Climate Change and the Role of Using Artificial Intelligence Applications in Apiculture

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Abstract
Wild and commercially significant plants are pollinated by honeybees. Currently, apiculture is suffering from the negative consequences of climate change, including extreme weather conditions and increasing temperature averages. Climate change can affect floral sources of honey bees, increase the frequency of parasites and diseases, and interfere with pollination cycles; thus, climate change poses a serious danger to apiculture and consequently beekeeping industry and global food production. Utilising cutting-edge technologies like artificial intelligence (AI) applications are crucial for reducing the negative effects of climate change on honey production and bee populations. AI can play a crucial role in apiculture by helping beekeepers to monitor and manage their hives more efficiently. This study employed a review-based approach to determine how AI can be employed in the beekeeping sector. The results suggests that combination of AI, ML and IoT can be used to evaluate environmental data, such as weather patterns, flowering seasons and satellite images interpretation. That can optimise beekeeping methods by forecasting the ideal periods for hive inspections, honey harvesting, and other tasks. This can increase the overall productivity of the hives and help bee keepers to make better decisions for the sustainability of their apiaries.
Keywords: Climate change, artificial intelligence, machine learning, apiculture, Cyprus.

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1. Introduction

1.1. Background and History of Beekeeping in Cyprus

Cyprus is the third largest island in the Mediterranean sea with a rich history spanning thousands of years, it is a strategically and geopolitically an important island (Şenol, 2021). Many civilizations have lived on Cyprus, including the Lusignans, Venetians, Ottoman Empire, and British Empire (Özsağlam, 2018). In the early Cretaceous, "bee like insects" first appeared in Western Gondwana, which includes Africa and South America. They then spread to other continents (Almeida et al., 2023). In the old time when there was no concept of bee keeping people were hunting wild honey to fulfil their nutritional and medicinal needs. Between 1500 and 1851, modern beekeeping evolved, leading to Langstroth's creation of the movable-frame hive (Eroğlu & Yüksel, 2020). After that in the next two millennia, beekeeping flourished throughout the Mediterranean region as the Egyptians developed advance apiculture by 2450 BCE (Kritsky, 2017).

In addition to its nutritional, medicinal, economic, and ecological advantages, honey bees and their products had historically symbolic meaning in early beliefs and World religions (Crane, 1999). With the passage of time and continuous attempts to increase production efficiency in nations, beekeeping now plays a major role in ecosystem services assurance, including agricultural pollination and human health (Eroğlu & Yüksel, 2020). Cyprus is home to 369 confirmed species of wild bees from six groups belonging the superfamily *Apoidea,* with 21 endemic species (Varnava et al., 2020). Although the taxonomic work is detailed, there is very little information known about the ecology of the native honey bees of Cyprus, *Apis mellifera cypria* (Kandemir et al., 2006).

1.2. Benefits of Beekeeping in Cyprus

Beekeeping offers economic, ecological, nutritional benefits, honey bees do pollination in agricultural crops as well as great possibilities for forest protection and rural development by providing the employment opportunities for people (Sokhai & Mardy, 2024; Teferi, 2018; Chanthayod et al., 2017). Cyprus is Mediterranean islands with diverse floras that attracts honey bees for foraging, which improves the quality of honey, people in rural Cyprus keep bees for household use and sell products related to beekeeping to make money. Some of the products of beekeeping are honey, pollen, bee venom, royal jelly and propolis that provides numerous benefits to human health (Pasupuleti et al., 2017).

Numerous scholars have provided the benefits of beekeeping in many different ways. For example Teferi (2018) stated that beekeeping delivers societal benefits in Ethiopia by alleviating poverty, preserving biodiversity, generating money, employment, and ecological security. Similarly, Qaiser et al., (2013) stated that beekeeping is a profitable business that can create jobs and reduce poverty in rural Pakistan. Additionally, beekeeping training programs have a good impact on the socio-economic condition of rural farmers and youths. In the case of Cyprus, commodity prices are rapidly rising. By keeping bees, residents in rural regions can quickly improve their income levels, allowing them to survive when everything becomes more expensive due to inflation.

The flora of Cyprus is distinctive and wide-ranging, containing significant plant and tree species (Eliades et al., 2018). Cyprus is home to olive varieties, eucalyptus, lavender, citrus and carob all of which boost honey bee productivity, which benefits both the people and the area. This can be an effort to improve honey production by characterize it as Cypriot honey with such unique flavours and taste. As a result, beekeeping practices in Cyprus could be more advantageous.

1.3. Challenges Faced by Honey Bee Colonies

The sustainability of beekeeping is threatened by several issues. Pests and pathogens are major problems, especially wax moths and *Varroa* mites, which can result in large colony losses (Singh & Sharma, 2017). Moreover, serious dangers to honey bee health and productivity are also posed by environmental abiotic stress factors such pesticide use, pollutants, climate change, and harsh weather. The adverse impact of environmental conditions on output and significant colony losses owing to climatic changes and other practices have caused economic challenges for beekeeping in recent years (Köseoğlu et al., 2021). In fact, Cyprus has seen severe trends in drought and water scarcity (Myronidis et al., 2018). The agriculture sector in Cyprus is heavily reliant on rains, and changes in rain patterns have had a significant impact on crop production. As a result of the reduced availability of water, wild plants that are useful for beekeeping are less likely to develop which create stress for the honey bees because they are unable to get pollens and nectar.

Honey bee colonies face several key challenges that are shown in Figure 1. Guyo & Legesse, (n.d.) explained that drought, illnesses, pests, chemical toxicity, and a lack of equipment are Ethiopia's biggest beekeeping issues. While, the Kangra district's beekeepers struggle since they don't know enough about bee management technologies and associated skills (Kumar &

Kundal, 2016). Similarly, low quality management, colony movement, chemical toxicity, and insufficient research are the primary issues that are faced by beekeepers in Nepal (Aryal et al., 2015) and Bangladesh (Jahan et al., 2021). Cyprus also lacks with the technological information and management's skills required for beekeeping, more technological innovation, research and government support is required to make the beekeeping sector sustainable and successful.

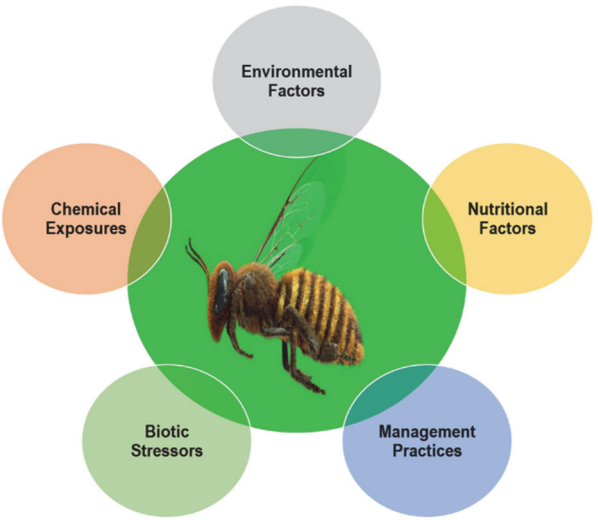

Figure 1. - Challenges Faced by the Bee Colonies
*Note: Created by authors.

1.4. Technology in Beekeeping

Recent technological developments have a big impact on apiculture by providing solutions to a number of problems. Beekeepers are able to manage apiaries more effectively due to remote monitoring devices that use sensors and communication technologies. An advance concept related to beekeeping is precision apiculture, a potential method for managing bee colonies which is centred on tracking individual colonies to maximize productivity and resource consumption (Zacepins et al., 2012). Latest technologies are designed to assist beekeepers by offering real-time data on the health and behaviour of colonies, especially during crucial times like the winter and summer and make decision in advance to potential negative outcome (Stalidzans, 2012). The majority of hives are located on farms that are inaccessible and remote from cities. Therefore, acoustic and optical sensors

are among the many sensing technologies that are being used to keep an eye on important variables including temperature, humidity, and hive weight (Anuar et al., 2023).

To identify and stop significant deviations, an autonomous Internet of Things (IoT) - based beekeeping systems are used remotely to monitor hive conditions (Zabasta et al., 2019). Similarly, (IoT)-based system for wide and long-term bee colony monitoring may identify a variety of characteristics and show the activity and expansion of honey bee colonies (Hong et al., 2020). One of the most common problems for beekeeping face globally is varroa mites, which destroy colonies all over the world due their feeding activity on honey bee larvae and adults, that cause immune suppression and pathogens transmission, mainly viruses. Also, they are difficult to observe being small and life cycle adapted to the honey bee developing stages. Varroa mites cause a significant number of colonies to disappear each year in Cyprus. Therefore, Real-time *Varroa* mite detection in beehives is possible by using an IoT-based edge computing solution that incorporates machine learning (Mrozek et al., 2021). Moreover, applications of nanotechnology have been identified in many areas of beekeeping, such as disease prevention, tools, feeding, and pollination (Abou-Shaara et al., 2020).

To date, AI being used more and more to solve problems in beekeeping, where related tools can help with hive management, health monitoring, disease and pest detection, and adjusting to the effects of climate change on apiculture (Astuti et al., 2024a). One of the biggest threats to beekeepers in Cyprus is hornets, which attack and destroy entire colonies.

Different insect groups, such as honey bee (workers and drones), hornets, and bumblebees, can be automatically identified from photos using deep learning and computer vision (Spiesman et al., 2021). Also, the application of AI-based audio monitoring systems can be used to analyse the sound and frequency within and between the hives (Thu et al., 2020). There are several types of advance technologies which are shown in Figure 2.

Figure 2 - Useful Technologies in Bee Keeping
*Note: Created by authors.

These technologies help beekeepers in the management of their hives globally. The beekeepers of Cyprus are still using the old methods for beekeeping; there is an urgent need to provide information to beekeepers about the new advanced technologies like IoT, machine learning and Ai that can help them to manage their colonies in a better way.

2. Materials and Methods

The material and method section involve 25 recent research articles from various Countries using keywords such as “smart bee keeping,” “climate change,” “artificial intelligence,” from various data sources like Google Scholar, Science Direct, and Springer Link. Relevant articles were reviewed in a comprehensive manner to produce results and discussions. Reviewed research articles are shown in the Table 1.

Table 1 - List of Research Articles Reviewed

No:	Title	Country	Citation
1.	“Predicting internal conditions of beehives using precision beekeeping”	Spain	(Robustillo et al., 2022)
2.	“Modeling bee hive dynamics: Assessing colony health using hive weight and environmental parameters”	Switzerland	(Degenfellner & Templ, 2024)
3.	“Beekeeping in Europe facing climate change: A mixed methods study on perceived impacts and the need to adapt according to stakeholders and beekeepers”	Denmark	(Van Espen et al., 2023)
4.	“Climate change will reduce the potential distribution ranges of Colombia’s most valuable pollinators”	USA	(Gonzalez et al., 2021)
5.	“Heat stress survival and thermal tolerance of Australian stingless bees”	Australia	(Nacko et al., 2023)

No:	Title	Country	Citation
6.	"A Brazilian native bee (Tetragonisca angustula) dataset for computer vision"	Brazil	(Leocádio et al., 2024)
7.	"HiveLink – IoT based smart bee hive monitoring system"	India	(Dsouza & Hegde, 2023)
8.	"Advancing beekeeping: IoT and Tiny ML for queen bee monitoring using audio signals"	Italy	(De Simone et al., 2024)
9.	"Digital transformation in beekeeping to carrying beehives into the future"	Turkey	(Burma, 2023)
10.	"European beekeepers' interest in digital monitoring technology adoption for improved beehive management"	Belgium	(Verbeke et al., 2024)
11.	"IoT embedded smart monitoring system with edge machine learning for beehive management"	Romania	(Doinea et al., 2024)
12.	"Honey production and climate change: beekeepers' perceptions, farm adaptation strategies, and information needs"	USA	(Landaverde et al., 2023)
13.	"Environmental threats to beekeeping in the Western Balkan countries - beekeepers' perceptions"	Serbia	(Šarić et al., 2023)
14.	"Climate change impacts on honeybee spread and activity: A scientific review"	Egypt	(Ali et al., 2023)
15.	"A smart beekeeping platform based on remote sensing and artificial intelligence"	Cyprus	(Grammalidis et al., 2023)
16.	"Design and development of energy efficient algorithm for smart beekeeping device to device communication based on data aggregation techniques"	Rwanda	(Ntawuzumunsi et al., 2023)

No:	Title	Country	Citation
17.	"Beekeeping opportunities, challenges and technology adoption in Gedeo Zone, Southern Ethiopia"	Ethiopia	(Delena & Kayamo, 2024)
18.	"The use of products with a monitoring system for remote bee detection in beekeeping in Czechia"	Czechia	(Kaňovská, 2024)
19.	"Buzzing with intelligence: current issues in apiculture and the role of artificial intelligence (AI) to tackle it"	Hungry	(Astuti et al., 2024b)
20.	"Image recognition using convolutional neural networks for classification of honey bee subspecies"	Italy	(De Nart et al., 2022)
21.	"IoT based smart beekeeping monitoring system for beekeepers in India"	India	(Pandimurugan et al., 2021)
22.	"Adoption and impacts of improved beehive technologies in the miombo woodland of Tanzania"	Tanzania	(Kuboja et al., 2021)
23.	"Toward an intelligent and efficient beehive: A survey of precision beekeeping systems and services"	France	(Hadjur et al., 2022)
24.	"Utilizing IoT technologies to improve beekeeping through remote hive monitoring"	India	(Pal et al., 2022)
25.	"Application of the Internet of Things in precision beekeeping in Latvia."	Latvia	(Zacepins et al., 2022)

3. Results and Discussions

By carefully reviewing the proposed bibliography, several key insights emerged regarding the main stress factors affecting honey bees. It is clear

that, with the aid of new technologies, innovative strategies are necessary for effective management, particularly in proactively safeguarding bee colonies to prevent issues that could have serious economic implications.

The beekeeping sector is facing challenges worldwide, which is also affecting the agricultural pollination because the bees are the main source of pollination. Climate change is a serious threat to the beekeeping industry. According to study, climate change is causing a shift in the blooming of flowers, change in the weather pattern, and an increase in the temperature, all of which are affecting the bee colonies (Ali et al., 2023; Gonzalez et al., 2021). For example, a research was conducted on the Australian stingless bee and they revealed that there is decline in the heat tolerance and heat stress survival which means that there are serious effects of increasing temperature on bees health (Nacko et al., 2023). Similarly, according to climatic estimations the potential global distribution patterns of important pollinators would decrease, which will increase the loss of biodiversity and limiting agricultural production (Gonzalez et al., 2021).

Furthermore, honey bee colonies are facing challenges like decrease in available food, pests like hornets and disease in addition to the challenges related to the environment. Infections caused by fungus, bacterial diseases and varroa mites are causing the colony loses in the World and posing a significant financial burden on bee keepers (Hadjur et al., 2022). Beekeepers in the Western Balkin countries are facing serious problems due to environmental hazards including pesticide exposure and destruction of habitat (Šarić et al., 2023). Similarly, the beekeepers of Cyprus are also facing challenges related to climate change specially changes in the rain pattern. Innovative technologies are required to help beekeepers for the better management of their hives as a result of these challenges.

3.1. Role of (IoT, AI and ML) in Beekeeping

The Internet of things, machine learning, and artificial intelligence all affect smart beekeeping. They offer improved solutions for problems like climate change. These tools facilitate effective hive management, predictive modelling, and real time monitoring, which all contribute to the effectiveness of apiculture.

3.1.1. Real Time Monitoring of Bee Hives

With the help of internet of things (IoT) we can monitor the hive parameters like temperature, humidity, and weight of the hives remotely through internet sources. The measurement of these parameters is important

for ensuring the health of the colony and to identify any threat to the colony on time. According to the studies the IoT based hives allows beekeepers to monitor their hive remotely from the far distances and allow them to take actions ad prevent their colony losses (Dsouza & Hegde, 2023; Pal et al., 2022). These systems have enhanced the hive conditions and facilitated the beekeepers of Latvia for the better management of their bee colonies (Zacepins et al., 2022).

3.1.2. Machine Learning for Predictions

The uses of machine learning algorithms forecast hive dynamics and identify trends that indicate possible dangers. For example, the predictive models that evaluate environmental factors like (temperature, humidity, rainfall) and hive weight have been created to evaluate colony health, giving beekeepers practical suggestions on how to keep colonies safe from collapsing (Degenfellner & Templ, 2024). To further improve the accuracy of apiculture management, machine learning (ML) techniques such as convolutional neural networks (CNNs) have been used for image identification to monitor hive activity and categorize honeybee subspecies (De Nart et al., 2022).

3.1.3. Mitigation of Challenges Caused by Climate Change and Diseases

Artificial intelligence powered solutions are essential for responding, how climate change is affecting apiculture. For instance, smart system that combine AI algorithms and remote sensing give beekeeper's information on environmental factors like temperature variations, humidity and the availability of flowering plants, allowing them to employ adaptive strategies (Grammalidis et al., 2023). By using this Ai based algorithms Cypriot beekeepers can also get information for the availability of nearby foraging places. As beekeepers express the need for solutions to minimize climate-related challenges and protect colony health, research conducted in Europe emphasizes the importance of implementing these types of technologies in bee keeping sector (Van Espen et al., 2023).

Improved disease diagnosis and prevention in honeybee colonies is another benefit of AI and IoT system. Tiny ML and IoT-powered audio signal analysis has been used to track queen bee activity and identify early indicators of hive stress or diseases (De Simone et al., 2024). Cypriot beekeepers can prevent colony losses and increase overall sustainability by pro-actively addressing any health risks by using such devices.

3.2. Benefits of Using Technology in Beekeeping

For beekeepers, the use of artificial intelligence (AI), internet of things (IoT), and machine learning (ML) technologies in apiculture have many advantages. These tools improve the sustainability of beekeeping operations, decrease labor related tasks, and improve decision-making. For example the algorithms that use less energy for IoT communication reduce the environmental impact of precision beekeeping systems, and remote sensing platforms enable beekeepers to effectively manage their hives (Ntawuzumunsi et al., 2023). Furthermore, according to studies from Ethiopia and other developing nations, implementing technology in beekeeping could deal with ecological and economic issues also technology-driven solutions can help small beekeepers by lowering costs, increasing output and encouraging sustainable practices (Burma, 2023; Delena & Kayamo, 2024). Another example, of how these technologies support the expansion of the beekeeping industry is the usage of technologies with the monitoring systems for remote hive management in Czechia (Kaňovská, 2024).

3.3. Challenges in the Adoption of Technology

Though the artificial intelligence and IoT have great potential in beekeeping, the implementation of these technologies is still facing difficulties. Main challenges for beekeepers, especially in developing nations, include high initial set up costs., lack of technical knowledge, and restricted access to advance technologies (Astuti et al., 2024b). Similarly, in Tanzania adopting better beehive technologies can boost bee keeper's income, however this depends on a number of factors like age, education, and access to loans and extension services (Kuboja et al., 2021). Cyprus is also facing similar challenges to adopt the modern technologies that can help beekeepers to manage their hives more efficiently. Furthermore, to guarantee the capacity and long-term sustainability of these technologies concerns about data privacy, system dependability, and energy consumption all of these need to be addressed.

4. Conclusion

The beekeeping business faces complex multifactorial challenges, including diseases, environmental stressors, and climate change, which threaten the sustainability of honeybee populations and their vital role in

global agriculture. These issues have been solved by AI, IoT, and ML technologies, which enable real-time monitoring, predictive modelling, and adaptive hive management. While there are many benefits to implementing these technologies, their widespread adoption depends on addressing obstacles like affordability and accessibility. Employing these innovations to ensure the resilience and productivity of honeybee colonies can help beekeepers support sustainable apiculture and ecosystem health.

References

Abou-Shaara, H. F., Staron, M., & Staroňová, D. (2020). Potential applications of nanotechnology in apiculture. *Entomology and Applied Science Letters*, *7*(4), 1-8.

Ali, M. A., Abdellah, I. M., & Eletmany, M. R. (2023). Climate change impacts on honeybee spread and activity: A scientific review. *Chelonian Research Foundation*, *18*(2), 531-554.

Almeida, E. A., Bossert, S., Danforth, B. N., Porto, D. S., Freitas, F. V., Davis, C. C., Murray, E. A., Blaimer, B. B., Spasojevic, T., & Ströher, P. R. (2023). The evolutionary history of bees in time and space. *Current Biology*, *33*(16), 3409-3422.

Anuar, N. H. K., Yunus, M. A. M., Kasuan, N., Baharuddin, M. A., Ibrahim, S., & Sahlan, S. (2023). *Technological Adoption and Challenges in Beekeeping: A Review*, 80-85.

Aryal, S., Thapa, R., & Jung, C. (2015). An overview of Beekeeping Economy and Its Constraints in Nepal. *Journal of Apiculture*, *30*, 135-142.

Astuti, P. K., Hegedűs, B., Oleksa, A., Bagi, Z., & Kusza, S. (2024a). Buzzing with Intelligence: Current Issues in Apiculture and the Role of Artificial Intelligence (AI) to Tackle It. *Insects*, *15*(6), 418.

Astuti, P. K., Hegedűs, B., Oleksa, A., Bagi, Z., & Kusza, S. (2024b). Buzzing with Intelligence: Current Issues in Apiculture and the Role of Artificial Intelligence (AI) to Tackle It. *Insects*, *15*(6), 418.

Burma, Z. A. (2023). Digital transformation in beekeeping to carrying beehives into the future. *International Journal of Nature and Life Sciences*, *7*(2), 89-99.

Crane, E. (1999). *The world history of beekeeping and honey hunting*. Routledge.

De Nart, D., Costa, C., Di Prisco, G., & Carpana, E. (2022). Image recognition using convolutional neural networks for classification of honey bee subspecies. *Apidologie*, *53*(1), 5.

De Simone, A., Barbisan, L., Turvani, G., & Riente, F. (2024). Advancing Beekeeping: IoT and TinyML for Queen Bee Monitoring Using Audio Signals. *IEEE Transactions on Instrumentation and Measurement*.

Degenfellner, J., & Templ, M. (2024). Modeling bee hive dynamics: Assessing colony health using hive weight and environmental parameters. *Computers and Electronics in Agriculture*, *218*, 108742.

Delena, M. F., & Kayamo, S. E. (2024). Beekeeping opportunities, challenges and technology adoption in Gedeo Zone, Southern Ethiopia. *Journal of Apicultural Research*, *63*(3), 456-461.

Doinea, M., Trandafir, I., Toma, C.-V., Popa, M., & Zamfiroiu, A. (2024). IoT Embedded Smart Monitoring System with Edge Machine Learning for Beehive Management. *International Journal of Computers Communications & Control*, *19*(4).

Dsouza, A., & Hegde, S. (2023). HiveLink, an IoT based Smart Bee Hive Monitoring System. *arXiv Preprint arXiv, 2309.12054*.

Eliades, N.-G. H., Aravanopoulos, F. A., & Christou, A. (2018). Mediterranean Islands Hosting Marginal and Peripheral Forest Tree Populations: The Case of Pinus brutia Ten. In Cyprus. *Forests*. -- https://api.semanticscholar.org/CorpusID:52108725.

Eroğlu, Ö., & Yüksel, S. (2020). Historical development and current status of beekeeping in Turkey and the World. *Atlas Journal*, *6*(27), 345-354.

Gonzalez, V. H., Cobos, M. E., Jaramillo, J., & Ospina, R. (2021). Climate change will reduce the potential distribution ranges of Colombia's most valuable pollinators. *Perspectives in Ecology and Conservation*, *19*(2), 195-206.

Grammalidis, N., Stergioulas, A., Avramidis, A., Karystinakis, K., Partozis, A., Topaloudis, A., Kalantzi, G., Tananaki, C., Kanelis, D., & Liolios, V. (2023). *A smart beekeeping platform based on remote sensing and artificial intelligence*. *12786*, 92-99.

Guyo, S. H., & Legesse, S. A. (n.d.). *On Beekeeping activities, opportunities, challenges and marketing in Ethiopia*. -- https://api.semanticscholar.org/CorpusID:237277878.

Hadjur, H., Ammar, D., & Lefèvre, L. (2022). Toward an intelligent and efficient beehive: A survey of precision beekeeping systems and services. *Computers and Electronics in Agriculture*, *192*, 106604.

Hong, W., Xu, B., Chi, X., Cui, X., Yan, Y., & Li, T. (2020). Long-Term and Extensive Monitoring for Bee Colonies Based on Internet of Things. *IEEE Internet of Things Journal*, *7*, 7148-7155.

Jahan, M. M. S., Rahman, M. S., Haque, M. P., & Saikat, M. M. H. (2021). Problems and Prospects of Apiculture in Bangladesh: A Review. *Fundamental and Applied Agriculture*. -- https://api.semanticscholar.org/CorpusID:243487499.

Kandemir, I., Meixner, M. D., Ozkan, A., & Sheppard, W. S. (2006). Genetic characterization of honey bee (Apis mellifera cypria) populations in northern Cyprus. *Apidologie*, *37*(5), 547-555.

Kaňovská, L. (2024). The Use of Products with a Monitoring System for Remote Bee Detection in Beekeeping in Czechia. *Agris On-Line Papers in Economics & Informatics*, *16*(1).

Kösoğlu, M., Tunca, R. İ., Yücel, B., Balkanska, R., & Yildirir, Z. T. (2021). Arıcılıkta Sürdürülebilirlik Mümkün Mü?. *MAS Journal of Applied Sciences*, *6*(3), 610-623.

Kritsky, G. (2017). Beekeeping from antiquity through the middle ages. *Annual Review of Entomology*, *62*(1), 249-264.

Kuboja, N. M., Isinika, A., & Kilima, F. (2021). Adoption and impacts of improved beehive technologies in the miombo woodland of Tanzania. *African Journal of Science, Technology, Innovation and Development*, *13*(2), 157-166.
Kumar, R., & Kundal, N. (2016). Beekeeping status in Kangra district of Himachal Pradesh. *Journal of Entomology and Zoology Studies*, *4*, 620-622.
Landaverde, R., Rodriguez, M. T., & Parrella, J. A. (2023). Honey production and climate change: Beekeepers' perceptions, farm adaptation strategies, and information needs. *Insects*, *14*(6), 493.
Leocádio, R. R. V., Segundo, A. K. R., & Pessin, G. (2024). A Brazilian native bee (Tetragonisca angustula) dataset for computer vision. *Data in Brief*, *55*, 110659.
Mrozek, D., Górny, R., Wachowicz, A., & Małysiak-Mrozek, B. (2021). Edge-based detection of varroosis in beehives with iot devices with embedded and tpu-accelerated machine learning. *Applied Sciences*, *11*(22), 11078.
Myronidis, D., Ioannou, K., Fotakis, D. G., & Dörflinger, G. (2018). Streamflow and Hydrological Drought Trend Analysis and Forecasting in Cyprus. *Water Resources Management*, *32*, 1759-1776.
Nacko, S., Hall, M. A., Gloag, R., Lynch, K. E., Spooner-Hart, R. N., Cook, J. M., & Riegler, M. (2023). Heat stress survival and thermal tolerance of Australian stingless bees. *Journal of Thermal Biology*, *117*, 103671.
Ntawuzumunsi, E., Kumaran, S., Sibomana, L., & Mtonga, K. (2023). Design and development of energy efficient algorithm for smart beekeeping device to device communication based on data aggregation techniques. *Algorithms*, *16*(8), 367.
Özsağlam, M. T. (2018). Limited recognition and limited relations: TRNC. *Journal of Management and Economics Research*, *16*(1), 314-328.
Pal, P., Sahu, M., & Juyal, R. (2022). Utilising Iot Technologies to Improve Beekeeping through Remote Hive Monitoring. *Journal of Survey in Fisheries Sciences*, 367-372.
Pandimurugan, V., Mandviya, R., Gadgil, A., Prakhar, K., & Datar, A. (2021). *IoT based Smart Beekeeping Monitoring system for beekeepers in India*, 65-70.
Pasupuleti, V. R., Sammugam, L., Ramesh, N., & Gan, S. H. (2017). Honey, propolis, and royal jelly: A comprehensive review of their biological actions and health benefits. *Oxidative Medicine and Cellular Longevity*, *2017*(1), 1259510.
Qaiser, T., Tahir, A., Taj, S., & Ali, M. (2013). Benefit-cost analysis of apiculture enterprise: A case study in district Chakwal, Pakistan. *Pakistan Journal of Agricultural Research*, *26*, 295-298.
Robustillo, M. C., Pérez, C. J., & Parra, M. I. (2022). Predicting internal conditions of beehives using precision beekeeping. *Biosystems Engineering*, *221*, 19-29.
Šarić, B. B., Muça, E. D., Subić, J., Džimrevska, I., & Rašić, S. (2023). Environmental threats to beekeeping in the Western Balkan countries-beekeepers' perceptions. *Environmental Research Communications*, *5*(6), 065003.
Şenol, C. (2021). Kuzey Kıbrıs Türk Cumhuriyeti'nin Hidrografik Yapısı, Su Sorunu ve Çözüm Önerileri. *Journal of Cyprus Studies*, *21*(45).
Singh, G., & Sharma, M. (2017). Diagnosis and remedial measures of common technological problems in bee keeping. *Journal of Krishi Vigyan*, *5*(2), 27-31.

Sokhai, K., & Mardy, S. (2024). A Review on the Aspect of Beekeeping and Economic Efficiency. *International Journal of Integrative Research*. -- https://api.semanticscholar.org/CorpusID:268269072

Spiesman, B. J., Gratton, C., Hatfield, R. G., Hsu, W. H., Jepsen, S., McCornack, B., Patel, K., & Wang, G. (2021). Assessing the potential for deep learning and computer vision to identify bumble bee species from images. *Scientific Reports*, *11*(1), 7580.

Stalidzans, E. (2012). *Application of Information Technologies in precision apiculture*. -- https://api.semanticscholar.org/CorpusID:51776305.

Teferi, K. (2018). Status of Beekeeping in Ethiopia – A Review. *Journal of Dairy & Veterinary Sciences*. -- https://api.semanticscholar.org/CorpusID:59593337.

Thu, P. T. K., Hong, Du, N. H., Doan, N., Luu, V. T., Hoang, N. V., Thai, P. H., Ngoc, P. T., Viet, N., Long, Phan, & Hong, T. T. (2020). *Audio Beehive Monitoring Based on IoT-AI Techniques: A Survey and Perspective*. -- https://api.semanticscholar.org/CorpusID:222361603

Van Espen, M., Williams, J. H., Alves, F., Hung, Y., de Graaf, D. C., & Verbeke, W. (2023). Beekeeping in Europe facing climate change: A mixed methods study on perceived impacts and the need to adapt according to stakeholders and beekeepers. *Science of the Total Environment*, *888*, 164255.

Varnava, A. I., Roberts, S. P. M., Michez, D., Ascher, J. S., Petanidou, T., Dimitriou, S., Devalez, J., Pittara, M., & Stavrinides, M. C. (2020). The wild bees (Hymenoptera, Apoidea) of the island of Cyprus. *ZooKeys*, *924*, 1-114.

Verbeke, W., Diallo, M. A., van Dooremalen, C., Schoonman, M., Williams, J. H., Van Espen, M., D'Haese, M., & de Graaf, D. C. (2024). European beekeepers' interest in digital monitoring technology adoption for improved beehive management. *Computers and Electronics in Agriculture*, *227*, 109556.

Zabasta, A., Zhiravetska, A., Kunicina, N., & Kondratjevs, K. (2019). Technical Implementation of IoT Concept for Bee Colony Monitoring. *2019 8th Mediterranean Conference on Embedded Computing (MECO)*, 1-4.

Zacepins, A., Komasilovs, V., Jelinskis, J., Ozols, N., & Kviesis, A. (2022). Application of the Internet of Things in precision beekeeping in Latvia. *Agrofor International Journal*, *7*(3).

Zacepins, A., Stalidzans, E., & Meitalovs, J. (2012). *Application of information technologies in precision apiculture*. *7*.