportional sample size formula (Newbold, 1995), with a 95% confidence interval and a margin of error of 8%.

$$n = \frac{N.p(1-p)}{(N-1)\sigma^2_{p_x} + p(1-p)} \qquad (1)$$

Where n as sample size and N as the number of beekeepers in the study area, $\sigma^2_{p_x}$ shows the variance and p represents the ratio of producers adopting sustainable practices in beekeeping (the ratio of producers adopting sustainable practices in beekeeping to reach the maximum sample size was assumed to be 0.50). The number of producers to be interviewed in each province was determined by considering the total number of producers in the provinces. Thus, 82 producers were interviewed in Muğla, 37 in İzmir, and 30 producers in Aydın.

The districts selected for study in each province were those with intensive honey production. According to 2018 data, Milas, Köyceğiz, and Marmaris districts account for 49.36% of the total honey production in Muğla, while Söke and Karpuzlu districts account for 52.12% of the total honey production in Aydın, and Bergama and Kemalpaşa districts account for 46.76% of the total honey production in İzmir. The number of producers surveyed in each district was determined based on the ratio of districts to the total number of producers. As a result, 36 producers were surveyed in Milas, 26 in Köyceğiz, 20 in Marmaris, 23 in Bergama, 14 in Kemalpaşa, 16 in Karpuzlu, and 14 in Söke. The producer interviewed in each district was chosen randomly.

3.3. *Developing the sustainability index*

Tomeasure the sustainability level of beekeeping farms, a composite sustainability index was calculated while taking into account the recommendations of OECD (2008). Figure 2 shows the methodology used in the study.

To select key sustainability indicators in the first stage, the SAFE method was used. The SAFE framework aims to assess sustainability in agriculture progressively by defining principles, criteria, and indicators (Van Cauwenbergh *et al.*, 2007). The study implemented criteria and indi-

Table 4 - Indicators for sustainable beekeeping.

Indicators and descriptions	
1. Economic	
Gross production value	Value of products such as honey, pollen, etc., produced in the hive, bee sales, government support, and pollination income. (TL)
Net profit	Net profit per hive. It is calculated by subtracting production costs from gross production value. (Excluding the provision of family labor) (TL)
Gross profit	Gross profit per hive. It is calculated by subtracting variable costs from gross production value. (TL)
Relative profit	Gross production value obtained in relation to the unit cost. (ratio)
Honey yield	Amount of honey produced per hive (kg)
Labor profitability	Net profit per employee (TL)
Risk management with diversification	The production of various bee products with high added value as risk management in the apiary (Likert). - According to the assessment of producers, the degree of effectiveness of the expression "Production of bee products other than honey" as a risk management strategy; (*1=not at all effective, 2=ineffective, 3= somewhat effective, 4=very effective, 5=extremely effective).*
Willing to diversification	Willingness to produce other hive products besides honey, such as pollen, propolis, royal jelly, bee bread, and bee venom in beekeeping (Likert). - The degree of agreement of producers to the statement "Besides honey in beekeeping, I also consider the production of other hive products with high economic value"; *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
2. Social	
Beekeeper's accommodation	The place where the beekeeper stays to carry out the beekeeping activity (categorical) *(1= tent or shed in the apiary, 2=caravan, 3=car, 4=village houses, 5=Rent house, 6=hotel near the hive, 7=self-built house, 8= returnee without accommodation, 9= stationary beekeeper).*
Time away from home	The time that the beekeeper is separated from his family members to carry out the beekeeping activity (categorical) *(1= More than 3 months, 2= 1-3 months, 3= Less than 1 month, 4= They go with the family, 5= stationary beekeeper)*
Transportation distance	The transport of hives in their ecological environment, is an indicator that influences the welfare of bees (categorical) *(1=more than 1854 km, 2=1136-1854 km, 3=415-1135 km, 4= less than 415 km)*
Working period in beekeeping	The time the beekeeper and his family worked in the apiary (hours)
Employment	Employment created by beekeeping (person)
Satisfaction with education and health services	Degree of producer agreement with the statement "I am satisfied with the services provided by schools and health centers in my region." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Access to social and cultural spaces	Degree of agreement of the producer to the statement "In my region, there are social and cultural areas." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*

3. *Environmental (shows the beekeeper's attitude towards the environment)*	
Environment for health	Environmental protection tendency of beekeepers to produce healthy bee products (Likert) -Degree of agreement of the producer to the statement "I protect nature for the production of healthy bee products." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Environment for sustainable production	Environmental protection tendency of the beekeeper for the ability to do beekeeping in the future (Likert) - Degree of agreement of the producer to the statement "I protect nature to be able to do beekeeping in the future." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Forest protection	The tendency of the beekeepers to protect the forest (Likert) - Degree of producer agreement with the statement "beekeepers are conscious about forest protection." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*
Conserving biodiversity	The opinion of beekeepers about the role of bees in the protection of biodiversity (Likert) - Degree of producer agreement with the statement "The honey bee is of great importance for biodiversity and a sustainable environment." *(1=Strongly disagree, 2=Disagree, 3=Neither agree or disagree, 4= agree, 5=Strongly agree)*

cators for each principle of sustainability based on the SAFE framework. After selecting the basic sustainability indicators, their value was calculated using the primary data sources obtained from the survey conducted with beekeepers.

In the second stage, Principal component analysis (PCA) was used as a data preparation technique to reduce the dimension and eliminate the dependency structure between indicators. Table 4 shows the characteristics of the indicators obtained from PCA analysis.

As the indicators and units of measurement used in this study differ from each other, the min-max method was used in the third stage (Freudenberg, 2003) to assign a value of 0 to the smallest indicator value and a value of 1 to the largest. This method eliminates scale errors caused by different units of measurement.

In the fourth stage, weighting was performed to determine the relative importance of the selected key indicators. Weighting techniques to create an index can be categorised as "positive" or endogenous, and "normative" or exogenous (Gómez-Limón and Sanchez-Fernandez, 2010). Positive or endogenous techniques allow obtaining weights of key indicators through statistical procedures, while normative or exogenous techniques attempt to assign different weights to indicators depending on the opinion of experts and external decision-makers (Fallah-Alipour *et al.*, 2018). The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) proposed by Chang (1996) was used in the study to weight the main sustainability indicators and incorporate experts' opinions into the analysis (Pala, 2016). The experts whose opinions were incorporated into the study consisted of faculty members who are experts in beekeeping, faculty members from the departments of agricultural economics who work in beekeeping and sustainable agriculture, expert agricultural engineers who work in the beekeeping department of the Agricultural Research Institute, forestry engineers, university students who research beekeeping and sustainable agriculture, and conscious beekeepers.

The weighted sum of indicators in Stage 5 was used to create the composite index of economic, social, environmental, and overall sustainability (Fallah-Alipour *et al.*, 2018).

$$KE = \sum_{k=1}^{k=n} W_k^* . I_k \qquad (2)$$

Table 5 - Categories of the farms by their production diversity.

Categories	*Number of Farms*	*%*	*Average Number of Hives*
Single-product farms	66	44.30	250.38
Diversified farms	83	55.70	305.80
Total	149	100.00	281.25

Table 6 - Grouping of the farms due to locations.

Provinces	*Number of Farms*	*%*	*Average Number of Hives*
Aydın	30	20.13	282.60
İzmir	37	24.83	231.51
Muğla	82	55.04	303.20
Total	149	100.00	281.25

Where KE is agricultural sustainability index derived from n indicators, I_k as the normalized value of the indicator and W_k^* is the standard weight of the indicator.

The study regions were compared and classified into relative sustainability levels for economic, social, and environmental dimensions, as well as an overall agricultural sustainability status, based on the results of the composite indices obtained. To accomplish this, the standard deviation range from the mean was utilized.

In addition, the farms were grouped in two different ways and their sustainability levels were compared according to these groups. In the first grouping, the product diversity of the farms was taken into account and the farms were divided into two categories: the first category was farms producing only honey and beeswax (single-product farms), and the second category was farms producing both honey and beeswax and at least one other bee product (diversified farms) (Table 5). The second grouping took into account the provinces where the farms are located (Table 6).

4. Result and discussion

4.1. *General situation of apiaries*

The average age of producers was 50.11 years, the average period of education was 6.31 years, the average farming experience of farmers was 32.14 years, and the average beekeeping experience was 25.15 years (Table 7). These values are similar to the results of other studies. In stud-

Table 7 - The average age, education level and experience of beekeepers.

Characteristics	*Categories*			*Provinces*				*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*p*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
Age	52.14	48.51	0.06	49.97	51.05	49.74	0.85	50.11
Duration of Education (year)	5.92	6.61	0.03**	6.40	5.95	6.44	0.45	6.31
Agricultural Experience (year)	33.39	31.02	0.38	31.94	32.21	32.19	0.98	32.14
Beekeeping Experience (year)	24.89	25.36	0.67	21.75	24.70	26.60	0.16	25.15

*(*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 8 - The household size of the farms.

	Categories			*Provinces*				*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*P*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
Male	2.02	2.07	0.71	2.20	1.81	2.10	0.09	2.05
Female	1.65	1.80	0.38	1.90	1.62	1.72	0.41	1.73
Total	3.67	3.87	0.38	4.10	3.43	3.82	0.14	3.78

ies conducted in different provinces of Turkey, it was found that the average age of beekeepers ranges from 40.85 to 54.71 years, the average period of education ranges from 5.68 to 9.28 years, and the average experience of beekeepers ranges from 11.08 to 23 years (Saner *et al.*, 2005; Ören *et al.*, 2010; Saner *et al.*, 2011; Emir, 2015; Çevrimli, 2017; Subaşı *et al.*, 2019; Onuç *et al.*, 2019; Aydın *et al.*, 2020).

The average household size was 3.78. The average number of males was 2.05 and the number of females was 1.73 (Table 8).

In 41.61% of the studied farms there are 1-200 hives, in 28.86% 201-350 hives and in 29.53% more than 350 hives (Table 9). In the study conducted in the Mediterranean region, the average number of hives was 179.06 (Subaşı *et al.*, 2019).

Upon analysis of the sub-indicators used to measure sustainability in the studied provinces, it was found that 30.00%, 43.24%, and 50.00% of farms in Aydın, İzmir, and Muğla provinces respectively, produced only honey and beeswax. Similar findings were reported in a study conducted in Kütahya province, where 67.2% of beekeepers produced honey only, 30.3% produced pollen, 0.5% produced royal jelly, and 22% produced beeswax (Özer, 2017). The honey yield per hive in Aydın, İzmir, and Muğla provinces were calculated to be 12.50 kg, 21.25 kg, and 15.84 kg, respectively (Table 10). In another study conducted in the Aegean Region, honey yield in apiaries with different hives varied between 11.4 kg and 21.4 kg (Koç and Karacaoğlu, 2016).

The gross production value per hive in these provinces was calculated as 236.15 TL, 352.64 TL, and 252.45 TL, respectively (Table 11). According to the results of the Kruskal-Wallis test, there was a statistically significant difference between the provincial groups ($\chi2=14.08$, $p=0.00$). Gross profit was calculated as 136.22 TL, 246.57 TL, and 123.24 TL, respectively. It is noteworthy that farms in Aydın and Muğla had a negative net profit, while farms in İzmir had a positive net profit. In the relative profit analysis, the farms in Aydın produced 0.96 value units for every 1 cost unit, the farms in İzmir produced 1.28 value units for every 1 cost unit, and the farms in Muğla

Table 9 - Distribution of farms by the number of hives.

	Categories				*Provinces*							
	Single-product farms (66)		*Diversified farms (83)*		*Aydın (30)*		*İzmir (37)*		*Muğla (82)*		*General (149)*	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
1-200 hives	31	46.97	31	37.34	14	46.66	23	62.16	25	30.49	62	41.61
201-350 hives	17	25.76	26	31.33	5	16.67	7	18.92	31	37.8	43	28.86
350+ hives	18	27.27	26	31.33	11	36.67	7	18.92	26	31.71	44	29.53
Total	66	100.00	83	100.00	30	100.00	37	100.00	82	100.00	149	100.00

Table 10 - Efficiency of bee products in farms.

	Categories			*Provinces*				*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*P*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
Honey (kg/hive)	15.20	17.55	0.20	12.50	21.25	15.84	0.00**	16.51
Beeswax (gr/hive)	306.30	392.70	0.19	302.85	295.55	399.89	0.17	354.40
Pollen (gr/hive)	-	486.10	-	794.20	473.19	382.73	0.56	486.10
Propolis (gr/hive)	-	18.03		7.17	23.01	18.18	0.37	18.03
Bee bread (gr/hive)	-	133.73		-	-	133.73		133.73

*(*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 11 - Annual operating results in farms (per hive).

	Categories		*Provinces*			*General (149)*
	Single-product farms (66)	*Diversified farms (83)*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	
Gross production value (TL)	*227.99*	*310.67*	*236.15*	*352.64*	*252.45*	*274.05*
Variable costs (TL)	117.44	117.67	99.93	106.07	129.21	117.58
Fixed costs (TL)	154.67	143.91	145.67	168.63	140.78	148.68
Production costs (TL)	*272.11*	*261.58*	*245.60*	*274.70*	*269.99*	*266.26*
Gross profit	110.55	193.00	136.22	246.57	123.24	156.47
Net profit	-44.12	49.09	-9.45	77.94	-17.54	7.79
Relative Profit	0.84	1.19	0.96	1.28	0.94	1.03

province produced 0.94 value units for every 1 cost unit. Previous studies conducted in the Mediterranean region reported a relative profit of 2.70, while a study conducted in Gökçeada, Çanakkale, reported a relative profit rate of 2.28 (Öztürk *et al.*, 2015; Subaşı *et al.*, 2019; Özyasin and Karaman, 2018).

When the farms were investigated in terms of employment, it was found that 273.08 male working days (MWD) were spent on beekeeping activities on farms in Aydın, 273.51 MWD on farms in İzmir, and 312.97 MWD on farms in Muğla (Table 12). In a study conducted by Onuç *et al.* (2019) in the Kemalpaşa district of İzmir province, the total workforce used in beekeeping was reported as 224.64 MWD (Onuç *et al.*, 2019).

Regarding the type of beekeeping, it was found that 70.00%, 75.68%, and 98.78% of producers in Aydın, İzmir, and Muğla provinces, respectively, were interregional migratory beekeepers (Table 13). The highest number of stationary beekeepers was found in Aydın province, the highest number of intra-provincial migratory beekeepers in İzmir province, and the highest number of inter-regional migratory beekeepers in Muğla province. In a study conducted in Çanakkale province, 87.36% of

Table 12 - Labor use in farms (MWD).

	Categories			*Provinces*				
	Single-product farms (66)	*Diversified farms (83)*	*p*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	*General (149)*
Family labor use	253.8	276.52	0.53	243.92	249.7	282.27	0.16	266.46
Temporary labor use	21.36	34.51	0.07	29.17	23.81	30.71	0.64	28.68
Total labor use	275.16	311.03	0.28	273.08	273.51	312.97	0.21	295.14

Table 13 - Beekeeping systems of farms.

	Categories				*Provinces*							
	Single-product farms (66)		*Diversified farms (83)*		*Aydın (30)*		*İzmir (37)*		*Muğla (82)*		*General (149)*	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Stationary	3	4.55	4	4.82	4	13.33	2	5.40	1	1.22	7	4.70
Intra-provincial	4	6.06	8	9.64	5	16.67	7	18.92	-	-	12	8.05
Interregional migratory	59	89.39	71	85.54	21	70.00	28	75.68	81	98.78	130	87.25
Total	66	100.00	83	100.00	30	100.00	37	100.00	82	100.00	149	100.00

beekeepers practiced migratory beekeeping, while 12.64% practiced stationary beekeeping (Aktürk and Aydın, 2019).

The average number of hive accommodation places on farms located in Aydın, İzmir, and Muğla provinces was calculated as 3.03, 3.49, and 3.52, respectively, while the total transport distance per farm was calculated as 939.63 km, 644.97 km, and 1426.70 km, respectively (Table 14). According to the results of the Kruskal-Wallis test, the differences between provincial groups in terms of distance ($\chi2$=36.831, p=0.000) were found to be statistically significant. In a study conducted in Muğla, Denizli, and Aydın provinces, the average number of hive accommodation places was calculated to be 3.9, and the average transport distance was calculated to be 769 km (Çevrimli, 2017).

In Aydın, İzmir, and Muğla provinces, 70.00%, 59.46%, and 90.24% of producers, respectively, live in tents and huts on the apiary, while 30.00%, 13.51%, and 2.44% of them finish their work without accommodation and return. Additionally, it was found that 30.00%, 16.21%, and

Table 14 - The average number of hive accommodation places in the farms.

		Categories			*Provinces*				*General (149)*
		Single-product farms (66)	*Diversified farms (83)*	*P*	*Aydın (30)*	*İzmir (37)*	*Muğla (82)*	*p*	
number of hive accommodation	Max	6	8		6	6	8		8
	Min	1	1		1	1	1		1
	Average	3.08	3.69	0.01*	3.03	3.49	3.52	0.31	3.42
Total transport distance (KM)		1132.92	1135.78	0.87	939.63	644.97	1426.70	0.00**	1134.51

*(*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 15 - Working conditions of beekeepers in the farms.

		Categories				*Provinces*						*General (149)*	
		Single-product farms (66)		*Diversified farms (83)*		*Aydın (30)*		*İzmir (37)*		*Muğla (82)*			
		N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Accommodations	tent/ hut in apiary	55	83.33	62	74.70	21	70.00	22	59.46	74	90.24	117	78.52
	finishes her work and returns	6	9.09	10	12.05	9	30.00	5	13.51	2	2.44	16	10.74
	Other	5	7.58	11	13.25	0	0.00	10	27.03	6	7.32	16	10.74
	Total	*66*	*100.00*	*83*	*100.00*	*30*	*100.00*	*37*	*100.00*	*82*	*100.00*	*149*	*100.00*
Away from family members	less than 1 month	17	25.76	17	20.48	11	36.67	13	35.14	10	12.20	34	22.82
	1-3 months	23	34.85	29	34.94	10	33.33	18	48.65	24	29.27	52	34.90
	more than 3 months	26	39.39	37	44.58	9	30.00	6	16.21	48	58.53	63	42.28
	Total	*66*	*100.00*	*83*	*100.00*	*30*	*100.00*	*37*	*100.00*	*82*	*100.00*	*149*	*100.00*

58.53% of the producers on farms in these provinces, respectively, live away from their family members for more than 3 months a year to do beekeeping (Table 15).

4.2. Assessment of sustainability levels in the farms

Principal component analysis (PCA) was utilized to determine the sustainability levels if there was a significant correlation among the selected key indicators and to group them into statistically similar indicator groups, making interpretation easier. The appropriateness of the data for PCA analysis was determined by the KMO and Bartlett test statistics (Table 16).

The results indicated a strong correlation between the indicators that were implemented in the model, which was confirmed through PCA analysis.

A total of 80.92% of the cumulative variance in the indicators can be explained by 7 components, as shown in Table 17. Components 1 and 5 reflect the economic sustainability of the beekeeping farms, and are related to factors such as profitability, financial stability, risk management, and production diversity. Components 2, 3, and 6 represent the social sustainability of beekeeping activities, and are based on factors such as the health and well-being of bees and beekeepers, the potential for job creation through beekeeping, and the ability of beekeepers to access social opportunities.

Components 4 and 7 are indicative of environmental sustainability and reflect the beekeeper's attitude toward the environment. Once the sub-indicators were obtained through PCA analysis, each sub-indicator value was standardized using the min-max method.

The weighting of each indicator resulting from the PCA method was determined using the Fuzzy AHP method in order to calculate the composite sustainability index. The hierarchical structure for this process is illustrated in Figure 3.

A questionnaire was created with indicators to determine the weight of sustainable beekeeping

Table 16 - KMO and Bartlett test results.

Kaiser-Meyer-Olkin (KMO) Test for Sampling Adequacy		0.711
Bartlett's Test of Sphericity	Approximate Chi-Square	3015.408
	Degrees of Freedom	171
	Significance Level	0.000

Table 17 - Principal component loads and related oriented indicator.

Rotated Component Matrix							
	Components						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Net profit	**0.985**	-0.015	0.082	0.018	-0.017	0.040	0.000
Gross profit	**0.984**	-0.011	0.085	0.017	-0.014	0.046	-0.001
Gross production value	**0.936**	-0.148	0.120	0.055	0.033	0.063	-0.015
Relative profit	**0.867**	0.213	0.017	-0.017	-0.029	0.033	0.003
Honey yield	**0.864**	-0.201	0.144	0.072	-0.006	0.080	-0.015
Labor profitability	**0.765**	0.060	-0.348	-0.009	-0.039	-0.039	0.028
Beekeeper's accommodation	0.018	**0.840**	-0.097	-0.037	-0.048	0.042	-0.050
Time away from home	-0.034	**0.805**	0.035	-0.119	0.037	0.131	0.000
Transportation distance	-0.050	**0.784**	-0.118	-0.172	-0.130	-0.171	0.083
Working period in beekeeping	0.037	-0.054	**0.966**	0.084	-0.067	-0.013	-0.022
Employment	0.105	-0.101	**0.965**	0.075	-0.035	-0.010	-0.011
Environment for health	0.062	-0.130	0.071	**0.965**	-0.017	0.043	-0.025
Environment for sustainable production	0.016	-0.175	0.088	**0.956**	0.027	0.054	0.039
Risk management with diversification	-0.137	0.022	-0.055	-0.030	**0.846**	0.002	-0.168
Willing to diversification	0.078	-0.130	-0.048	0.031	**0.838**	-0.081	0.162
Satisfaction with education and health services	0.026	-0.147	0.049	0.112	-0.095	**0.826**	0.032
Access to social and cultural spaces	0.107	0.182	-0.068	-0.023	0.023	**0.783**	0.045
Forest protection	-0.077	0.118	-0.198	-0.127	-0.252	-0.054	**0.715**
Conserving biodiversity	0.069	-0.101	0.167	0.154	0.269	0.167	**0.689**

Figure 3 - Hierarchical structure in relation to the sustainability of beekeeping operations.

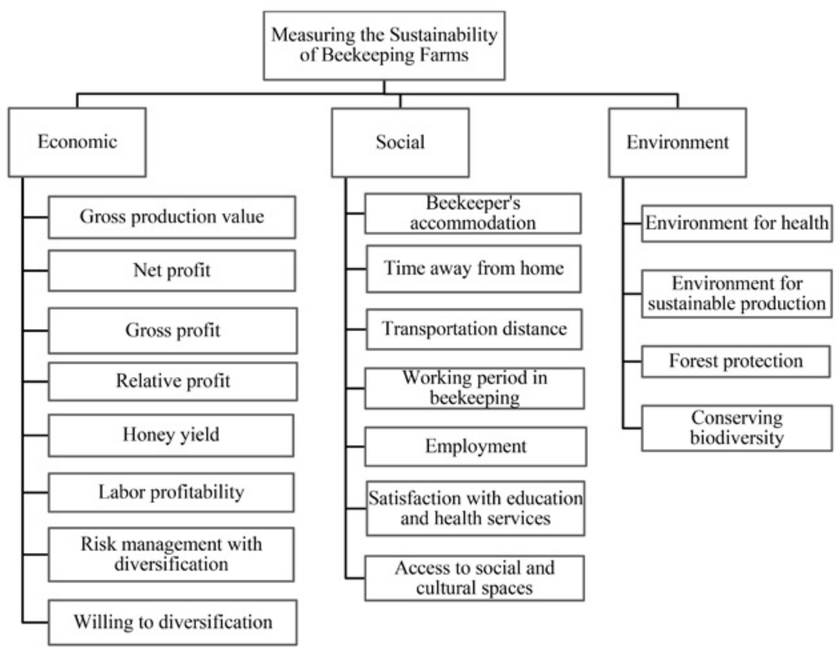


Table 18 - Weighting of the three dimensions of sustainability with the Fuzzy AHP method.

Criteria	*Standardized Weight*	*Rank*
Economic	0.346	1
Environmental	0.332	2
Social	0.321	3

CR (Consistency Ratio: 0.065).

dimensions, which was sent to experts. The questionnaire assessed the importance of each criterion relative to others, assigning values from 1 to 9. The scores obtained from 12 subject matter experts were first blurred and then the geometric mean of the fuzzy scores was taken to obtain a fuzzy pairwise comparison matrix for the main criteria and sub-criteria. Using these values, the weight of the three basic dimensions of sustainable beekeeping (economic, social, and environmental) and their corresponding indicators were calculated. The economic criterion was found to be the most important, with a weight value of 0.346 (Table 18). This was followed by the environmental criteria with a weighting value of 0.332 and the social criteria with a weighting value of 0.321. The consistency ratio of the criteria was calculated to be 0.065, which is below 10%, indicating that the created pairwise comparison matrix is consistent.

Interpretation of the results revealed that the most important sub-criterion of the economic criterion is net profit with a weighting value of 0.127, the most important sub-criterion of the social criterion is employment with a weighting value of 0.146, and the most important sub-criteria of the environmental criteria are environmental protection tendency of the beekeeper for the ability to do beekeeping in the future and the beekeeper's opinion of beekeepers about the role of bees in the protection of biodiversity (Table 19).

The consistency ratio for the sub-criteria re-

Table 19 - Weighting of the sustainability indicators with the Fuzzy AHP method.

Sub-Criteria		*Within criteria*		*Compound of criteria*	
		Weight	*Rank*	*Weight*	*Rank*
Econ. (CR=0.004)	Net profit	0.127	1	0.0439	11
	Labor profitability	0.126	2	0.0436	12
	Relative profit	0.125	3	0.0433	13
	Honey yield	0.125	3	0.0433	13
	Risk management with diversification	0.125	3	0.0433	13
	Gross profit	0.124	4	0.0429	14
	Willing to diversification	0.124	4	0.0429	14
	Gross production value	0.123	5	0.0426	15
Soc. (CR= 0.061)	Employment	0.146	1	0.0469	4
	Satisfaction with education and health services	0.145	2	0.0465	5
	Transportation distance	0.144	3	0.0462	6
	Working period in beekeeping	0.143	4	0.0459	7
	Beekeeper's accommodation	0.142	5	0.0456	8
	Access to social and cultural spaces	0.141	6	0.0453	9
	Time away from home	0.140	7	0.0449	10
Env. (CR=0.002)	Environment for sustainable production	0.252	1	0.0837	1
	Conserving biodiversity	0.252	1	0.0837	1
	Forest protection	0.250	2	0.0830	2
	Environment for health	0.247	3	0.0820	3

Table 20 - Sustainability index values of beekeeping farms.

Composite Sustainability Index	*Minimum*	*Maximum*	*Average*
Economic Sustainability Index	0.09	0.87	0.45
Social Sustainability Index	0.08	0.99	0.36
Environmental Sustainability Index	0.50	1.00	0.92
General Sustainability Index	0.36	0.83	0.58

lated to the economic, social, and environmental criteria was calculated as 0.004, 0.061, and 0.002, respectively. These results indicate that the pairwise comparison matrix created for the sub-criteria is consistent (Table 19).

The fact that the consistency ratios for all sub-criteria are less than 10% indicates that the pairwise comparison matrix created for the sub-criteria is consistent (Table 19). Afterward, the economic sustainability index, social sustainability index, environmental sustainability index, and general sustainability index of beekeeping farms were calculated using the normalized values and standard weights of the basic indicators. The calculated sustainability index values range from 0 to 1, with values closer to 1 indicating a more sustainable system.

The economic sustainability index was calculated to be 0.45, the social sustainability index as 0.36, the environmental sustainability index as 0.92, and the general sustainability index as 0.58 for the farms that were investigated. Given that many of the traditional criteria used to evaluate environmental sustainability are not applicable to the beekeeping sector, the study measured the attitudes of beekeepers towards the environment as a means of assessing environmental sustainability. The fact that this value is high indicates that beekeepers in the study region are sensitive to environmental protection (Table 20). This finding is similar to the results of other studies. According to the study conducted by Hayran *et al.* (2018) in Mersin province, Turkey, farmers show great interest in preserving natural resources for future generations.

A reference table was created by using the average value and standard deviation of the general sustainability index of beekeeping farms to make comparisons between different groups of farms (Table 21).

Table 21 - The reference values for the general sustainability of beekeeping operations.

Category	*Score*	*Range*
Not sustainable	A	0.00-0.49
Relatively unsustainable	B	0.50-0.58
Relatively sustainable	C	0.59-0.65
Sustainable	D	0.64-1.00

A study on groups of farms that diversified their production found that farms producing other bee products in addition to honey are more sustainable than those focusing solely on honey. This was evident from the economic, social, and environmental sustainability indices and the overall sustainability index (sustainability level C). The Mann-Whitney U-test revealed that the difference between the two groups was statistically significant for both the economic sustainability index (Mann-Whitney U=1863.00, p=0.001) and the general sustainability index (Mann-Whitney U=2175.00, p=0.031) (Table 22).

In terms of economic sustainability, İzmir ranked first with an index value of 0.49, followed by Muğla Province with an index value of 0.44 and Aydın Province with an index value of 0.43 in third place. Aydın and İzmir provinces ranked first in the social sustainability index with an index value of 0.41, followed by Muğla with an index value of 0.32. In terms of environmental sustainability, İzmir ranked first with an index value of 0.95, followed by Muğla Province with an index value of 0.93 and Aydın Province with an index value of 0.85.

The general sustainability index of İzmir Province ranked first (sustainability level C), while Aydın and Muğla provinces were tied for second (sustainability level B) (Table 22). The Kruskal-Wallis test indicated that the dif-

Table 22 - Sustainability index values by farm groups.

Farm Groups		Econ. S. Index	p value	Soc. S. Index	p value	Env. S. Index	p value	General S. Index	p value	General S. rank
Categories	Single-product farms (66)	0.41	0.001**	0.35	0.227	0.93	0.382	0.56	0.031*	B
	Diversified farms (83)	0.48		0.37		0.92		0.59		C
Provinces	Aydın (30)	0.43	0.072	0.41	0.001**	0.85	0.001**	0.56	0.001**	B
	İzmir (37)	0.49		0.41		0.95		0.62		C
	Muğla (82)	0.44		0.32		0.93		0.56		B
General		0.45	-	0.36	-	0.92	-	0.58	-	-

*A: Not sustainable, B: Relatively unsustainable, C: Relatively sustainable, D: Sustainable (*p<0.05; **p<0.01; ***p<0.001 significant level).*

Table 23 - General sustainability levels of beekeeping farms.

Category	Aydın (30)		İzmir (37)		Muğla (82)		General (149)	
	count	%	count	%	count	%	count	%
Not sustainable (A)	8	26.67	0	0.00	14	17.07	22	14.77
Relatively unsustainable (B)	9	30.00	15	40.54	34	41.46	58	38.93
Relatively sustainable (C)	10	33.33	9	24.32	25	30.49	44	29.53
Sustainable (D)	3	10.00	13	35.14	9	10.98	25	16.78
Total	30	100.00	37	100.00	82	100.00	149	100.00

ference between the provincial groups was statistically significant in the social sustainability index ($\chi2=13.45$, p=0.001), environmental sustainability index ($\chi2=13.11$, p=0.001), and general sustainability index ($\chi2=13.06$, p=0.001) (Table 22).

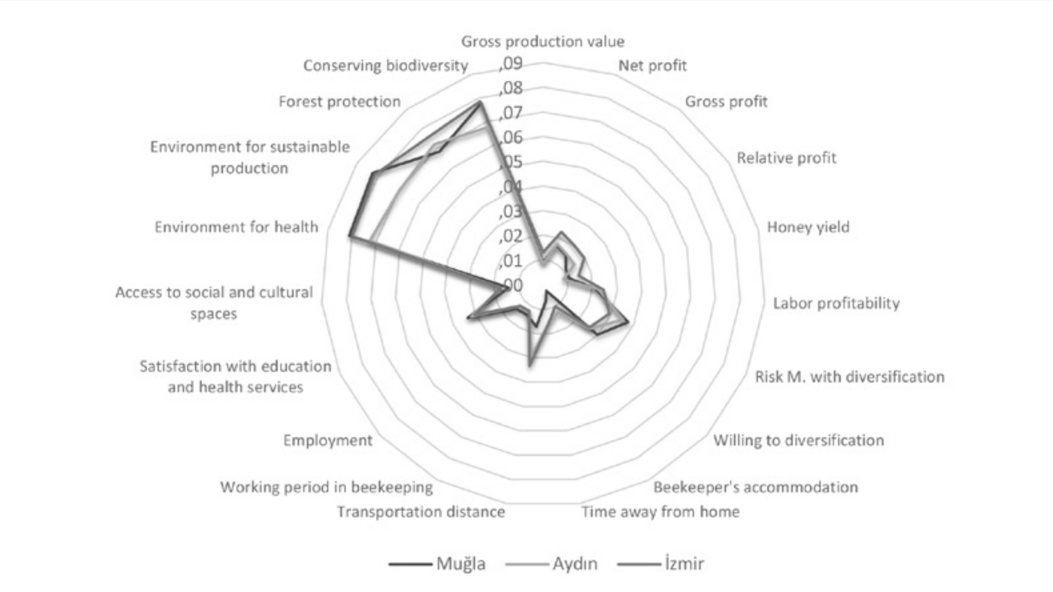
The study shows that 14.77% of beekeepers' activities were not sustainable, and 38.93% were threatened and relatively unsustainable. The activities of 29.53% of beekeepers were relatively sustainable, while 16.78% were sustainable. The beekeeping activities in Aydın, İzmir, and Muğla were relatively sustainable (C) and sustainable (D) for 43.33%, 59.46%, and 41.46% of beekeepers, respectively (Table 23). The study suggests that restricting beekeepers to migratory beekeeping in their regions and improving different ecotypes in geographical regions and making them available to beekeepers could promote the sustainability of beekeeping (Kösoğlu *et al.*, 2017).

The status of general sustainability in relation to the basic indicators in the provinces studied is shown in Figure 4.

5. Conclusion

Beekeeping is a multifaceted activity that plays an important role in social, economic, and environmental aspects and contributes significantly to natural ecosystems. Effective beekeeping practices and colony management are critical factors in ensuring the success and sustainability of beekeeping operations. This study focuses on evaluating the various interrelated dimensions of sustainability in beekeeping farms located in the Aydın, İzmir, and Muğla provinces of the Aegean region, with a specific emphasis on beekeeping practices. In this research, which was conducted using data from a total of 149 beekeeping farms, including 30 in Aydın, 37 in İzmir and 82 in Muğla, evaluations and analyzes were made in relation to the production diversity of the farms and the provinces in which they are located.

Figure 4 - The status of general sustainability by the basic indicators in the provinces.



According to the results, beekeeping farms that have integrated production diversity practices are more sustainable, both economically and in terms of overall sustainability, than those that solely focus on honey production.

Beekeeping operations can reduce price and production risks by diversifying their production, transitioning from a single-product, low-yield production model to a diversified beekeeping model that includes high-value-added products such as pollen, propolis, royal jelly, bee venom, perga, and apilarnil. This practice can promote more sustainable beekeeping. However, on farms that focus exclusively on honey production, beekeeping often takes the form of a unified production and livelihood. This narrow focus on honey can lead to a disregard for bee health and product safety, as beekeepers prioritize increasing honey production at the expense of other factors. Therefore, diversifying production is essential to achieve sustainable beekeeping practices that consider the bees' health and well-being, as well as the quality and safety of the products they produce.

In terms of economic sustainability, İzmir ranks first, followed by Muğla in second place and Aydın in third place. However, the differences between their values are relatively small. In terms of the sub-indicators of economic sustainability, Aydın province has the highest number of producers with production diversity, while İzmir province has the highest honey yield, gross production value, and gross profit. This suggests that beekeeping farms in İzmir are leading in terms of economic sustainability.

Aydın and İzmir provinces rank first in terms of the social sustainability index, with Muğla province in second place. When considering the sub-indicators of social sustainability, Muğla has high labor input, but the prevalence of inter-regional migration in the province negatively impacts economic sustainability due to high transportation costs. This also has a negative impact on the welfare of bees and beekeepers, resulting in Muğla's ranking last in terms of social sustainability within the three provinces.

Based on the results, it would be advisable to limit beekeepers to migratory beekeeping within their respective regions in order to ensure the sustainability of beekeeping. This approach is considered an effective way to enhance the diverse ecotypes in various geographical regions and make them more accessible to beekeepers, while also preserving the genetic diversity of honeybees in Turkey, both currently and in the future.

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