THE IMPACT OF CLIMATE AND ENVIRONMENTAL CHANGE ON HONEY BEES AND BEEKEEPING

Veli ACAR[1]*, Yaşar ERDOĞAN[2]

ABSTRACT

Climate and environmental change is one of the biggest challenges of the twenty-first century. Extreme weather conditions and natural disasters have caused great harm to honey bees. It is clear that climate and environmental change will be a very important stress factor for bee colonies and beekeepers, increasing bee colony losses and decreasing income levels.In this study, we propose the main challenges that beekeepers will face in the future due to the changing climate and some precautions that should be taken (beekeepers moving to pollen-rich areas, providing additional food supplements to colonies, providing clean water sources, changing the type of hives, afforestation in the apiary, changing the harvest time).In addition, beekeepers face serious constraints and by integrating climate conditions with existing knowledge and local practices, we can strengthen beekeepers' adaptive capacity.

Keywords: Beekeeping, climate change, environmental change, adaptation

İKLİM VE ÇEVRE DEĞİŞİKLİĞİNİN BAL ARILARI VE ARICILIK ÜZERİNDEKİ ETKİSİ

ÖZET

İklim ve çevre değişikliği yirmi birinci yüzyılın en büyük sorunlarından biridir. Aşırı hava koşulları ve doğal afetler bal arılarına büyük zarar verdi. İklim ve çevre değişikliğinin arı kolonileri ve arıcılar için çok önemli bir stres faktörü olacağı, arı kolonisi kayıplarını arttıracağı ve gelir seviyelerini düşüreceği açıktır.Bu çalışmada, değişen iklim nedeniyle arıcıların gelecekte karşılaşacağı temel zorluklar ve alınması gereken bazı önlemler (arıcıların polen bakımından zengin bölgelere taşınması, kolonilere ek gıda takviyesi sağlanması, temiz su kaynaklarının sağlanması, arıcıların iklim koşullarının değiştirilmesi) önerilmiştir. kovanların türü, arı kovanındaki ağaçlandırma, hasat zamanının değiştirilmesi).Ayrıca arıcılar ciddi kısıtlamalarla karşı karşıyadır ve iklim koşullarını mevcut bilgi ve yerel uygulamalarla entegre ederek arıcıların uyum kapasitesini güçlendirebiliriz.

Anahtar Kelimeler: Arıcılık, iklim değişikliği, çevre değişikliği, uyum

[1*]Bayburt Üniversitesi, Demirözü Meslek Yüksekokulu, Bayburt, Türkiye. vacar@bayburt.edu.tr,
Orcid ID: 0000-0002-7289-423X
[2] Bayburt University, Demirözü Vocational School, Department of Veterinary Medicine, Bayburt, Turkey, ORCID ID: 0000-0001-6154-7008,

1. INTRODUCTION

Honey bees have spread and adapted all over the world except the polar region (hot dry deserts, regions with continental climates, regions with temperate climates). Different honey bee species have adapted to different geographical regions (Figure 1).

Local ecotypes have adapted to all kinds of climate conditions of the regions they grow and have developed physiological and morphological behaviors. However, ecosystems have changed at very high rates all over the world. This change is in the form of habitat, fauna, nitrogen accumulation, biological invasions, carbon dioxide accumulation in the atmosphere and climate change. (Tylianakis, Didham, Bascompte, & Wardle, 2008).

Current environmental change affects both bees and beekeepers. Environmental change affects the physiology and ecology of bees (Shelley ER Hoover et al., 2012).

Environmental change affects honey bee colonies directly by affecting their physiology, development and immune system, and indirectly by affecting plant flowering periods and populations of parasites and pathogens (Bowler et al., 2017; Shelley ER Hoover & Hoover, 2014; Leemans & Eickhout, 2004) (Figure 2).

Climate is defined as the average weather conditions that do not change over many years in a fairly large area. Climate is an extremely important factor for the activities of the honey bee (Apis mellifera) (Le Conte & Navajas, 2008).

Chemicals used in agricultural activities, environmental pollutants resulting from industrial activities, pathogens and climate change can negatively affect plant and animal life (Cunningham et al., 2022).

Additionally, these pollutants accumulate throughout the environment in soil, water and air, accumulating in body tissues and causing reproductive failure (Leemans & Eickhout, 2004), neurotoxic damage and even death. (Moroń, Szentgyörgyi, Skórka, Potts, & Woyciechowski, 2014; Williams et al., 2015).

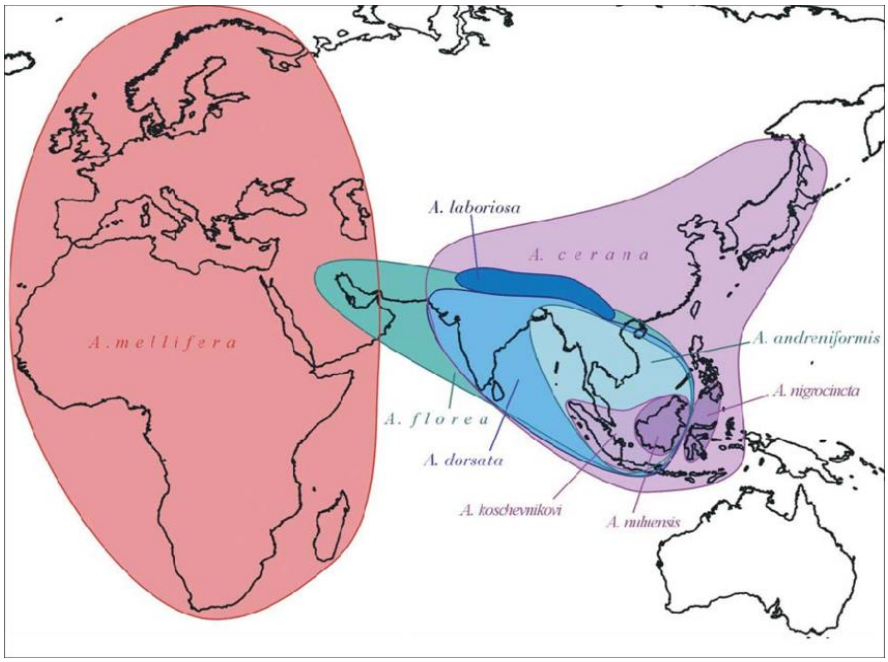

Figure 1: *Apis mellifera* habitats (Franck, Garnery, Solignac, & Cornuet, 2000)

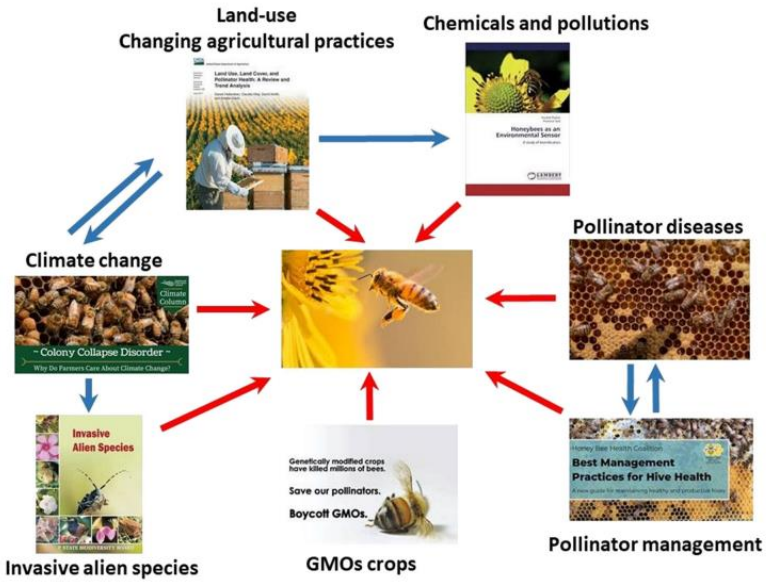

Figure 2. The impact of environmental change on honey bees (Neov, Shumkova, Palova, & Hristov, 2021)

The harms of these chemicals that cause environmental pollution are not limited to the natural environment and climate change. They can also cause respiratory diseases and many other ailments such as cancer in humans (Briffa, Sinagra, & Blundell, 2020; Lambert et al., 2012).

Determining the future effects of climate change on humans, honeybees and all other living things is a very difficult situation. According to the latest reports of the United Nations Intergovernmental Panel on Climate Change and scientific studies, climate change will cause temperatures to increase, precipitation patterns to change and seasons to shift. It will also cause excessive rainfall, extreme droughts and major floods. (Garnaut, 2008; Hov et al., 2013; Myhre et al., 2019; Van Aalst, 2006)

These environmental changes will affect all agricultural activities and will have painful consequences. Diseases and pests will increase in animal and plant production and yields will decrease significantly (Becklin et al., 2016; Lacetera, 2019; Nelson et al., 2009).

2. The İmpact Of Climate And Environmental Change On Honey Bees And Beekeeping

It is unthinkable that honey bees and beekeeping will not be affected by environmental change. These effects will certainly be in the form of reduced honey yield and reduced pollination (Le Conte & Navajas, 2008; Malisa & Yanda, 2016). Pollination is the movement of the male reproductive units of plants from flower to flower. Pollination is most intensively carried out by flies, butterflies, moths, some wasps, beetles, tobacco aphids and of course honeybees. (Forrest, 2017). There are 20,000 species of bees in the world, divided into seven families (Winfree, 2010) most of these are located in the northern hemisphere (Conrad, Peters, & Rehan, 2021). Beekeeping is a form of agricultural production that is responsible not only for honey production but also for pollinating 30% of global food production (Khalifa et al., 2021). Therefore, bees and beekeeping are vital to world food security.

The most cultivated bee race in the world is Apis mellifera. The reason why Apis mellifera is so widespread all over the world is not only because of its high honey yield but also because of the extremely high adaptability of this race (Arias & Sheppard, 2005).

Apis mellifera's high survival ability is also affected by its determination to collect nectar and its ability to enter the long winter periods with a strong honey stock and to come out strong in the spring by consuming little. Therefore, it is not a coincidence that Apis mellifera's pollination and honey production ability has been successfully introduced to the whole world. Despite the ability of all honey bees, especially Apis mellifera, to adapt to climate change and environmental changes, it is certain that this change will also affect beekeeping quite a lot. (Flores et al., 2019).

Although all wild and cultivated bees are affected by climate change, the destructive effect on wild bees is greater due to reasons such as intervention and relocation of cultivated bees. (Balfour, Gandy, & Ratnieks, 2015; Dubois, Pasquaretta, Barron, Gautrais, & Lihoreau, 2021).

Protecting wild bees is much more difficult due to limited human control and intervention (Alger, Burnham, Boncristiani, & Brody, 2019; Novelli, Vercelli, & Ferracini, 2021).

But by implementing more climate-smart methods, beekeepers and entomologists can make coping with climate change an easier and more realistic process for farmed bees (Gajardo-Rojas et al., 2022; Vercelli, Novelli, Ferrazzi, Lentini, & Ferracini, 2021). Honey bees are currently at the top of the list of endangered animals for agricultural production organization. (Landaverde, Rodriguez, & Parrella, 2023).

The reason for these concerns is that studies have shown an extreme decline in bee populations (Bartomeus et al., 2014; Forrest, 2017).

Recently, extensive information has been gathered showing how climate change is affecting the lives of bees and limiting their ability to provide their services in the ecosystem (Le Conte & Navajas, 2008; Soroye, Newbold, & Kerr, 2020).

The biggest indicators of environmental change are extreme weather conditions (excessive rain, excessive snow, excessive wind and extreme temperatures). These extreme weather conditions affect beekeeping extremely (Gray et al., 2023).

Floods and forest fires have increased exponentially today (Dorey et al., 2021; Insolia et al., 2022). In this case, bee colony losses increase. Due to increasing temperatures, the broodless period of bee colonies will shorten and perhaps disappear completely.

It is certain that climate and environmental change will catastrophically increase the impact of bee mites on colonies (de Jongh et al., 2022; Hillayová, Korený, & Škvarenina, 2022; Le Conte & Navajas, 2008; Neumann, Yañez, Fries, & de Miranda, 2012; Noël, Le Conte, & Mondet, 2020; Novelli et al., 2021). In other words, it is estimated that pests such as small hive beetles (Aethina tumida) and wasps (Vespa spp.) will be positively affected by climate change (Barbet-Massin et al., 2013.

Varroa destructor is one of the most important and dangerous pests for bees and beekeeping worldwide (Flores et al., 2021; Hillayová et al., 2022). This pest significantly reduces the life span and productivity of bee colonies. Studies show that the density of Varroa destructor and therefore its damage increases significantly depending on the air temperature (Garcia & Rodriguez, 2011; Hillayová et al., 2022; Mendoza, 2024).

This will affect bee health and economic contributions. Seasonal change and the extension of the dry period will affect the flowering periods and even cause a long dry period (Flores et al., 2019). Inadequate nutrition of honey bees will weaken their immune system and make them vulnerable to diseases. (Castle, Alkassab, Bischoff, Steffan-Dewenter, & Pistorius, 2022; Dolezal & Toth, 2018; Kerr et al., 2015).

Such gaps in flowering periods may result in the spread of invasive plant species, which are increasing due to global and environmental change (Dietzsch, 2009; Liu et al., 2017).

Although there is a perception that invasive plant species may benefit beekeeping, this situation is definitely not sustainable. Plant invasion jeopardizes the availability of essential nutrients provided by floral resources, thus causing a food deficit and endangering beekeeping.

3. Temporary Measures That Can Be Taken

Bee breeds that are more resistant to the stress brought on by climate change can be developed. Natural disasters are not a situation that beekeepers can control, and studies and planning can ensure that honeybees are least affected by this situation (O'Brien, O'keefe, Rose, & Wisner, 2006). One of the most important planning that beekeepers need to do is choosing the location of the apiary.

Minimizing floods and forest fires by increasing public and manager awareness reduces bee colony losses (Faux & Kane, 2021).

It should be noted that in the event of climate change, much more effective methods of combating mites, small hive beetles and other invasive species must be found (Dall'Olio et al., 2022).

Rations that include protein, carbohydrates, micronutrients and microbiota required for the nutrition of bee colonies should be developed for future famine situations (Brodschneider & Crailsheim, 2010; Brown et al., 2022; Paray et al., 2021).

Studies have shown that food supplements to bee colonies increase the amount and speed of egg laying by queen bees (Shelley E Hoover, Ovinge, & Kearns, 2022; Ullah, Shahzad, Iqbal, & Baloch, 2021).

Today, additional feeding of bee colonies is usually done in the early spring and late autumn periods when flowers are limited (Shelley E Hoover et al., 2022; Vercelli et al., 2021).

It is necessary to produce queen bees that are adapted to the region and have high adaptation to difficult conditions (Meixner, Kryger, & Costa, 2015).

If we look at it from another perspective, increasing environmental differences and changes may lead to the emergence of new breeds that can better adapt to these conditions and provide efficiency (Blacquière et al., 2019). However, it does not seem possible to predict this situation exactly now.

Even small measures such as afforestation of apiaries to protect bee colonies from high temperatures or moving colonies to high plateaus by migratory beekeeping will perhaps be life-saving for beekeeping (Gajardo-Rojas et al., 2022).

In addition to these measures, establishing bee pastures in the region and choosing strong plants in the creation of these pastures can reduce the possible negative effects in the future (Kaiser-Bunbury et al., 2017). Additional studies should be carried out and measures should be taken to minimise the damage and destruction caused by climate change and environmental change.

More efforts should be made to apply scientific studies to the field, and all beekeeping-related unions, associations and cooperatives should be made aware of this issue.

As a result, there are significant gaps in our knowledge about beekeeping under climate change. Therefore, more coordinated efforts by all relevant stakeholders globally will be required to provide adequate responses to this epic challenge.

REFERENCES

Alger, S. A., Burnham, P. A., Boncristiani, H. F., & Brody, A. K. (2019). RNA virus spillover from managed honeybees (Apis mellifera) to wild bumblebees (Bombus spp.). PloS one, 14(6), e0217822.

Arias, M. C., & Sheppard, W. S. (2005). Phylogenetic relationships of honey bees (Hymenoptera: Apinae: Apini) inferred from nuclear and mitochondrial DNA sequence data. Molecular phylogenetics evolution, 37(1), 25-35.

Balfour, N. J., Gandy, S., & Ratnieks, F. L. (2015). Exploitative competition alters bee foraging and flower choice. Behavioral Ecology Sociobiology, 69, 1731-1738.

Bartomeus, I., Potts, S. G., Steffan-Dewenter, I., Vaissiere, B. E., Woyciechowski, M., Krewenka, K. M., . . . Westphal, C. (2014). Contribution of insect pollinators to crop yield and quality varies with agricultural intensification. PeerJ, 2, e328.

Becklin, K. M., Anderson, J. T., Gerhart, L. M., Wadgymar, S. M., Wessinger, C. A., & Ward, J. K. (2016). Examining plant physiological responses to climate change through an evolutionary lens. Plant physiology, 172(2), 635-649.

Blacquière, T., Boot, W., Calis, J., Moro, A., Neumann, P., & Panziera, D. J. B. I. (2019). Darwinian black box selection for resistance to settled invasive Varroa destructor parasites in honey bees. Biological Invasions, 21(8), 2519-2528.

Bowler, D. E., Hof, C., Haase, P., Kröncke, I., Schweiger, O., Adrian, R., . . . Brooker, R. W. (2017). Cross-realm assessment of climate change impacts on species' abundance trends. Nature ecology evolution, 1(3), 0067.

Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon, 6(9).

Brodschneider, R., & Crailsheim, K. (2010). Nutrition and health in honey bees. Apidologie, 41(3), 278-294.

Brown, A. F., Rodriguez, V., Brzoska, C., Pfister, J., Neumann, P., & Retschnig, G. (2022). Dream team for honey bee health: Pollen and unmanipulated gut microbiota promote worker longevity and body weight. Frontiers in Sustainable Food Systems, 6, 864741.

Castle, D., Alkassab, A. T., Bischoff, G., Steffan-Dewenter, I., & Pistorius, J. J. S. o. t. T. E. (2022). High nutritional status promotes vitality of honey bees and mitigates negative effects of pesticides. Science of the Total Environment, 806, 151280.

Conrad, K. M., Peters, V. E., & Rehan, S. M. (2021). Tropical bee species abundance differs within a narrow elevational gradient. Scientific reports, 11(1), 23368.

Cunningham, M. M., Tran, L., McKee, C. G., Polo, R. O., Newman, T., Lansing, L., . . . Guarna, M. M. (2022). Honey bees as biomonitors of environmental contaminants, pathogens, and climate change. Ecological Indicators, 134, 108457.

Dall'Olio, R., Mondet, F., Beaurepaire, A., Gabel, M., Locke, B., Moro, A., . . . Neumann, P. (2022). COLOSS survivors task force: Global efforts to improve honey bee colony survival. Bee World, 99(1), 17-19.

de Jongh, E. J., Harper, S. L., Yamamoto, S. S., Wright, C. J., Wilkinson, C. W., Ghosh, S., & Otto, S. J. (2022). One Health, One Hive: A scoping review of honey bees, climate change, pollutants, and antimicrobial resistance. PLoS one, 17(2), e0242393.

Dietzsch, A. C. (2009). Impacts of the alien invasive Rhododendron ponticum L. on native plants, pollinators and their interaction. Trinity College Dublin,

Dolezal, A. G., & Toth, A. L. (2018). Feedbacks between nutrition and disease in honey bee health. Current opinion in insect science, 26, 114-119.

Dorey, J. B., Rebola, C. M., Davies, O. K., Prendergast, K. S., Parslow, B. A., Hogendoorn, K., . . . O'Reilly, R. L. (2021). Continental risk assessment for understudied taxa post-catastrophic

wildfire indicates severe impacts on the Australian bee fauna. Global Change Biology, 27(24), 6551-6567.

Dubois, T., Pasquaretta, C., Barron, A. B., Gautrais, J., & Lihoreau, M. (2021). A model of resource partitioning between foraging bees based on learning. PLOS Computational Biology, 17(7), e1009260.

Faux, C. M., & Kane, T. R. (2021). Honey Bees: Disaster Preparedness and Response. The Veterinary Clinics of North America. Food Animal Practice, 37(3), 559-567.

Flores, J. M., Gámiz, V., Jiménez-Marín, Á., Flores-Cortés, A., Gil-Lebrero, S., Garrido, J. J., & Hernando, M. D. (2021). Impact of Varroa destructor and associated pathologies on the colony collapse disorder affecting honey bees. Research in veterinary science, 135, 85-95.

Flores, J. M., Gil-Lebrero, S., Gámiz, V., Rodríguez, M. I., Ortiz, M. A., & Quiles, F. J. (2019). Effect of the climate change on honey bee colonies in a temperate Mediterranean zone assessed through remote hive weight monitoring system in conjunction with exhaustive colonies assessment. Science of the Total Environment, 653, 1111-1119.

Forrest, J. R. (2017). Insect pollinators and climate change. Global climate change terrestrial invertebrates, 69-91.

Franck, P., Garnery, L., Solignac, M., & Cornuet, J.-M. (2000). Molecular confirmation of a fourth lineage in honeybees from the Near East. Apidologie, 31(2), 167-180.

Gajardo-Rojas, M., Muñoz, A. A., Barichivich, J., Klock-Barría, K., Gayo, E. M., Fontúrbel, F. E., . . . Veas, C. (2022). Declining honey production and beekeeper adaptation to climate change in Chile. Progress in Physical Geography: Earth Environment, 46(5), 737-756.

Garcia, M., & Rodriguez, B. (2011). Evaluation of the Use of Different Concentrations of Commercial Acaricide in the Control of Varroa (Varroa destructor). Infested Apiary. Bachelor's Thesis, University of El Salvador, San Salvador, El Salvador.

Garnaut, R. (2008). The Garnaut climate change review (Vol. 13): Citeseer.

Gray, A., Adjlane, N., Arab, A., Ballis, A., Brusbardis, V., Bugeja Douglas, A., . . . Coffey, M. F. (2023). Honey bee colony loss rates in 37 countries using the COLOSS survey for winter 2019–2020: the combined effects of operation size, migration and queen replacement. Journal of Apicultural Research, 62(2), 204-210.

Hillayová, M. K., Korený, Ľ., & Škvarenina, J. (2022). The local environmental factors impact the infestation of bee colonies by mite Varroa destructor. Ecological Indicators, 141, 109104.

Hoover, S. E., & Hoover, T. M. (2014). Impact of environmental change on honeybees and beekeeping. In Beekeeping for poverty alleviation and livelihood security (pp. 463-479): Springer, Dordrecht.

Hoover, S. E., Ladley, J. J., Shchepetkina, A. A., Tisch, M., Gieseg, S. P., & Tylianakis, J. M. (2012). Warming, CO2, and nitrogen deposition interactively affect a plant-pollinator mutualism. Ecology letters, 15(3), 227-234.

Hoover, S. E., Ovinge, L. P., & Kearns, J. D. (2022). Consumption of supplemental spring protein feeds by western honey bee (Hymenoptera: Apidae) colonies: effects on colony growth and pollination potential. Journal of economic entomology, 115(2), 417-429.

Hov, Ø., Cubasch, U., Fischer, E., Höppe, P., Iversen, T., Kvamstø, N. G., . . . Duarte Santos, F. (2013). Trends in extreme weather events in Europe: implications for national and European Union adaptation strategies.

Insolia, L., Molinari, R., Rogers, S. R., Williams, G. R., Chiaromonte, F., & Calovi, M. (2022). Honey bee colony loss linked to parasites, pesticides and extreme weather across the United States. Scientific reports, 12(1), 20787.

Kaiser-Bunbury, C. N., Mougal, J., Whittington, A. E., Valentin, T., Gabriel, R., Olesen, J. M., & Blüthgen, N. (2017). Ecosystem restoration strengthens pollination network resilience and function. Nature, 542(7640), 223-227.

Kerr, J. T., Pindar, A., Galpern, P., Packer, L., Potts, S. G., Roberts, S. M., . . . Richardson, L. L. (2015). Climate change impacts on bumblebees converge across continents. Science, 349(6244), 177-180.

Khalifa, S. A., Elshafiey, E. H., Shetaia, A. A., El-Wahed, A. A. A., Algethami, A. F., Musharraf, S. G., . . . Abdel-Daim, M. M. (2021). Overview of bee pollination and its economic value for crop production. Insects, 12(8), 688.

Lacetera, N. (2019). Impact of climate change on animal health and welfare. Animal Frontiers, 9(1), 26-31.

Lambert, O., Veyrand, B., Durand, S., Marchand, P., Le Bizec, B., Piroux, M., . . . Pouliquen, H. (2012). Polycyclic aromatic hydrocarbons: bees, honey and pollen as sentinels for environmental chemical contaminants. Chemosphere, 86(1), 98-104.

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.

Le Conte, Y., & Navajas, M. (2008). Climate change: impact on honey bee populations and diseases. Revue Scientifique et Technique-Office International des Epizooties, 27(2), 499-510.

Leemans, R., & Eickhout, B. (2004). Another reason for concern: regional and global impacts on ecosystems for different levels of climate change. Global environmental change, 14(3), 219-228.

Liu, Y., Oduor, A. M., Zhang, Z., Manea, A., Tooth, I. M., Leishman, M. R., . . . Van Kleunen, M. (2017). Do invasive alien plants benefit more from global environmental change than native plants? Global Change Biology, 23(8), 3363-3370.

Malisa, G., & Yanda, P. (2016). Impacts of climate variability and change on beekeeping productivity. Bulletin of Animal Health Production in Africa, 64(1), 49-55.

Meixner, M. D., Kryger, P., & Costa, C. (2015). Effects of genotype, environment, and their interactions on honey bee health in Europe. Current opinion in insect science, 10, 177-184.

Mendoza, B. (2024). Systematization: Results and Impacts of the Beekeeping Park in the Department of Chalatenango. Retrieved from https://www.acicafoc.org/wp-content/uploads/2020/09/ACOPIDECHA-El-Salvador.pdf

Moroń, D., Szentgyörgyi, H., Skórka, P., Potts, S. G., & Woyciechowski, M. (2014). Survival, reproduction and population growth of the bee pollinator, Osmia rufa (Hymenoptera: Megachilidae), along gradients of heavy metal pollution. Insect Conservation Diversity, 7(2), 113-121.

Myhre, G., Alterskjær, K., Stjern, C. W., Hodnebrog, Ø., Marelle, L., Samset, B. H., . . . Schulz, M. (2019). Frequency of extreme precipitation increases extensively with event rareness under global warming. Scientific reports, 9(1), 16063.

Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., . . . Batka, M. (2009). Climate change: Impact on agriculture and costs of adaptation (Vol. 21): Intl Food Policy Res Inst.

Neov, B., Shumkova, R., Palova, N., & Hristov, P. (2021). The health crisis in managed honey bees (Apis mellifera). Which factors are involved in this phenomenon? Biologia, 76(8), 2173-2180.

Neumann, P., Yañez, O., Fries, I., & de Miranda, J. R. (2012). Varroa invasion and virus adaptation. Invert. Pathol, 103, 96-119.

Noël, A., Le Conte, Y., & Mondet, F. (2020). Varroa destructor: how does it harm Apis mellifera honey bees and what can be done about it? Emerging Topics in Life Sciences, 4(1), 45-57.

Novelli, S., Vercelli, M., & Ferracini, C. (2021). An easy mixed-method analysis tool to support rural development strategy decision-making for beekeeping. Land, 10(7), 675.

O'Brien, G., O'keefe, P., Rose, J., & Wisner, B. (2006). Climate change and disaster management. Disasters, 30(1), 64-80.

Paray, B. A., Kumari, I., Hajam, Y. A., Sharma, B., Kumar, R., Albeshr, M. F., . . . Khan, J. M. (2021). Honeybee nutrition and pollen substitutes: A review. Saudi Journal of Biological Sciences, 28(1), 1167-1176.

Soroye, P., Newbold, T., & Kerr, J. (2020). Climate change contributes to widespread declines among bumble bees across continents. Science, 367(6478), 685-688.

Tylianakis, J. M., Didham, R. K., Bascompte, J., & Wardle, D. A. (2008). Global change and species interactions in terrestrial ecosystems. Ecology letters, 11(12), 1351-1363.

Ullah, A., Shahzad, M. F., Iqbal, J., & Baloch, M. S. (2021). Nutritional effects of supplementary diets on brood development, biological activities and honey production of Apis mellifera L. Saudi Journal of Biological Sciences, 28(12), 6861-6868.

Van Aalst, M. K. (2006). The impacts of climate change on the risk of natural disasters. Disasters, 30(1), 5-18.

Vercelli, M., Novelli, S., Ferrazzi, P., Lentini, G., & Ferracini, C. (2021). A qualitative analysis of beekeepers' perceptions and farm management adaptations to the impact of climate change on honey bees. Insects, 12(3), 228.

Williams, G. R., Troxler, A., Retschnig, G., Roth, K., Yañez, O., Shutler, D., . . . Gauthier, L. (2015). Neonicotinoid pesticides severely affect honey bee queens. Scientific reports, 5(1), 14621.

Winfree, R. (2010). The conservation and restoration of wild bees. Annals of the New York academy of sciences, 1195(1), 169-197.