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RESEARCH PAPER

Awareness and Adoption of Smart Beekeeping Technologies Among Migratory Beekeepers in Türkiye: The Case of Mersin, Denizli, and Kırklareli

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Abstract

This paper investigates the awareness, perceived benefits and barriers, and adoption intentions of smart beekeeping technologies among migratory beekeepers in Türkiye. A survey consisting of 24 questions divided into six thematic categories has been conducted to 44 beekeepers from three regions (Denizli n=11, Kırklareli n=21, Mersin n=12) via telephone interviews. The survey has a high internal consistency and its Cronbach's Alpha result has been calculated as 0.85. The Cronbach's Alpha results calculated for six categories in the survey ranged between 0.73 and 0.98. The results show significant differences between the regions. The highest scores in Technological Readiness and Expectations for Education and Support were obtained in Mersin, whereas Kırklareli received the lowest scores in the category of Knowledge and Awareness and in Perceived Benefits. Although the level of Knowledge and Awareness is average in Denizli, this province obtained the highest scores in Perceived Benefits as well as in Acceptance and Intention. This result suggests that willingness to adopt is not only dependent on knowledge but also shaped by contextual needs and perceived value. While respondents in Kırklareli stated many concerns with respect to the cost and technical challenges, a high expectation for education and support were observed across all regions. This study provides empirical insights into the digital transformation of the Turkish beekeeping sector and contributes to the agricultural technology adoption literature.

Introduction

The global population, which stood at approximately 900 million in the 1800s, has reached 7.4 billion today and is projected to rise to around 9.4 billion by 2050. This population growth is expected to increase global food demand by 100-110% between 2005 and 2050 (Tilman et al., 2011). Meeting this growing demand inevitably requires the intensification of agricultural practices, including widespread pesticide use. However, most pesticides are non-selective and harm both harmful and beneficial insects. Among the affected beneficial insects, bees are particularly vulnerable (Johnson et al., 2010). Pollinating insects, especially honey bees, play a critical role in the global food supply. Indeed, 87 major food crops worldwide depend on animal pollination, while only 28 can be pollinated by wind (Klein et al., 2007). From a beekeeping perspective, Türkiye hosts at least five distinct honey bee subspecies and nearly 10000 plant species, 3506 of which are endemic. Thanks to this rich biodiversity, Türkiye produces over 107000 tons of honey annually, making it one of the leading countries in global beekeeping (Çakmak, 2016). Anatolia is home to five of the 27 subspecies of honey bees in the world and harbors approximately 19% of global honey bee genetic diversity, positioning it as a unique ecological region for the sustainability of global beekeeping (Kence, 2006). This genetic richness, supported by the region's ecological structure and integrated with its agricultural culture, is reflected in Türkiye's beekeeping profile: with approximately 7.5 million colonies and an annual production exceeding 100000 tons of honey, the country ranks second worldwide (Anonymous, 2022a). However, for many years, uncontrolled migratory beekeeping activities, colony transport, and the introduction of queen bees from domestic and foreign sources into regions where local bee subspecies naturally occur have led to significant genetic dilution of native populations (Sıralı & Cınbırtoğlu, 2022). The extent of this genetic erosion continues to grow and now poses a serious threat to environmental sustainability. Genetic diversity is a fundamental resource for critical processes such as pollination, disease resistance, breeding, and adaptation. The Rio Protocol also emphasizes the necessity of conserving such genetic resources. On the other hand, while the global average honey yield per colony is around 21 kg, this figure remains at 15-16 kg in Türkiye. Despite efforts over the past two decades, there has been no significant increase in productivity, and in some cases, a decline has been observed (Semerci, 2017). In response, the Ministry of Agriculture and Forestry has supported numerous breeding projects. However, the complex genetic structure of honey bees, the challenges of preserving live genetic material, the long-time horizon required for breeding programs, and the need for skilled personnel and persistent efforts all necessitate strong collaboration among public institutions, the private sector, and civil society organizations (i.e., beekeeping unions).

Türkiye ranks third in the world in terms of the number of bee colonies, after India and China, and second in honey production, following China (Anonymous, 2022b). Thanks to its rich floral resources, diverse climatic regions, vast areas of uncultivated land, local bee genotype diversity, and suitability for both stationary and migratory beekeeping, Türkiye holds a favorable position in global beekeeping. Although Türkiye hosts approximately 75% of the world's honey-producing plant flora, its honey yield per colony remains below the global average (Sıralı, 2009). This highlights the need not only to increase the number of colonies nationwide but also to enhance productivity per colony. Protecting regionally adapted local bee genetic resources and applying accurate selection and breeding strategies based on these sources can enable beekeeping enterprises to reach desired productivity levels (Akdeniz, 2014). Much research has been conducted on various challenges of Türkiye’s beekeeping sector. These studies focused mainly on the following subjects: prevalence of bee diseases and pests (Akdeniz et al., 2021; Aydın et al., 2003; Tunca & Çimrin, 2012) , the use of old and inefficient queen bees (Özdemir et al., 2016; Şahinler & Şahinler, 1996), lack of technical knowledge among beekeepers (Erkan & Aşkın, 2001; Özbilgin et al., 1999; Şahinler & Şahinler, 1996; Söğüt et al., 2019), poor record-keeping practices in both breeding and financial operations (Erkan & Aşkın, 2001; Kekeçoğlu & Rasgele, 2013; Şeker et al., 2017) , weak organizational structures (Çevrimli & Sakarya, 2018), misuse of medications (Sıralı & Doğaroğlu, 2005), inadequate awareness of pollination and pesticide impacts(Akdeniz et al., 2017; Akdeniz et al., 2021), difficulties in marketing bee products (Akdeniz et al., 2021; Saner et al., 2019; Şeker et al., 2017). One of the main reasons for the low honey yield per colony is the inability of beekeeping enterprises to keep pace with innovative and technical practices (Öztürk, 2017). Particularly in light of the effects of global warming and climate change, new-generation approaches are required in areas such as hive maintenance, feeding conditions, and colony management.

Today, digitalization stands at the core of sustainability and efficiency goals in the agriculture and livestock sectors, and within this transformation process, the beekeeping sector has increasingly begun to benefit from digital technologies. Given that beekeeping activities are influenced by numerous variables, such as seasonal sensitivity, climate change, floral diversity, pest management, and colony health, technology-assisted decision-making mechanisms are gaining importance in this field. In recent years, both the encouraging influence of academic research and the growing needs of producers have accelerated initiatives aimed at developing digital tools and systems tailored specifically for Türkiye’s beekeeping sector. Solutions such as in-hive temperature and humidity monitoring, colony weight tracking, GPS-based migratory route planning, mobile alert systems, artificial intelligence-based pest detection applications, and digital data recording systems contribute significantly to maintaining colony health, enhancing production efficiency, and improving enterprise income in a sustainable manner. These developments have also attracted global attention. European beekeepers accept climate change as a serious threat and therefore consider more resistant bee species and the use of technology-driven applications important (Van Espen et al., 2023). Similarly, Mosisa and Hordofa (2024) showed that the adoption of modern beehives in Ethiopia significantly increased household income and asset accumulation. These findings suggest that technological adoption is not only important for production efficiency but also critical for economic sustainability (Addorisio et al., 2025). Awareness and knowledge are basic factors when it comes to adopting new technology. They are often mentioned first because they make such a difference. Jacques et al. (2017) and Delena and Kayamo (2024) pointed out that beekeepers with more education and stronger knowledge of disease management got better results. They also showed more willingness to use technology in their work.

Even so, there is another side. Many beekeepers agree that modern tools can be useful, yet they still feel blocked. Low awareness and limited practical know-how are still there as real barriers. Interest in digital hive monitoring and precision beekeeping has been growing for some time, but actual use is not that common (Vardakas et al., 2024; Verbeke et al., 2024). Some things make adoption easier, like simple use, visible benefits, or easy access to data. Others slow it down, such as high costs, weak technical skills, or poor training opportunities (Vapa-Tankosić et al., 2020). Education level, having access to credit, and being part of a cooperative also matter a lot (Rasa, 2020; Uchechukwu et al., 2022).

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So, progress in digital transformation in beekeeping is not just about having the tools. What also counts is how much people know and how ready they are to work with these systems. That is why this study looks at migratory beekeepers in three provinces of Türkiye: Mersin, Denizli, and Kırklareli. The goal is to see how they understand, perceive, and adopt smart beekeeping technologies, and in doing so, to support the digitalization of the sector.

Material and Methods

The data used in this study were collected through a structured survey administered to beekeepers operating in three different provinces of Türkiye: Denizli, Kırklareli, and Mersin.

The motivation behind selecting Mersin, Denizli, and Kırklareli is related to practical and contextual factors. These provinces represent three distinct agro-climatic regions such as Mediterranean, Aegean, and Thrace in Türkiye. They also play a vital role in migratory beekeeping. Since their nectar calendars varied, they are significant destinations for migratory beekeeping practices. The aim of this research is to identify the regional differences in the awareness and use of smart beekeeping technologies by focusing on these areas. In addition, strong relationships with district agricultural directorates eased access to beekeeper lists in these provinces, which facilitated efficient phone-based data collection. Together, these factors provided that the study combined thematic relevance with logistical feasibility.

The survey was carried out through phone interviews. This approach made it possible to reach participants directly, especially those living in remote or rural areas, while keeping the process practical and timely. Conducting the survey by phone allowed the team to clarify any unclear questions immediately, which helped improve the quality of the responses. The interviews were conducted by members of our research lab specializing in digital agriculture and rural development. They called each participant directly and guided them step by step. To keep things consistent, the same interview protocol was followed. All answers were saved in a secure digital file for later use.

In total, 44 migratory beekeepers were surveyed from three provinces, Denizli (11), Kırklareli (21), and Mersin (12). The sample distribution reflects both regional representation and accessibility. Participants were selected through purposive sampling, focusing on individuals actively engaged in migratory beekeeping, whose contact information was accessible via beekeeper associations or local project collaborators. While variables such as age, education, and experience were not used as sampling criteria, the diversity in participant profiles ensured a broad spectrum of perspectives. The primary objective was to capture a regionally diverse and practically relevant view of awareness and adoption patterns across Türkiye’s migratory beekeeping landscape.

The survey itself was prepared by the author. It built on earlier studies about technology use in farming and beekeeping. The final version had 24 questions. They were grouped into six themes: (1) Technology Readiness, (2) Knowledge and Awareness, (3) Perceived Benefits, (4) Perceived Barriers and Risks, (5) Acceptance and Intention, and (6) Expectations for Education and Support. Each item was rated on a five-point Likert scale, from 1 = “Strongly disagree” to 5 = “Strongly agree.”

Reliability was checked with Cronbach’s Alpha. Scores were calculated for each theme and also for the full survey. Each theme had four Likert-type items. The results showed high internal consistency, which means the survey was a reliable tool.

Results and Discussion

The Cronbach’s Alpha values were found to be 0.96 for Technological Readiness, 0.89 for Knowledge and Awareness, 0.91 for Perceived Benefits, 0.73 for Perceived Barriers and Risks, 0.84 for Acceptance and Intention, and 0.98 for Expectations for Education and Support. According to the literature, values above 0.70 are generally considered acceptable for internal reliability, while values above 0.80 are regarded as good to excellent (Tavakol & Dennick, 2011). Table 1 presents the calculated Cronbach’s alpha coefficients for each construct included in the survey, providing evidence for the internal consistency and reliability of the measurement scales.

Table 1. Survey reliability results

Construct	Number of Items	Cronbach’s Alpha
Technological Readiness	4	0.96
Knowledge and Awareness	4	0.89
Perceived Benefits	4	0.91
Perceived Barriers and Risks	4	0.73
Acceptance and Intention	4	0.84
Expectations for Education and Support	4	0.98
Overall Survey	**24**	**0.85**

Based on these thresholds, all constructs in the current study demonstrated strong internal consistency. The overall Cronbach's Alpha value for the entire survey was calculated as 0.85, further supporting the reliability of the instrument. Given the satisfactory reliability coefficients and the clarity of the underlying conceptual framework, it was determined that additional exploratory factor analysis would not be necessary at this stage of the study.

As shown in Table 2, the regional average scores were calculated for each of the six categories, providing a comparative overview of respondents from Denizli, Kırklareli, and Mersin. The following subsections provide a detailed analysis of each category, highlighting regional disparities and common themes emerging from the data.

As illustrated by the regional averages, notable differences emerged in participants' Technological Readiness levels. Beekeepers in Mersin had the highest mean score in this category, with an average of 4.15. This shows a strong willingness to use digital tools and a clear openness to new technologies. Denizli came next with a score of 3.66, which points to a generally positive attitude, though the readiness level there is somewhat mixed. Kırklareli, on the other hand, scored lowest at 2.96. This points to weaker use of digital tools and less comfort with new practices. The regional contrast shows that digital skills are not spread evenly. These gaps are most likely the result of different levels of exposure, missing infrastructure, or limited training chances. Because of this, there is a clear need for extra capacity-building, especially in places where readiness is lowest. More focused support in those regions could help smart beekeeping technologies take root more broadly and be adopted on fairer terms.

Beyond the observed differences in readiness, it is also important to assess how familiar beekeepers are with the technologies themselves.

The results for the "Knowledge and Awareness" category show that beekeepers in all three provinces have a generally low level of awareness about smart beekeeping technologies. Denizli scored highest with 2.66, Mersin came next with 2.38, and Kırklareli had the lowest score at 1.80. These numbers make it clear that, although there is global attention on digital change in beekeeping, local awareness still lags behind. Beekeepers in Denizli seemed a bit more familiar with tools like smart hive systems, pest detection devices, and digital migration planning. This might reflect local training efforts or earlier contact with other agricultural technologies. In contrast, the very low results in Kırklareli suggest limited understanding and little exposure to such tools, showing the need for region-specific education programs. The overall low averages across all provinces also reveal a wider problem: information and practical knowledge about smart beekeeping is not being spread effectively. To change this, awareness campaigns, easier access to information, and demonstration-based training will be essential. Without this basic foundation, beekeepers are likely to stay cautious or unable to shift toward more modern, technology-driven practices.

While awareness remains relatively low, respondents' attitudes toward the potential advantages of these technologies offer a more optimistic picture.
The results regarding the "Perceived Benefits" category reveal a strong overall belief among participants in the potential advantages of smart beekeeping technologies. Denizli exhibited the highest mean score (4.59), followed closely by Mersin (4.40), while Kırklareli reported a relatively lower but still positive perception (3.71). Although participants differed in how familiar they were with smart technologies (as described earlier), responses across all three provinces revealed a shared belief in their usefulness. Most beekeepers felt that these systems could help prevent colony losses, detect pests earlier, and support quicker action through mobile alerts. Many respondents also believed that using such tools could help improve efficiency and make beekeeping more profitable. Beekeepers in Denizli and Mersin gave higher scores, which may be due to a greater willingness to try new methods or favorable local conditions that support the use of these technologies. In Kırklareli, the scores were still positive but a bit lower, possibly because of concerns about cost or access. These findings show that many beekeepers see value in smart systems and are open to using them. This highlights the need for affordable and practical solutions that fit their daily work. It also suggests that clear guidance and local support could help more people adopt these tools in the future.

Table 2. Regional averages

Region	Technological Readiness	Knowledge and Awareness	Perceived Benefits	Perceived Barriers and Risks	Acceptance and Intention	Expectations for Education and Support
Denizli	3.66	2.66	4.59	2.91	4.84	4.18
Kırklareli	2.96	1.80	3.71	3.77	4.15	4.18
Mersin	4.15	2.38	4.40	3.50	4.56	4.67

Despite recognizing the benefits, participants also expressed concerns and identified several barriers that could hinder adoption.

The analysis of the Perceived Barriers and Risks category reveals notable regional differences in how participants assess the challenges associated with smart beekeeping technologies. Among the three provinces, Kırklareli reported the highest mean score (3.77), indicating a greater perception of potential difficulties or reservations. Mersin had an average of 3.50. Denizli showed the lowest perceived barriers with 2.91. In Kırklareli, the picture is different. Beekeepers there seem more worried about cost, ease of use, and whether smart systems can really be trusted. Their stronger sense of risk may come from having little past experience with digital tools. It may also reflect weak infrastructure or a lack of local support. Many likely think about breakdowns, poor internet service, or the extra time it takes to learn and fix new systems. Denizli tells another story. The low score there points to a more positive view about using these technologies. This might be linked to earlier exposure or stronger help from institutions. Mersin falls in between. Beekeepers acknowledge some problems but do not see them as deal-breakers. These differences show that each region faces its own barriers. Where doubts are higher, stronger infrastructure, simpler tools, and quick technical help could ease worries. Just as important is trust. Seeing the systems in action, or hearing from fellow beekeepers who already use them, can make the move feel less risky and more achievable.

Nevertheless, beekeepers' intentions to adopt these technologies appear to be resilient even in the face of perceived challenges.

The average scores in the Acceptance and Intention category indicate a generally high willingness among participants to adopt smart beekeeping technologies, provided that certain conditions are met. Denizli recorded the highest average score (4.84), followed by Mersin (4.56) and Kırklareli (4.15). There were high levels of support for smart beekeeping across all three provinces, though some regional differences were observed. In Denizli, many beekeepers expressed enthusiasm about using new technologies, often emphasizing the importance of cost, government support, and whether the tools fit local needs. This may be related to previous experiences or a more open attitude toward change. In Mersin, similar views were reported, especially when the tools were seen as useful in daily operations. Beekeepers in Kırklareli also showed interest, but their responses were more cautious, possibly due to earlier concerns mentioned in the study. These patterns suggest that the regional context matters and that support from local organizations such as cooperatives or agricultural officers could encourage wider adoption.

Finally, these intentions are closely tied to the expectations around education and support mechanisms, which play a pivotal role in enabling adoption.

The analysis of the Expectations for Education and Support category reveals a strong and nearly uniform expectation among beekeepers for structured training and assistance in the adoption of smart technologies. Both Denizli and Kırklareli reported identical average scores of 4.18, while Mersin exhibited a slightly higher mean of 4.67, indicating an even more pronounced demand for support services in that region. These findings reflect a shared recognition across all three provinces of the critical role that education, guidance, and post-adoption technical support play in facilitating successful technology uptake. The elevated score in Mersin may be attributed to greater perceived complexity of smart systems or to a lack of previous exposure, increasing reliance on institutional support. Participants emphasized the importance of training formats that are accessible and practical, such as mobile app-supported modules, region-specific workshops, and direct consultation with local experts. Additionally, the expressed need for technical helplines and follow-up support underscores that technology adoption is viewed not as a one-time decision, but as a continuous learning process. Taken together, these insights suggest that any large-scale deployment of smart beekeeping technologies should be accompanied by comprehensive capacity-building initiatives. Localized training, peer learning networks, and cooperative-driven support frameworks will be essential to close the knowledge gap and ensure sustainable implementation across diverse beekeeping communities.

The findings of this study, which examines the attitudes of migratory beekeepers in Türkiye toward smart beekeeping technologies, align with the general trend in the current literature on the adoption of global agricultural technologies and the distribution of smart beekeeping systems. Adoption can be defined as the extent to which beekeepers use an innovation after acquiring exact knowledge about it (Bekuma, 2018). One of the main focuses of this study is to demonstrate that knowledge alone is not only sufficient and that willingness to accept is also shaped by contextual needs and perceived value. These findings further support the technology adoption literature that indicates technology acceptance decisions are influenced by personal, economic, institutional, and psychological factors (Bekuma, 2018; Mulatu et al., 2021). It seems that the trend to use smart beekeeping technologies of professional beekeepers is higher than hobby beekeepers (Verbeke et al., 2024).

The concerns about cost and technical difficulties observed in Kırklareli and the low perceived benefit scores align with the main challenges encountered in the adoption of smart beekeeping systems worldwide. The main barrier to smart beekeeping systems becoming widespread is high purchasing costs (Danieli et al., 2023). Economic constraints and limited access to credit are major barriers to beekeepers purchasing modern equipment (Bekuma, 2018; Mulatu et al., 2021; Tulu et al., 2020).

The fact that most beekeepers in Türkiye are migratory increases the level of difficulty in the Perceived Barriers and Risks category. Migratory beekeepers usually move their hives to remote or forested areas where power supply constraints and signal strength may hinder data transmission, this poses a major challenge in implementing remote monitoring systems (Hadjur et al., 2022; Wakjira et al., 2021). Furthermore, having access to financial resources and technical knowledge emerges as a stronger driving force in the formation of intention for professional beekeepers than for hobby beekeepers (Verbeke et al., 2024).

The high scores in the Expectations for Education and Support category observed across all regions, with Mersin receiving the highest scores, confirm the critical role of institutional support in the adoption process. The education level is a significant factor expected to encourage adoption by increasing the understanding of technology (Bekuma, 2018; Mulatu et al., 2021; Vapa-Tankosić et al., 2020). Extension services increase the possibility of adopting new technologies by providing information on agricultural practices for beekeepers (Bekuma, 2018; Mulatu et al., 2021; Tulu et al., 2020). It is crucial that training is practice-oriented and tailored to individual needs, considering the different educational levels of beekeepers, to ensure the effective use of technology (Gratzer et al., 2021). Professional beekeepers expect support from scientific and research institutions to further improve beekeeping practices (Vapa-Tankosić et al., 2020). Therefore, the success of digital transformation among migratory beekeepers depends on facilitating conditions such as access to financial resources and the availability of effective training and extension services.

Conclusion

This study set out to see how migratory beekeepers in three regions of Türkiye: Denizli, Kırklareli, and Mersin, approach smart beekeeping technologies. We focused on their awareness, the benefits they see, the barriers they face, and whether they intend to adopt these tools. The survey was divided into six categories. It held up well as a measurement tool, with Cronbach's Alpha values ranging from 0.73 to 0.98 and an overall score of 0.85. In short, the instrument proved reliable for capturing beekeeper attitudes toward technology.

The data showed that regions do not behave alike. Mersin beekeepers appeared the most ready for new technologies and had stronger expectations for support. In contrast, those in Kırklareli reported lower levels of awareness and fewer perceived benefits. Denizli gave an interesting picture: awareness was only moderate, yet perceived benefits and adoption intentions were high. This reminds us that willingness to adopt is not only about knowing; it is also about how relevant and valuable the technology feels in context.

Concerns over costs and technical problems were voiced most strongly in Kırklareli. Still, no matter the region, there was wide agreement on the importance of education and continued support to ease adoption. This points to the need for strategies that reflect local realities, as affordable options, practical demonstrations, and cooperative-based support all matter here.

Taken together, the findings highlight both the opportunities and the obstacles of digital transformation in beekeeping. The work contributes to ongoing discussions on technology use in farming. It also offers insights that can help shape policies, guide training programs, and support the design of more down-to-earth and inclusive smart farming practices for Türkiye's beekeeping sector.

Ethical Statement

This study was approved by the Ethics Committee of Işık University. The research was reviewed by the Ethics Committee of Işık University at its meeting held on September 15, 2025 (Decision No: 13, Meeting No: 2025/04). The Committee confirmed that the study involves no risk to participants, includes no vulnerable individuals, and that all participants provided informed consent voluntarily. It was also verified that participants' privacy and confidentiality were respected, that identifying information was kept anonymous, and that all collected data would be used solely for scientific and public benefit purposes. The study was therefore found ethically appropriate by unanimous decision.

AI-assisted language tools were employed only for grammar improvement and text editing. The authors take full responsibility for the scientific content and affirm that all analyses, results, and conclusions are original.

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Conflict of Interest

The author declares that there is no conflict of interest.

Author Contributions

Corresponding author: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Writing – Review & Editing, Project Administration.

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