MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE SCIENTIFIQUE

UNIVERSITE AKLI MOHAND OULHADJ – BOUIRA

FACULTE DES SCIENCES DE LA NATURE ET DE LA VIE ET DES SCIENCES DE LA TERRE

DEPARTEMENT DES SCIENCES AGRONOMIQUES

Réf : ……./UAMOB/FSNVST/DEP.AGRO/23

MEMOIRE DE FIN D'ETUDES

EN VUE DE L'OBTENTION DU DIPLOME MASTER

Domaine : SNV **Filière** : Sciences Agronomiques
Spécialité : Production et nutrition animale.

Présenté par :

KAID Loubna Chaïma & DJEMMAL Ilhem

Thème

Optimizing beekeeping efficiency: integrating multi criteria decision support system and suitability mapping

Soutenu le : 04/07/2023 **Devant le jury composé de**

Nom et Prénom	***Grade***		
FARID LIBDIRI	*MCB*	*Univ. de Bouira*	*Président*
MAZARI AIT. KACI	*MAA*	*Univ. de Bouira*	*Encadrant*
SALIM LAMINE	*MCB*	*Univ. de Bouira*	*Examinateur*

Année Universitaire : 2022/2023

Aknowledgements

Aknowledgments

We begin by thanking and expressing our gratitude to Almighty God for giving us the courage and willpower to successfully complete this work.

Our deepest thanks go to our supervisor, Mr. AIT KACI, for proposing this research topic, agreeing to guide us, and for his patience and trust. We are grateful for his invaluable assistance, constructive criticisms, and advice.

Our heartfelt thanks are also extended to the members of the jury: Mr. LIBDIRI, for agreeing to chair the jury; and Mr. LAMINE for agreeing to examine our work.

Our sincere and warmest thanks to all the teachers who have contributed to our education during our academic journey.

We would like to express our gratitude to all those who have contributed, directly or indirectly, to the completion of this work.

Dedications

Dedications

Glory be to God, the Almighty, the Merciful, the Master of the Universe, the All-Powerful, the All-Knowing.
Peace and blessings upon the Prophet Muhammad (pbuh).
I am grateful to Allah for the life and health He has bestowed upon me.
I dedicate this work to...

To my parents,
Your reassuring affection towards me has always been a source of inspiration.
May this work be the result of years of sacrifices and prayers that you have made for me. You are deeply rooted in my heart, May God bless you with robust health Throughout your lives.

To my siblings,
For the spirit of unity and love that binds us together. This work is also the result of your numerous sacrifices. Thank you for all your advice and support.

To all my friends,
To all those who have crossed my path and left their mark on my life, rest assured that I hold an unforgettable memory of each one of you.

Chaima
Ilhem

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Abstract

Résumé

L'objectif de cette thèse est de développer un cadre de cartographie de l'aptitude à l'apiculture (BSM) dans la région de Bouira en utilisant une approche de système d'aide à la décision multicritère (MC-DSS). L'étude impliquera l'intégration de divers critères, y compris les précipitations annuelles, la pente, la proximité des routes et des sources d'eau, l'utilisation des terres, l'altitude et l'aspect., afin d'identifier les emplacements les plus appropriés pour les activités apicoles. La recherche comprendra également une évaluation des systèmes de production apicole à Bouira, en tenant compte de facteurs tels que les pratiques de gestion des ruches, la production de miel et la santé des colonies.

Les résultats de l'étude seront présentés sous forme de carte, mettant en évidence les zones les plus propices à l'apiculture dans la région. Ces informations constitueront une ressource utile pour les apiculteurs, les législateurs et les parties prenantes impliquées dans le développement et la gestion du secteur apicole.

Abstract

The aim of this thesis is to develop a Beekeeping Suitability Mapping (BSM) framework in the Bouira region using a Multi-Criteria Decision Support System (MC-DSS) approach. The study will involve the integration of various criteria, including annual rainfall, slope, proximity to roads and water sources, land use, altitude, and aspect to identify the most suitable locations for beekeeping activities. The research will also include an assessment of beekeeping production systems in Bouira, considering factors such as hive management practices, honey production, and colony health.

The results of the study will be presented in the form of a map, highlighting the areas with the highest suitability for beekeeping in the region. This information will serve as a valuable resource for beekeepers, policymakers, and stakeholders involved in the development and management of the apicultural sector.

الملخص

الهدف من هذه الأطروحة هو تطوير إطار رسم خرائط ملاءمة تربية النحل (BSM) في منطقة البويرة باستخدام نهج نظام دعم القرار متعدد المعايير (MC-DSS). ستشمل الدراسة تكامل معايير مختلفة ، بما في ذلك معدل هطول الأمطار السنوي و المنحدرات والقرب من الطرق ومصادر المياه، واستخدام الأراضي والإرتفاع والإشعاع والإتجاه، لتحديد أنسب المواقع الأكثر ملاءمة لأنشطة تربية النحل. سيشمل البحث أيضًا تقييمًا لأنظمة إنتاج تربية النحل في بويرة ، مع مراعاة عوامل مثل ممارسات إدارة خلايا النحل, إنتاج العسل, وصحة المستعمرة.

سيتم عرض نتائج الدراسة على شكل خريطة ، تسلط الضوء على المناطق الأكثر ملاءمة لتربية النحل في المنطقة. ستكون هذه المعلومات موردًا مفيدًا لمربي النحل والمشرعين وأصحاب المصلحة المشاركين في تطوير وإدارة قطاع تربية النحل.

Overview

Overview

Bees exhibit remarkable characteristics in terms of their intricate morphology and unique lifestyle. Their morphology encompasses specialized body structures that enable efficient foraging and resource collection. These adaptations enhance their ability to navigate their environment, locate food sources, and optimize resource utilization. Additionally, bees possess a complex social organization, featuring a division of labor and highly sophisticated communication systems. This social structure further enhances their effectiveness in tasks such as resource allocation, defense, and navigation. The combination of their remarkable morphological features and intricate social organization contributes to the overall success and efficiency of bees in their ecological role(GRUTER 2021). Beyond their biological attributes, bees provide invaluable ecosystem services, particularly through their role in pollination. They play a fundamental role in the reproduction of flowering plants and ensuring the continuity of countless species (Abrol, 2012). Through the transfer of pollen, bees facilitate fertilization and subsequent seed and fruit production, thereby ensuring the reproductive success of numerous plant species. The reliance of both cultivated and wild plants on bee pollination underscores the critical importance of these insects for maintaining biodiversity and sustaining agricultural productivity (Delaplane 2021). The diverse and far-reaching ecosystem services provided by bees contribute to the preservation of biodiversity and the overall balance of natural systems (Abrol, 2012). Consequently, humans have been captivated by bees, leading them to explore ways to domesticate these incredible insects since ancient times. The centuries-long endeavor to cultivate and manage bee colonies has given rise to the practice we now know as Apiculture, the practice of beekeeping, has emerged as a way to nurture and harness the invaluable services that bees provide. Beekeeping offers a wide range of benefits, encompassing economic, environmental, and social dimensions (Bradbear, 2009; Schouten & Lloyd, 2019). It presents individuals and communities with opportunities to generate income by capitalizing on the valuable products produced by honeybees. Honey, in particular, holds significant international demand due to its distinct taste, nutritional value, and medicinal properties, making it a sought-after commodity worldwide (Ahmad, Joshi, & Gurung, 2007). Additionally, beeswax can be sold as a raw material or processed into various value-added items such as cosmetics and candles, further contributing to the economic viability of beekeeping enterprises (Aguiree & Pasteur, 1998; Bradbear, 2009; Hilmi, Bradbear, & Mejia, 2011).

However, the apiculture sector faces numerous challenges that pose threats to bee populations and the sustainability of beekeeping practices. One pressing concern is the decline in bee populations, caused by factors like habitat loss, pesticide use, climate change, and the spread of diseases and parasites. These issues have a cascading effect on ecosystems, disrupting pollination cycles and endangering the survival of various plant species. Additionally, beekeepers often encounter difficulties in accessing modern beekeeping equipment and technologies, hindering the growth and productivity of the sector (De Jong & Lester, 2023). Understanding the practical beekeeping systems in a specific region is crucial for beekeepers to navigate the challenges they face. By recognizing the strengths and weaknesses of different beekeeping methods, beekeepers can effectively overcome obstacles and maximize their success.

To meet the demands of the apiculture sector, beekeepers employ various production systems. In one hand, Traditional systems, such as fixed comb beekeeping and log hives, have been practiced for centuries, offering simplicity and compatibility with local resources. Notably, these methods emphasize the utilization of natural comb construction, thereby preserving the bees' intrinsic behavioral patterns and fostering sustainable beekeeping practices. Consequently, beekeepers with limited financial resources can actively participate in apiculture, thanks to these cost-effective systems that promote accessibility and inclusivity (TECA, 2020). On the other hand, modern beekeeping systems, such as movable frame hives, have gained popularity due to their numerous advantages. These systems feature standardized hive designs that allow for easy manipulation and inspection of bee colonies. This facilitates better pest control measures and disease management, reducing the risk of colony losses. Furthermore, movable frame hives offer increased honey production and provide beekeepers with greater control over the management of their colonies. (TECA, 2020). Moreover, standardized hive designs enable scalability and facilitate the adoption of advanced techniques, such as queen rearing and selective breeding, further improving the quality of bee colonies and their productivity(Blackiston 2020). While modern beekeeping systems often require a higher initial investment and technical expertise, they offer long-term benefits in terms of efficiency and productivity. The ability to easily inspect frames, manipulate combs, and manage colonies according to specific needs enhances the overall productivity of beekeepers(Ranz 2020). Ultimately, the choice of beekeeping system depends on various factors, including local conditions, available resources, beekeeper's goals, and financial capabilities. Understanding the strengths and weaknesses of each system allows beekeepers to make informed decisions, tailoring their approach to the unique requirements of their region. Whether embracing traditional methods or adopting modern techniques, beekeepers can effectively contribute to the sustainable development of the apiculture sector while ensuring the well-being of their bee colonies(CAAS 2020).

Addressing the challenges faced by the apiculture sector requires the implementation of innovative solutions that can revolutionize the industry. One such solution involves the integration of Multi-Criteria Decision Support Systems (MCDSs) methods in conjunction with suitability mapping techniques. These tools provide valuable insights and assistance in making informed decisions regarding the location and management of beekeeping operations. MCDSs are powerful analytical tools that help evaluate multiple factors and criteria to determine the most suitable locations for beekeeping. Factors taken into consideration may include climate conditions, vegetation types, land use patterns, and market access. (Fernandez et al., 2016). By analyzing these factors, beekeepers can identify areas that offer optimal conditions for honeybee colonies. This evaluation process helps them optimize resource allocation by selecting locations where honeybees are likely to thrive, reducing the risk of colony loss and enhancing overall productivity. Suitability mapping complements the MCDS approach by visually representing the suitability of different areas for beekeeping activities. By using geographic information systems (GIS) and remote sensing data, suitability maps can be created to highlight regions that offer favorable conditions for the health and productivity of honeybee colonies. These maps can incorporate various spatial variables, such as temperature, precipitation, floral resources, and land cover types, to provide a comprehensive overview of the potential suitability of an area for beekeeping. The integration of MCDSs and suitability mapping enables beekeepers to strategically place their beekeeping infrastructures in areas with the highest suitability scores. This approach ensures that resources, such as hives and apiaries, are allocated to locations that offer the best combination of environmental factors for honeybee success. Beekeepers can also use these tools to identify areas that may require additional support or intervention to enhance their suitability for beekeeping.

Part I: Beekeeping production systems in BOUIRA

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Introduction:

Apiculture, an age-old agricultural practice, has held significant importance within rural communities, serving as a critical component for meeting their self-sufficiency needs in honey production and facilitating successful fruit tree cultivation through indispensable flower pollination. (Fao, 2020) Algeria, renowned for its deep-rooted history of beekeeping spanning generations, witnesses a notable demand for honey, underscoring its immense value. (Tamali & Özkırım, 2019) The country's substantial potential in honey production acts as a catalyst for economic development, with the overarching objective of achieving self-sufficiency. According to official data from the Ministry of Agriculture and Rural Development, Algeria currently boasts 51,539 registered beekeepers and an impressive distribution of 1.6 million bee colonies across diverse regions, including the northern mountains, steppes, and southern areas. Such regional diversity provides an ecological advantage, enabling the bees to access a wide range of floral resources and optimize honey production. However, recent statistical figures from the National Office of Statistics (ONS) reveal a concerning decline in national honey production. In 2020, the estimated honey production in Algeria stood at 53,765 quintals, representing a 15% decrease compared to the 63,469 quintals recorded in 2019. This decline raises scientific and agricultural concerns, warranting further investigation into the underlying factors contributing to this downward trend.

Similarly, according to statistics provided by the Direction of Agricultural Services (DSA) of Bouira, honey production in the region has experienced a substantial decline over the past six years. The data indicates a worrisome decrease of 77% in honey production highlighting the urgent need for scientific inquiry and research to understand the factors responsible for such a significant reduction. A comprehensive understanding of the diverse beekeeping production systems prevalent in a specific region, such as Bouira, holds immense significance for beekeepers as they navigate the intricacies of their craft and strive for optimal outcomes. In Bouira, beekeepers employ a range of production systems, including both traditional and modern approaches, each offering unique methodologies and advantages. Traditional beekeeping practices in Bouira involve the use of traditional hives made of cork, which are considered outdated in terms of honey harvesting and pose challenges due to their small size and increased susceptibility to diseases. On the other hand, modern beekeeping in the region encompasses four diverse types of production systems. Family beekeeping satisfies self-consumption needs, while extensive beekeeping aims to increase overall production without focusing on individual unit yield. Semi-intensive beekeeping requires simple management practices suitable for hobbyists who prioritize ease of maintenance. Additionally, intensive beekeeping methods are employed to achieve high bee populations during honey flow and maximize harvest. However, it is important to note that intensive techniques can sometimes lead to bees becoming irritable and difficult to manage, regardless of their breed. Modern beekeeping practices in Bouira also incorporate scientific techniques such as queen breeding and selection, requeening, artificial insemination, transhumance, and directed pollination, with the ultimate goal of optimizing profitability. There has been limited research conducted on the diverse range of production systems. However, it is imperative to consider the diversity of these systems for the successful implementation of rural research and development initiatives. These initiatives are most effective when they align with groups of operations that share similar characteristics and approaches. (Khalissa et al., 2019) The primary objective of this article is to contribute to the identification of beekeeping production systems in the Bouira region. Through a comprehensive typological study, this research aims to provide an insightful understanding of the local context, highlight the distinctive characteristics of various breeding types, identify strengths and weaknesses, and ultimately offer tailored recommendations for individual beekeepers or groups of beekeepers.

2. Materials and Methods

Research area

The province of Bouira is situated in the central-northern region of the country. It covers an area of 4456.26 km², representing 0.19% of the national territory. The capital city of the province is located approximately 120 km from the capital city of Algiers. it is bordered by the Djurdjura mountain range on one side and the Dirah mountains on the other, opening up towards the east to the Soummam valley. Bouira is delimited by the wilaya of Tizi Ouzou to the north, the wilaya of Bordj Bou Arreridj to the east, the wilaya of M'Sila to the south, and the provinces of Médéa and Blida to the west (DSA Bouira, 2020). The province has two large agricultural areas: to the east, the M'chedallah area covering 1,600 hectares, and to the west, the Aribs Ain Bessem area spanning 2,200 hectares. The agricultural production in the area is predominantly focused on cereals and olive cultivation. Forest areas hold a significant role in the province, covering 112,250 hectares, which corresponds to 25.20% of the total land area. The prominent forest species found in these areas include Aleppo pine, holm oak, and cork oak (DSA Bouira, 2020).

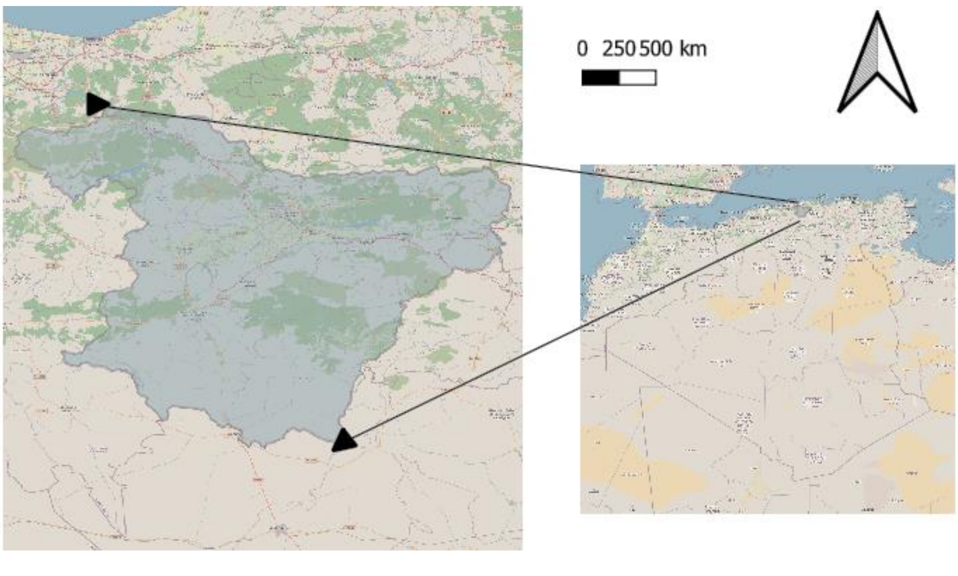

Figure. 1 Map of the study area (wilaya of Bouira) built with Qgis.

Part I: Beekeeping production systems in BOUIRA

Methodology

The approach followed to conduct this work was as follows:

1. Elaboration of a questionnaire: A questionnaire was developed to gather relevant information for the study. This involved carefully formulating questions that would provide valuable insights and data.

2. Engagement with public repositories and cooperatives: The subsequent phase entailed initiating communication with the Department of Agricultural Services (DSA) in Bouira, as well as the cooperatives operating in both Ain Laloui and Bouira. Through these interactions, the aim was to obtain contact information of beekeepers, enabling us to establish direct communication and request their informed consent for participation in the study.

3. Conducting the Field Survey: The survey took place from 09/05/2023 to 31/05/2023 among 38 beekeepers. It involved visiting multiple locations and employing various methods such as face-to-face interviews, online surveys, phone calls, and observations. We carefully planned and prepared for the survey, ensuring we reached each location on time. Face-to-face interviews allowed for direct interaction and observation of beekeeping practices. Online surveys provided convenience and wider reach, while phone calls enabled real-time conversations. We actively observed beekeeping activities during our visits. Throughout the survey, we recorded data to ensure comprehensive analysis. This multi-method approach aimed to gather diverse perspectives and insights on beekeeping practices and challenges in various locations.

4. After conducting the field survey, we tabulated the questionnaires using Google Forms to process and organize the data collected. We paid close diligence to ensure accuracy and completeness. The survey gathered both qualitative and quantitative data on various aspects of beekeeping practices, trends, and constraints in honeybee production. The major data categories include Sociodemographic characteristics of respondents: We collected information on sex, age, educational background, and the number of honeybee colonies held by the respondents. Beekeeping production practices: We recorded data on the respondents' current number of hives, types of hives used, and whether they practiced transhumance (moving bee colonies seasonally). Constraints of beekeeping in the area: We identified and documented honeybee pests and diseases that pose challenges to beekeeping in the surveyed area.

5. Data management and statistical analysis: Once the responses were tabulated, the data was subjected to processing and analysis using RStudio. The data was summarized using descriptive statistics (mean, mean comparison, frequency, percentages, and ranges). Multi-response analysis was also used for variables that need to be ranked.

3. Results and discussions

- **Sociodemographic characteristics of the surveyed individuals**

1. Household Characteristics.

Out of the total 38 respondents that participated in the study to generate qualitative and quantitative data on beekeeping, about 89.2% were male and the rest 10.8% were female. Historically, beekeeping has been predominantly male dominated, with limited participation from women. This could be attributed to various factors such as societal norms, cultural expectations, and traditional gender roles.

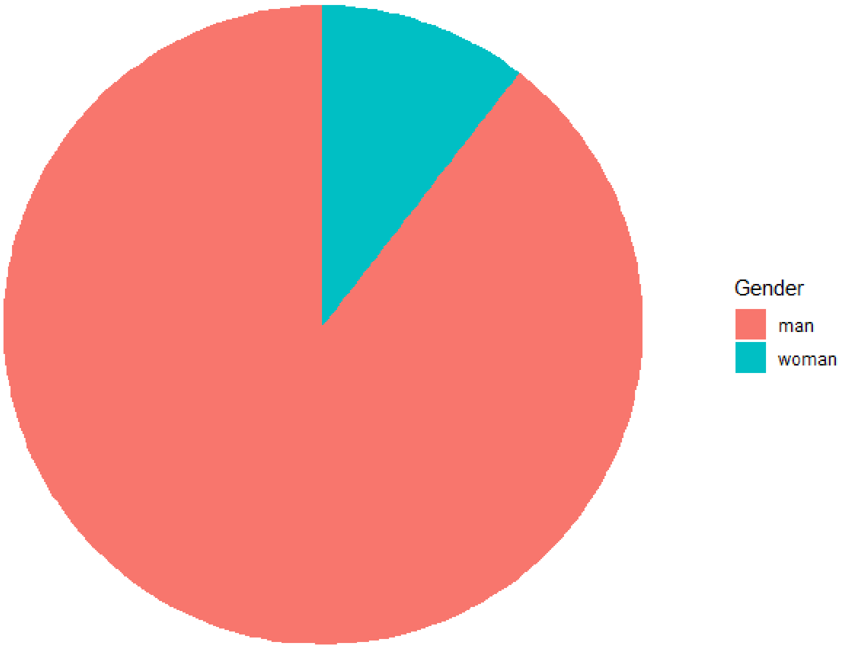

Figure 2. gender distribution of the respondents.

Survey results showed that the beekeepers' age ranges from 25 to 71 years old with mean age of 47.21 out of which more than 55.26% of the respondents age was less than 50 years old. This result showed that beekeeping can be performed by all age groups and reasonably without any difficulties and actively performed by younger age groups. younger respondents were actively involved, accommodating experiences from elders, and finally become independent beekeepers.

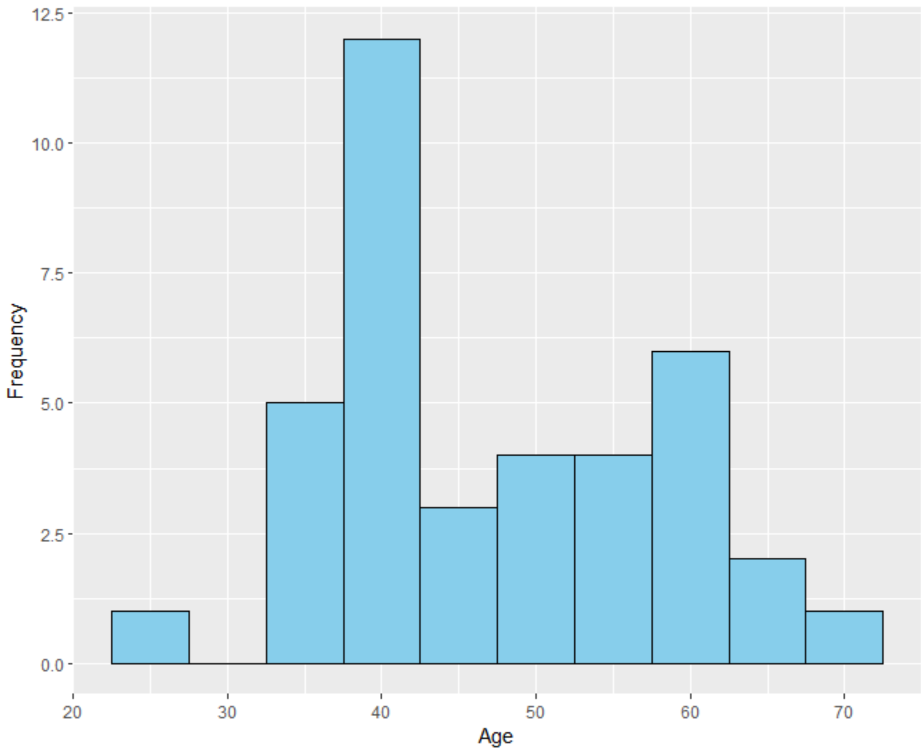

Figure 3. Age distribution of the respondents.

2. Educational Status of Respondents.

The survey results indicate that the majority of participants in the study were affiliated with higher levels of education, with 31.58% being university-educated, followed by 28.95% with a high school education. Middle school participants accounted for 21.05% of the sample, while elementary school participants represented 15.79% of the respondents. It is worth noting that only a small percentage, 2.63%, reported being unschooled. The substantial presence of university-educated participants indicates that formal education could be a driving force behind the pursuit of beekeeping. University programs or courses related to agriculture, environmental sciences, or biology may offer specialized knowledge on the importance of bees, their role in pollination, and sustainable beekeeping practices. The higher level of education may provide access to resources, research, and networks that can contribute to the participants' expertise and dedication to beekeeping. While the percentage of unschooled participants was relatively small, at 2.63%, their inclusion provides valuable insight into alternative pathways for beekeeping knowledge acquisition. Individuals who are unschooled may have obtained practical knowledge through firsthand experience, informal mentorship, or self-directed learning.

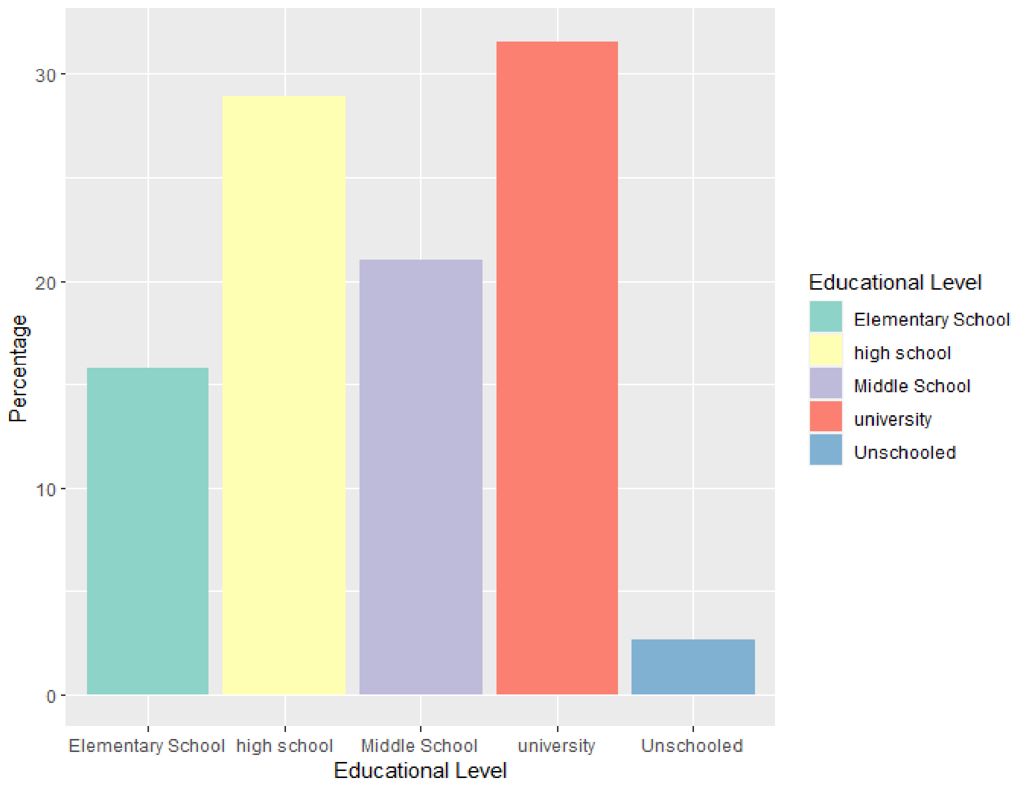

Figure 4. Education level distribution of the respondents.

4. Beekeeping Experience of Respondents.

The range of experience varied from 4 to 43 years; The average years of experience was found to be approximately 7.74 years; this indicates a moderate level of experience within the beekeeping community and highlights the diversity of backgrounds and expertise among the participants. And is explained by the transmission of the profession from father to son, as well as the support programs initiated by the State that have encouraged young people to engage in this activity (National Fund for Rural Development of the DSA et PPDRI for forest conservation). Additionally, the establishment of various services, such as the production and supply of modern beekeeping equipment, honey extraction, wax embossing, marketing of hive products, and the guidance of new beekeepers through training sessions, has further contributed to this trend.

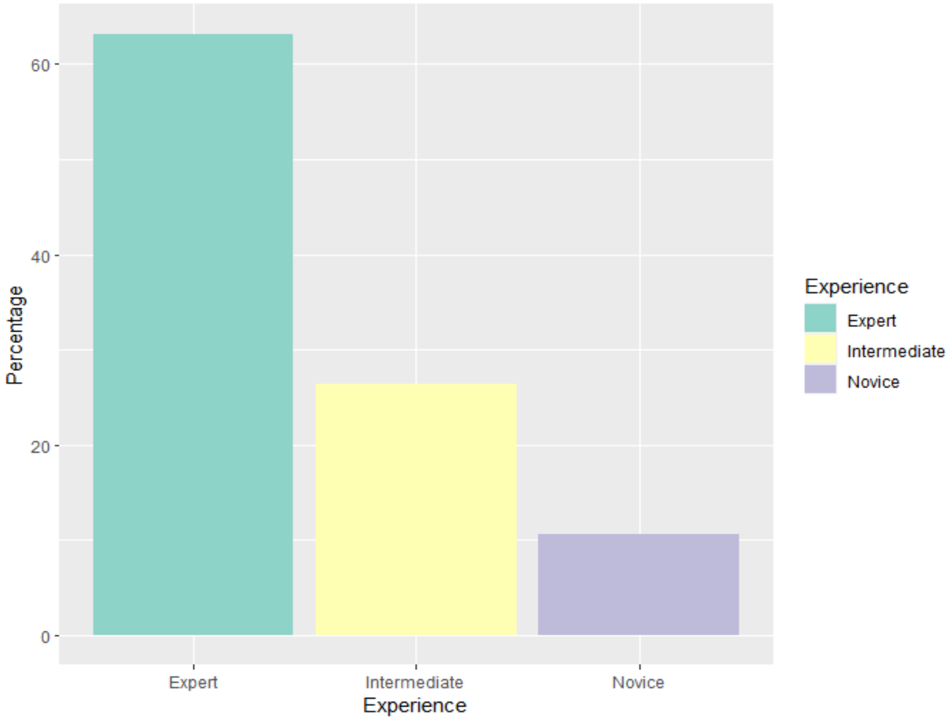

Figure 5. Experience distribution of the respondents.

- **General management practices of the apiary**

1.The number of hives of the respondents

It was observed that the respondents exhibited a wide range of hive sizes in their beekeeping operations. The number of hives reported by the participants varied significantly, ranging from 3 to 1500 hives. Interestingly, the most common number of hives reported by the respondents was 70. This finding highlights the diversity in beekeeping practices and emphasizes that beekeepers operate at various scales, from small-scale enthusiasts to larger commercial operations. The distribution of hive numbers underscores the significance of considering the different management approaches and challenges associated with varying hive sizes.

2. hives feed distribution of the respondents.

It was observed that beekeepers employ different feeding practices to support the health and well-being of their hives. The majority of respondents, comprising 45.9%, reported feeding their hives on a seasonal basis. This approach aligns with the natural cycles of beekeeping, providing supplemental nutrition during periods of increased activity or when natural forage is limited. Additionally, 24.3% of beekeepers reported feeding their hives weekly, ensuring a consistent and steady supply of nourishment. Another 18.9% of respondents indicated monthly feeding, likely striking a balance between resource availability and hive requirements. The remaining beekeepers either fed their hives daily or rarely, indicating diverse approaches to hive management. These findings underscore the importance of tailored feeding strategies in maintaining healthy and thriving bee colonies, with consideration given to the unique needs of each hive.

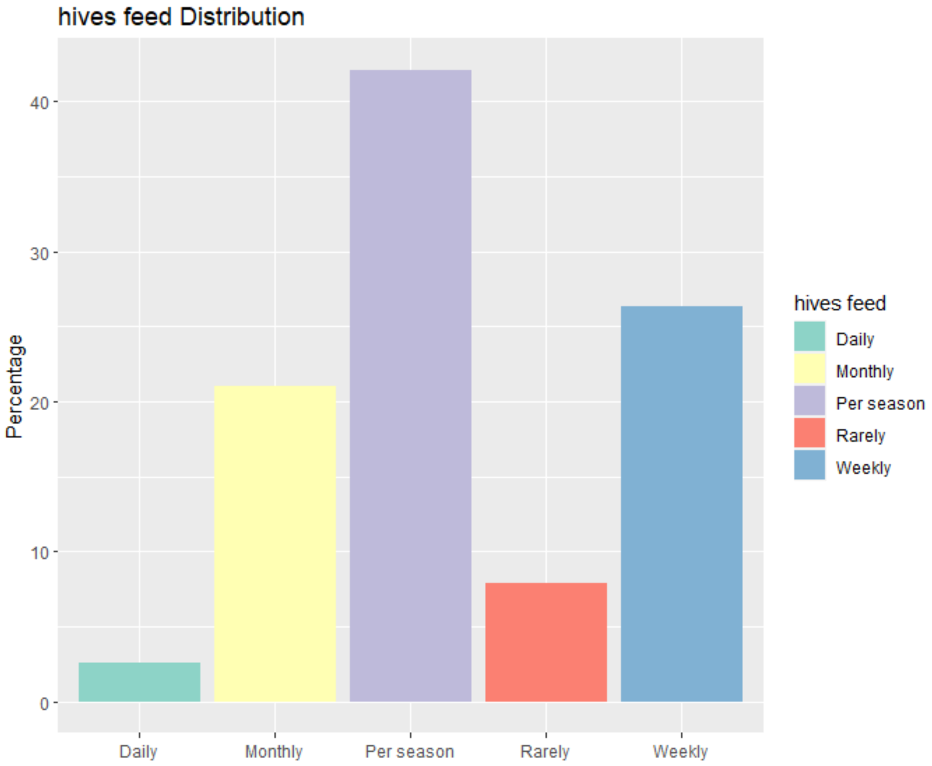

Figure 6. Hives feed distribution.

3.The beekeeping environment.

According to Figure 7, which represents the beekeepers' preferred areas in Bouira, it is evident that all beekeepers favor forested and mountainous regions that offer diverse agricultural opportunities. These areas are abundant in honey-producing flowers and encompass a variety of trees such as carob, olive, fig, oak, ash, and eucalyptus. Some beekeepers opt to position their hives in meadows where borage, high-quality hay, and field mustard thrive. Additionally, a portion of beekeeping activities take place in open-field vegetable cultivation areas, particularly in the Ain Bessam district of the Bouira province. Overall, the figure highlights the beekeepers' inclination towards natural and resource-rich environments for their apiaries.

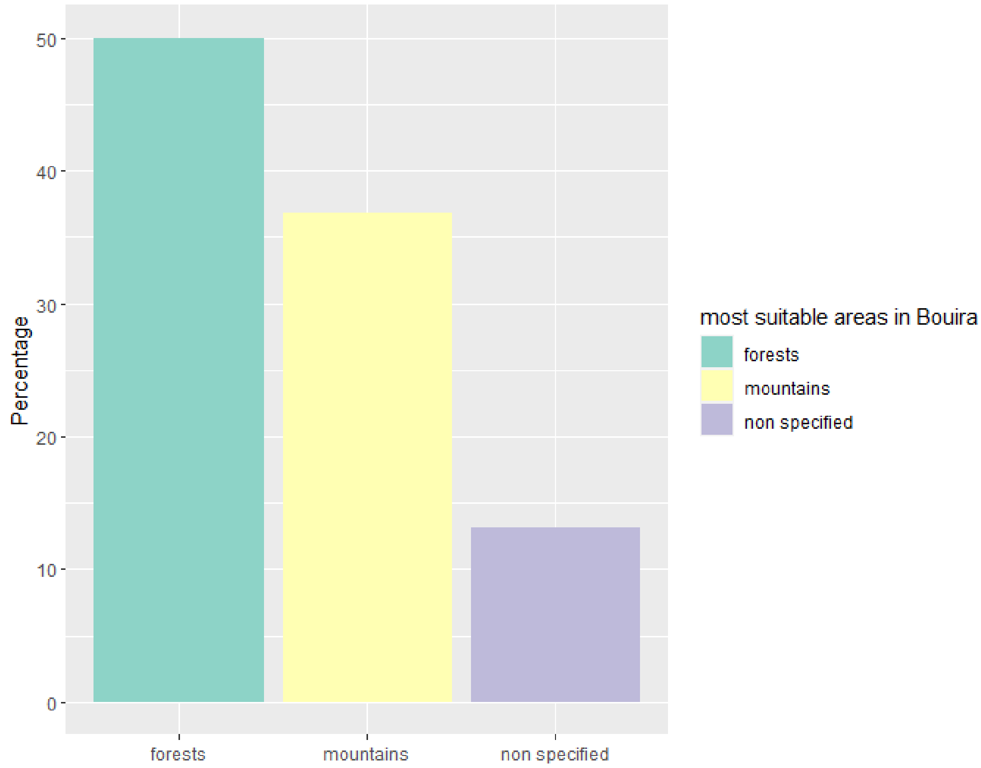

Figure 7. Most suitable areas according to the respondents.

It was noted that a significant percentage of beekeepers (81.4%) reported changes in the suitability of their beekeeping sites, resulting in several negative impacts. These changes included higher mortality rates among bees, reduced honey production, decreased vegetation cover, and deteriorating site conditions. Beekeepers also highlighted the influence of climate change, with factors such as higher temperatures, water shortage, drought, and poor rainfall affecting site suitability and resource availability. Urbanization and competition for vegetation were identified as additional challenges. The presence of pests, including wasps, further contributed to the difficulties faced by beekeepers.

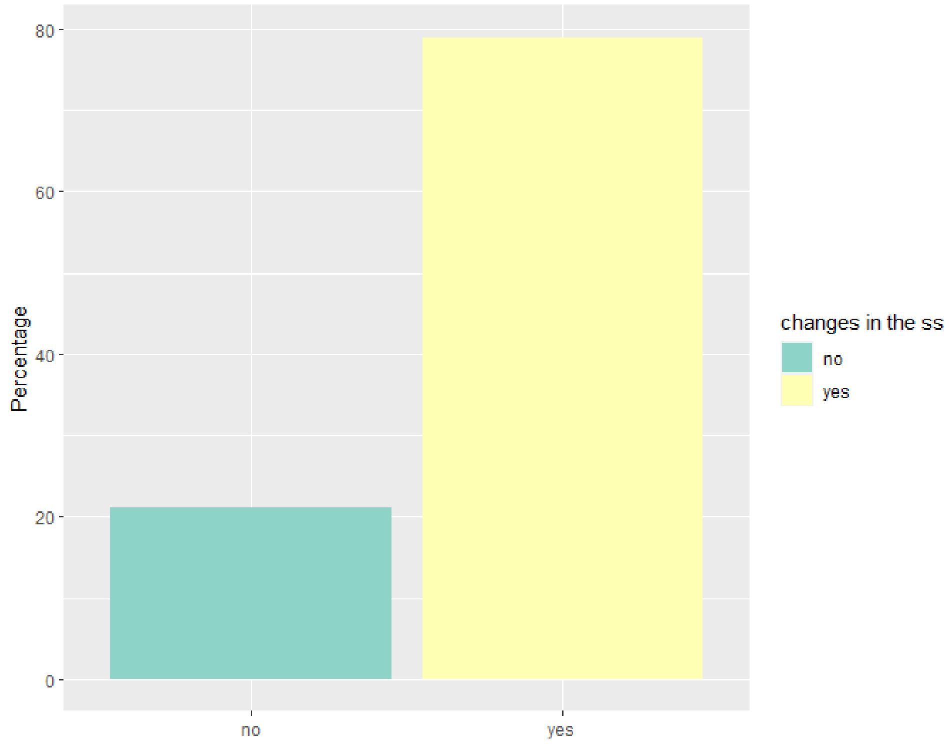

Figure 8. changes in the suitability overtime of current beekeeping site according to the respondents.

The presence of other beekeepers in the area and its impact on the beekeeping environment were examined. A significant majority of beekeepers (63.9%) strongly agreed that the presence of other beekeepers does affect the suitability of their site. This suggests that the density of beekeeping activities in a particular area can have tangible effects on the overall beekeeping environment. When multiple beekeepers operate in close proximity, factors such as competition for forage resources, potential disease transmission, and increased stress on the local bee population may arise. These effects can result in reduced honey production, increased colony losses, and compromised overall hive health. Conversely, the remaining beekeepers disagreed with the notion that the presence of other beekeepers had a significant impact on site suitability. Their perspective suggests that factors such as proper hive management, proactive disease prevention, and maintaining adequate forage resources can mitigate any potential negative effects. Understanding the dynamics of multiple beekeepers in an area is crucial for effective site selection and management decisions, as it can help beekeepers develop strategies to minimize the negative impact of neighboring hives and foster a healthier beekeeping environment.

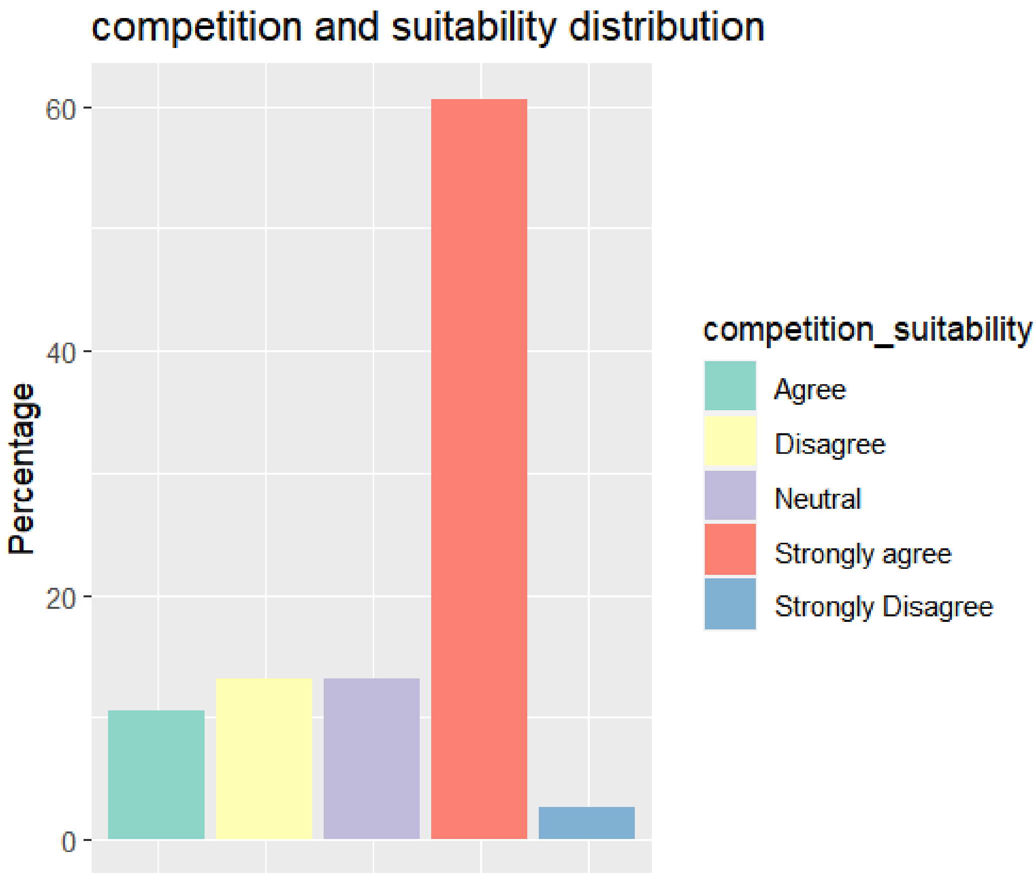

Figure 9. competition and presence of other beekeepers' effects according to the respondents.

4.Type of farming

The survey revealed that half of the interviewed beekeepers, which is 52.63%, have stationary apiaries as shown in Figure 7, while 47.37% are migratory beekeepers. The sedentary beekeepers provided various reasons for their choice. One of the primary factors cited was the relatively smaller size of their hive populations, which makes transhumance less practical for them. These beekeepers predominantly focus on utilizing the honey produced for their own consumption rather than commercial purposes. Consequently, they opt to maintain their hives in a stationary manner. Regarding hive types, it is noteworthy that all beekeepers surveyed, both transhumant and sedentary, utilize the Langstroth hive. The Langstroth hive is a widely adopted and standardized hive design, known for its versatility and ease of management. Its consistent usage among the beekeeping community ensures uniformity in hive structures, facilitating knowledge sharing, and enabling the implementation of standardized beekeeping practices.

The findings highlight the differing practices and motivations of beekeepers, with the sedentary group opting for hive management approaches that align with their specific circumstances and needs. Moreover, the uniform adoption of the Langstroth hive emphasizes its popularity and suitability for beekeeping operations across the surveyed population.

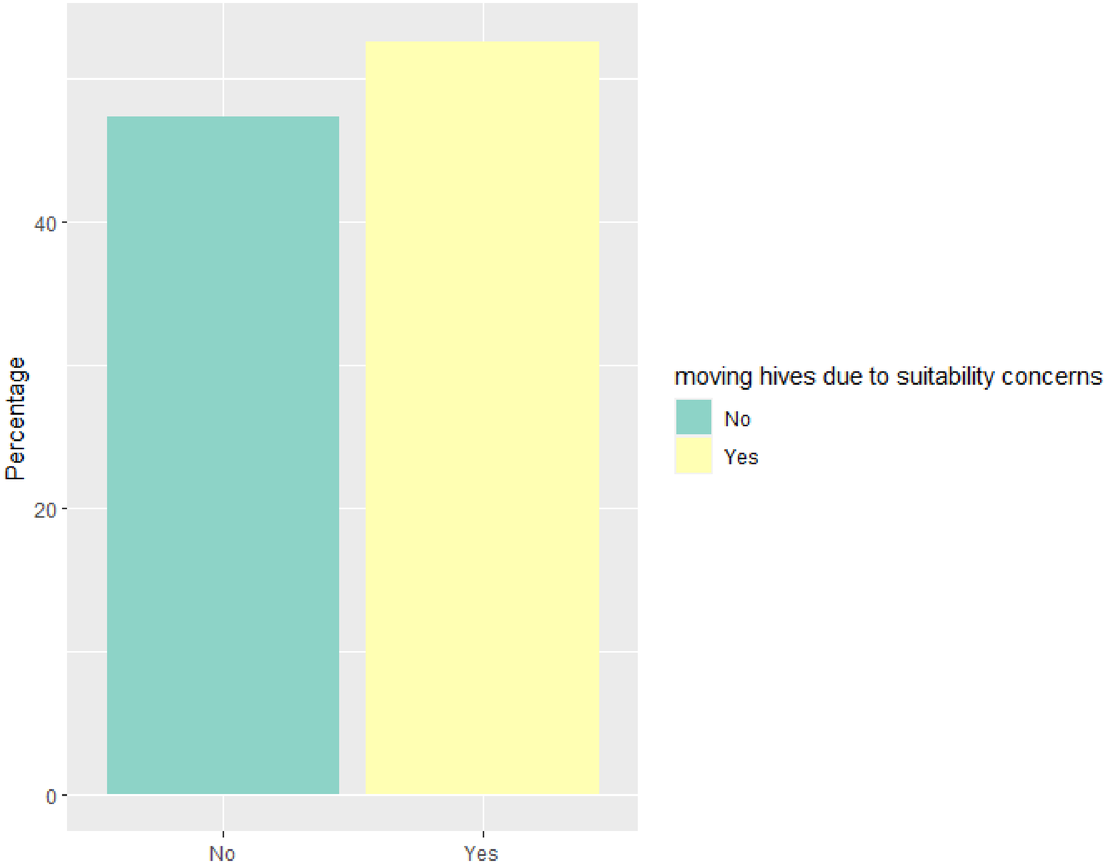

Figure 10. sedentary and transhumant hives distribution.

4. Mortality of bee colonies

An overwhelming majority of beekeepers, approximately 97.3%, have reported experiencing colony losses in the past. These losses have varied in magnitude, ranging from the unfortunate loss of 15 hives to the complete devastation of entire bee populations. Such losses are highly detrimental to beekeepers and the overall ecosystem. Multiple factors contribute to these losses, with pests and diseases being the most significant culprits. Specifically, pests like varroa mites, Nosema, hornets, and the Eurasian bee eater bird have been identified as major threats to bee colonies. Additionally, changes in climate patterns have emerged as another significant factor, characterized by fluctuations in temperature, humidity, and prolonged periods of drought. These combined factors pose severe challenges to the survival and well-being of bee populations.

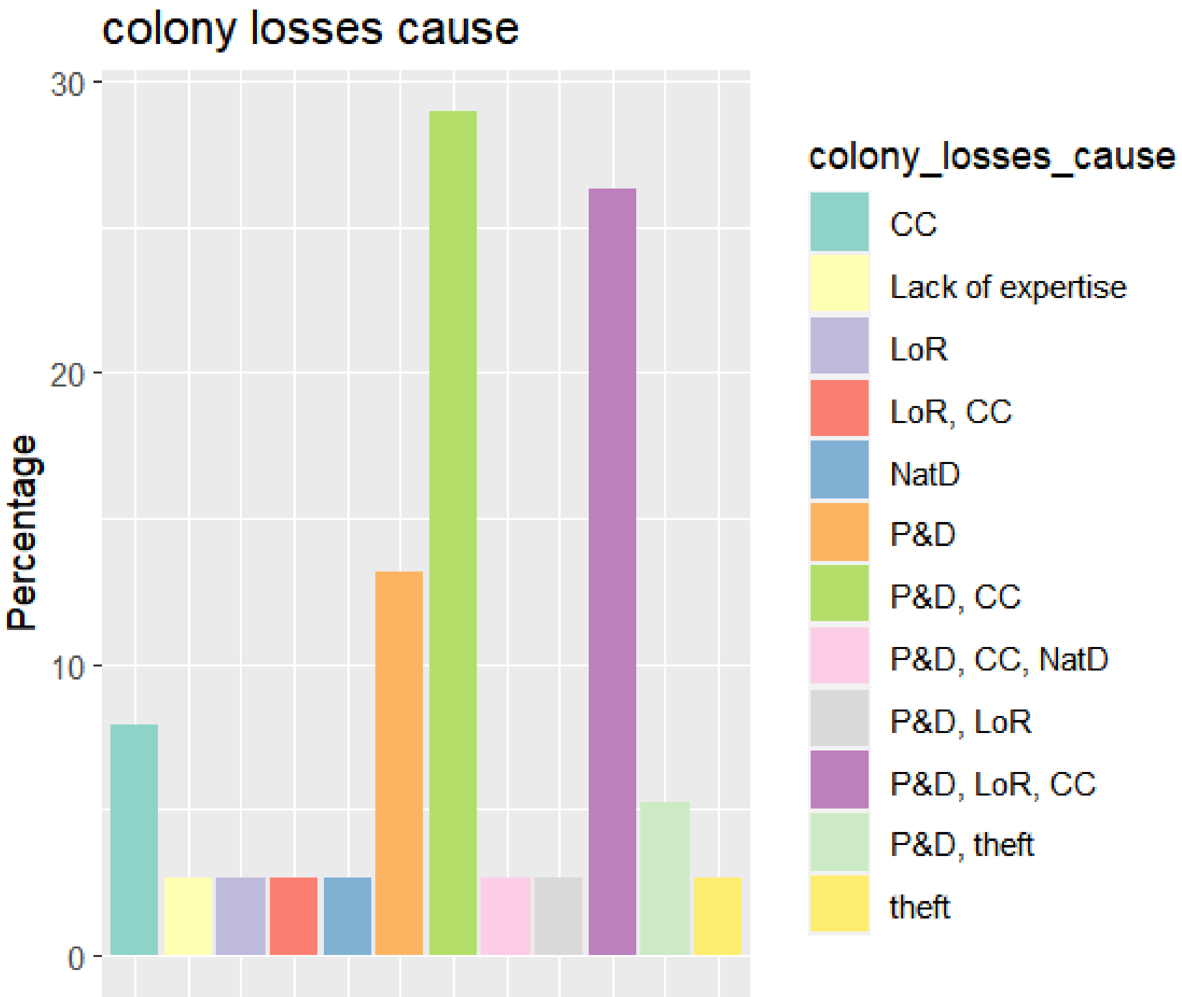

Figure 11. colony losses cause according to the respondents.

P&D: pests and diseases
LoR: lack of resources
CC: climate change
NatD: natural disasters

However, there exists a notable positive trend within the beekeeping community, where a significant majority of beekeepers (approximately 94.6%) actively undertake measures to safeguard their hives.

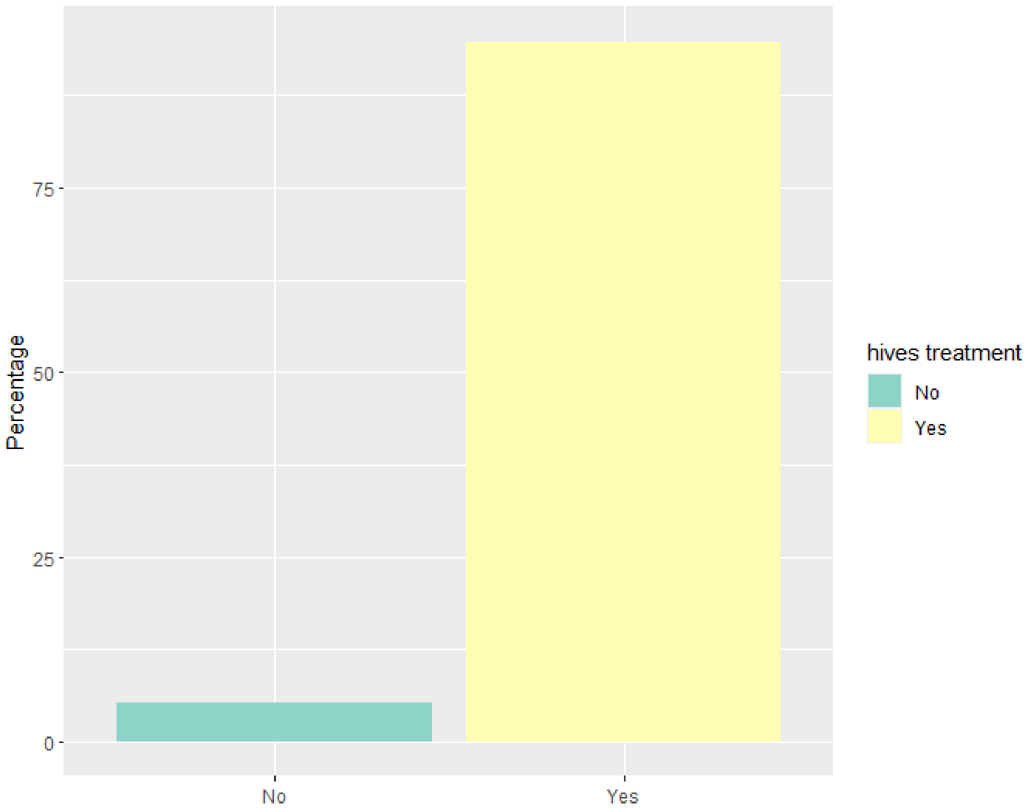

Figure 12. Hives treatment against pest and diseases distribution.

It was evident that beekeepers employ various measures to mitigate colony losses and ensure the well-being of their hives. The most common strategies reported by the respondents included regular monitoring of hives and their health, providing an adequate supply of food and water, and protecting hives from pests and diseases. Close and consistent monitoring allows beekeepers to promptly identify any signs of stress, disease, or irregular behavior within the colonies, enabling them to take timely action and provide necessary interventions. Additionally, beekeepers emphasized the importance of ensuring a balanced diet for the bees, especially during periods of limited natural forage. This involves providing supplementary food sources, such as sugar syrup or pollen substitutes, to support the nutritional needs of the colonies. Protecting hives from pests and diseases through the use of preventive measures, including integrated pest management techniques and regular inspections, was also highlighted by the respondents. Furthermore, several beekeepers emphasized the significance of consistency and dedication in their work as an essential factor in minimizing colony losses. By adhering to established beekeeping practices and maintaining a routine, they believe that the likelihood of negative impacts on the colonies can be reduced. These findings underscore the multifaceted approach employed by beekeepers to safeguard their hives, ensuring the sustainability and resilience of their colonies.

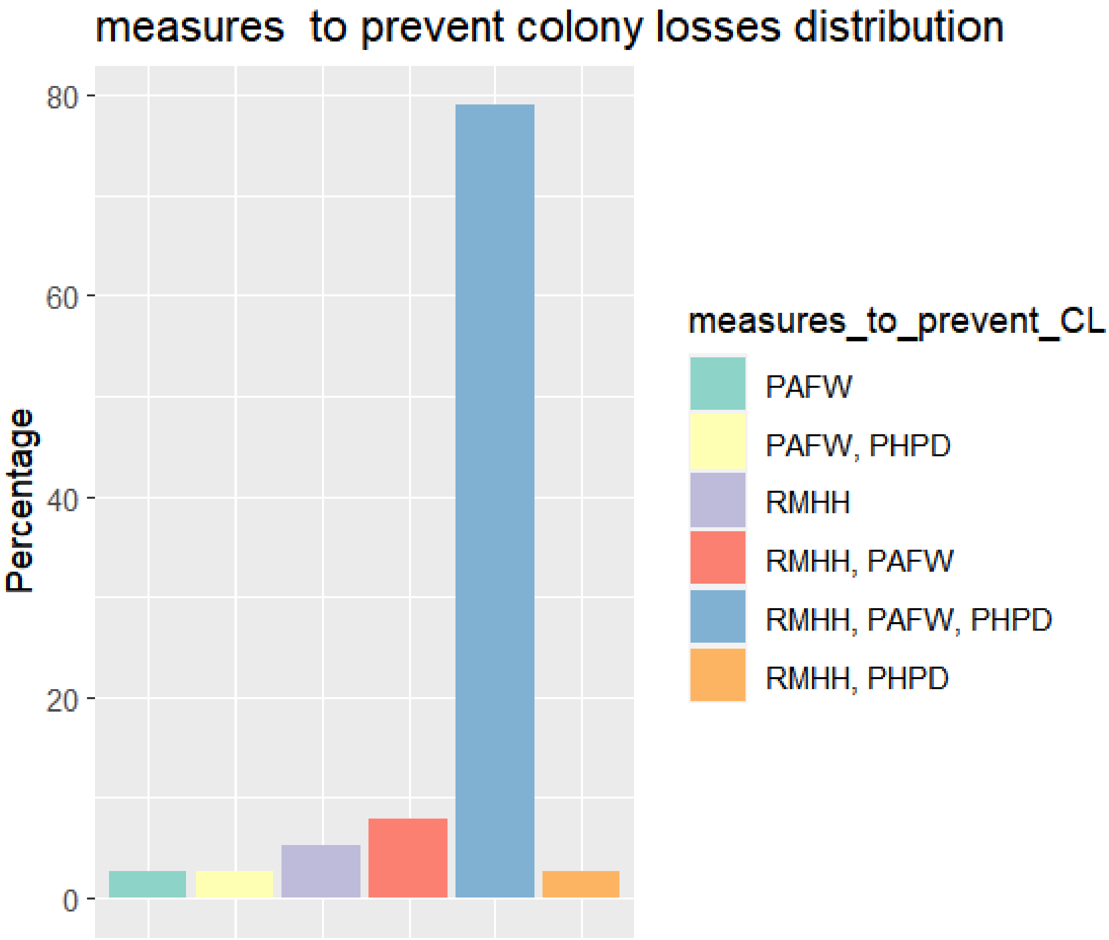

Figure 13. Measures to prevent colony losses.

Regular monitoring of hive health : RMHH
Providing adequate food and water : PAFW
Protecting hives from pests and diseases : PHPD

Inquiring about the significance of training courses, an overwhelming majority (approximately 97.3%) of beekeepers expressed a strong belief in the importance of accessing beekeeping courses and training. These educational opportunities are seen as invaluable for enhancing skills, gaining mastery, and

deepening the understanding of the craft. It is worth noting that these findings underscore the dedication of beekeepers to ensuring the well-being and survival of their colonies through proactive measures and ongoing education.

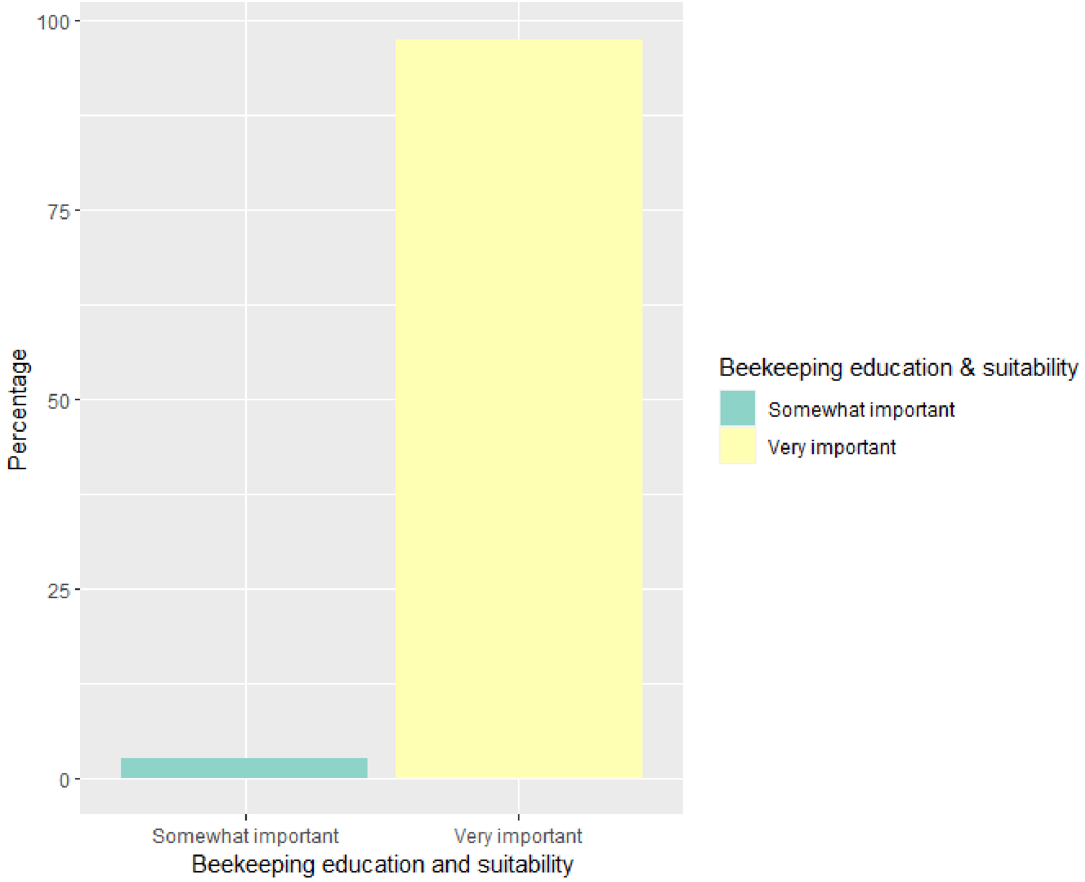

Figure 14. Beekeeping education importance according to the respondents.

5. Practice of transhumance

A significant proportion of transhumant beekeepers (approximately 64.7%) practice transhumance occasionally, as needed, while a slightly lower percentage (around 47.1%) engage in annual transhumance. The preferred destinations for transhumance are typically the southern provinces, such as Biskra or Djelfa. The rationale behind this choice primarily revolves around achieving higher honey yields and diversifying the range of honey produced. The southern regions boast a greater abundance of medicinal plants, which is believed to contribute to increased hive health and honey production.

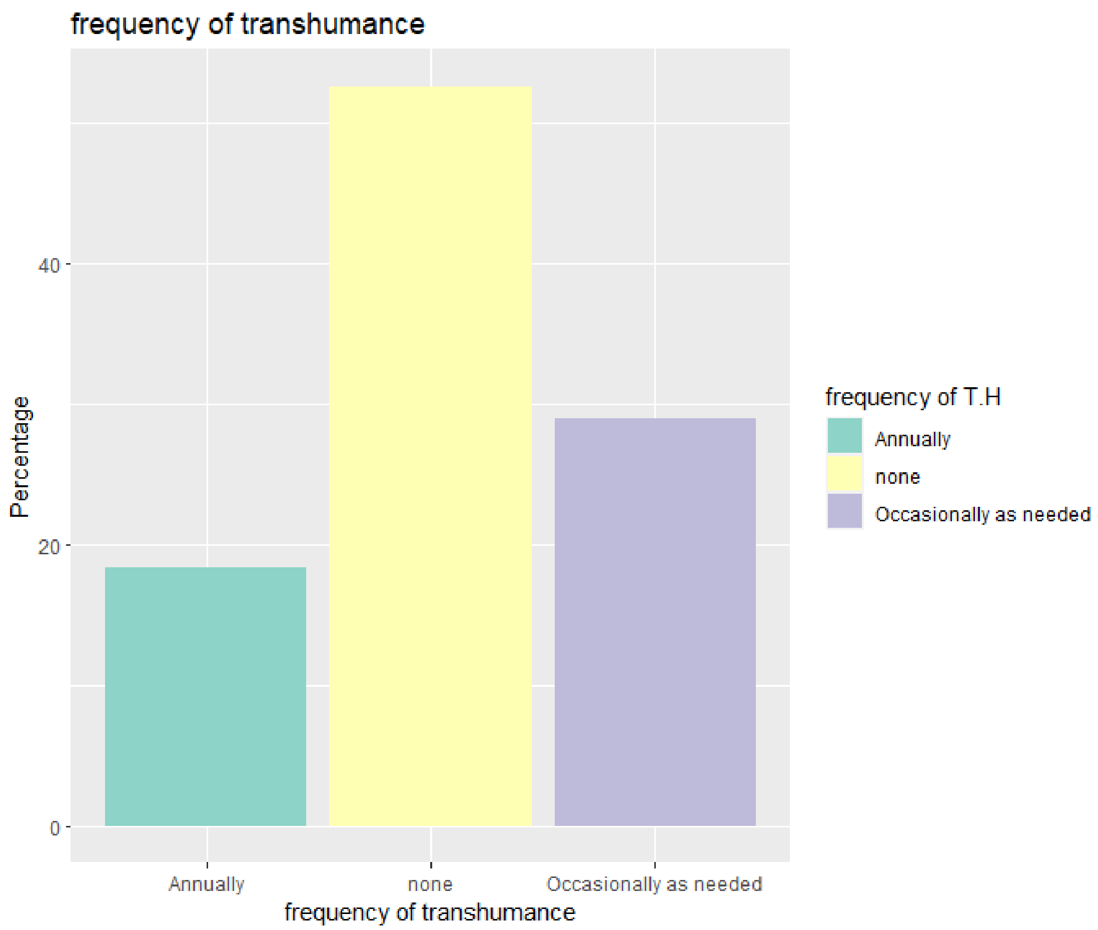

Figure 15. frequency of transhumance.

The impact of transhumance on honey production was explored, revealing divergent perspectives among beekeepers. The practice of transhumance garnered mixed opinions regarding its effect on honey production. A portion of the respondents believed that transhumance leads to a significant increase in honey production emphasizing that for transhumance to yield positive outcomes, it is crucial for the colonies to be in optimal health prior to relocation. They attribute this boost to the bees' exposure to a wider variety of nectar and pollen sources, resulting in enhanced foraging opportunities and increased honey yields. Conversely, some beekeepers held the viewpoint that transhumance may result in a slight decrease in honey production. They argue that the stress associated with hive relocation, coupled with potential disturbances in colony development, could temporarily disrupt honey production. These contrasting opinions underscore the complexity of factors influencing honey production in transhumance-based beekeeping systems.

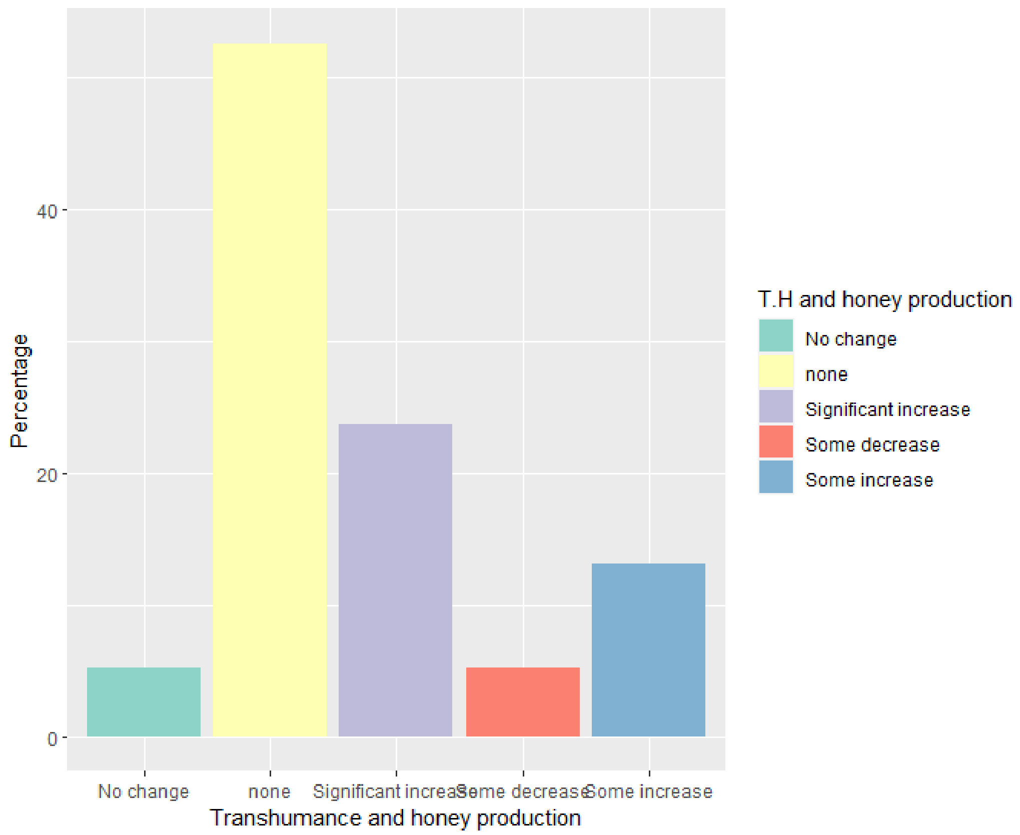

Figure 16. transhumance effect on honey production according to the respondents.

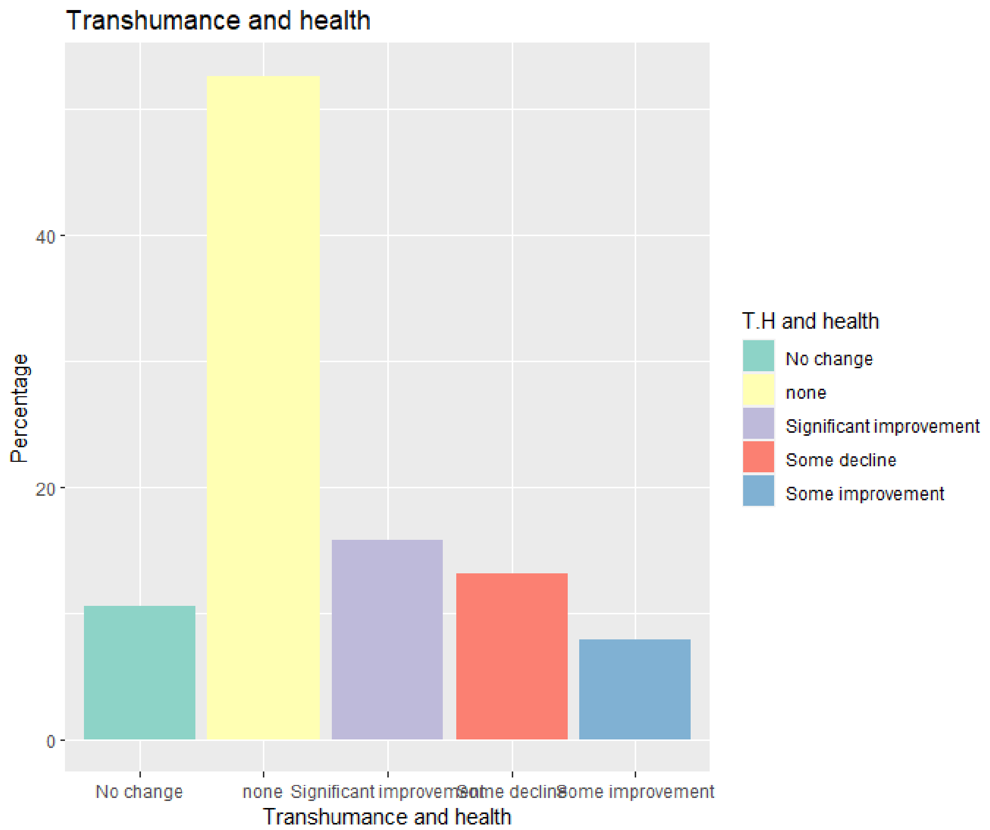

Figure 17. transhumance effect on hives health according to the respondents.

It became evident that beekeepers practicing transhumance face several primary challenges. The foremost challenge reported by the respondents was the need to protect hives from pests and diseases. The frequent movement of hives increases the risk of infestation and exposure to pathogens, requiring diligent monitoring and preventive measures. Additionally, theft emerged as a significant concern, as the portable nature of transhumance makes hives vulnerable to theft or vandalism. Security measures, such as employing strong hive locks and monitoring systems, were considered essential to mitigate this risk. The cost associated with the entire transhumance procedure was also identified as a challenge, encompassing expenses related to transportation, equipment, and labor. Moreover, finding suitable locations for hive placement and managing the logistics of moving hives were identified as additional challenges, albeit to a lesser degree. These findings highlight the multifaceted nature of challenges faced by beekeepers practicing transhumance, emphasizing the need for careful planning, adequate resources, and effective management strategies to ensure the success and sustainability of transhumance. beekeeping operations.

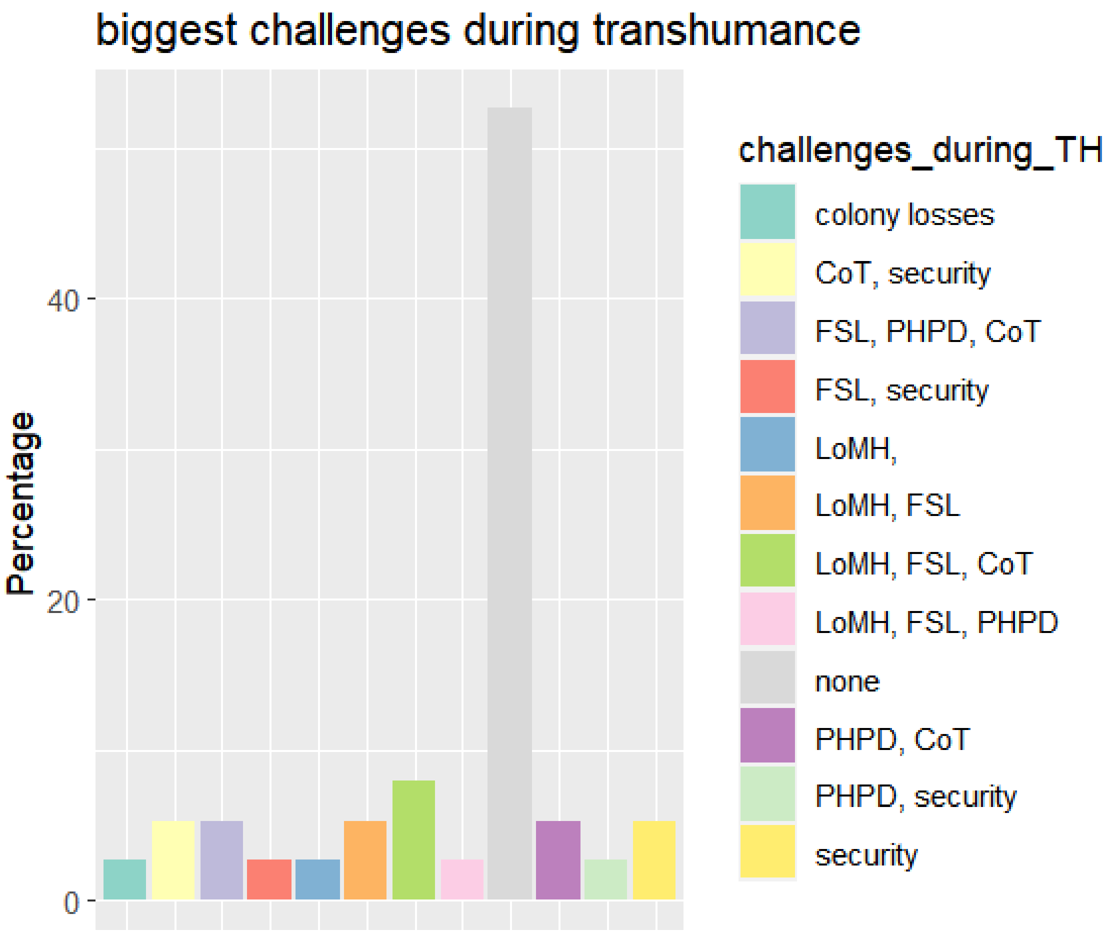

Figure 18. biggest challenges during transhumance according to the respondents.

Logistics of moving the hives: LoMH
Finding suitable locations: FSL
Cost of transportation: CoT
Protecting hives from pests and diseases: PHPD

Part I: Beekeeping production systems in BOUIRA

Correlation matrix for num var:

correlations between categorical variables

Perform correlation analysis for categorical variables

The chi-square test of independence was performed on the contingency table created from the

different variables. We excluded all insignificant correlations.

The results of the chi-square tests between the variable "Educational_Level" and all the

other variables in the dataset

Based on the chi-square tests, the p-values indicate the presence of a significant correlation

between the variable "Educational_Level" and the following variables:

Experience (p-value = 0.03833)

hives_feed (p-value = 0.02773)

changes_in_the_ss (p-value = 0.0387)

water_flower_plants_ss (p-value = 0.03785)

These variables show a statistically significant relationship with the educational level of the

beekeepers in the dataset.

The results of the chi-square tests between the variable "Experience" and all the other

variables in the dataset

moving_hives_due_to_suitability_concerns p-value = 0.03049

factors_to_select_a_site p-value = 0.002447

hives_feed p-value = 0.001809

hives_managed p-value = 0.00341

The results of the chi-square tests between the variable "hives feed" and all the other

variables in the dataset

water_flower_plants_ss p-value = 0.0009507

The results of the chi-square tests between the variable "

Part I: Beekeeping production systems in BOUIRA

Beekeeping_education_suitability" and all the other variables in the dataset

CL_profitability p-value = 0.007445

The results of the chi-square tests between the variable " coop_participation" and all

the other variables in the dataset

frequency_of_TH p-value = 0.02019

TH p-value = 0.04

moving_hives_due_to_suitability_concerns p-value = 0.02604

water_flower_plants_ss p-value = 0.02314

The results of the chi-square tests between the variable " health_assesement" and all the

other variables in the dataset

measures_to_prevent_CL p-value = 0.0002922

hives_protection p-value = 0.000268

moving_hives_due_to_suitability_concerns p-value = 0.02604

water_flower_plants_ss p-value = 0.02314

Conclusion

In conclusion, this study aimed to investigate the beekeeping production systems in Bouira through a survey conducted with 38 beekeepers. The results shed light on important aspects of beekeeping practices in the region. It was found that the majority of beekeepers in Bouira utilize modern hive systems, indicating an awareness of the benefits and advancements in hive technology. This adoption of modern hives suggests a commitment to improving beekeeping practices and enhancing hive productivity.

Secondly, the survey identified several factors influencing beekeeping productivity. Access to quality forage resources, availability of water, and suitable climatic conditions were crucial determinants of honey production. Additionally, beekeepers who demonstrated a sound understanding of bee biology and behavior, as well as those who implemented effective pest and disease management strategies, tended to achieve higher yields and healthier colonies.

Furthermore, the study highlighted challenges faced by beekeepers in the Bouira region. Insufficient access to training programs and technical assistance emerged as a significant barrier to improving production systems as well as limited financial resources, were identified as impediments to beekeeping development in the area.

To address these challenges and enhance beekeeping production in Bouira, several recommendations can be put forward. First, the establishment of training programs and knowledge-sharing platforms can empower beekeepers with the necessary skills and information to adopt modern practices and improve overall productivity. Government and non-governmental organizations can play a vital role in facilitating these initiatives.

Second, improving access to credit and financial support systems can assist beekeepers in acquiring modern equipment, expanding their apiaries, and investing in necessary infrastructure. This will help enhance production efficiency and promote sustainable growth in the sector.

Additionally, fostering collaboration and networking among beekeepers, as well as creating marketing channels for local honey products, can strengthen the market presence of Bouira's beekeeping industry. This can be achieved through the establishment of cooperative societies, participation in local and regional trade fairs, and the development of online platforms for honey sales.

By addressing the identified barriers and implementing the recommended measures, stakeholders can support the growth of beekeeping in Bouira, ensuring sustainable practices, increased productivity, and improved livelihoods for local beekeepers.

PART Ⅱ- GIS-Based Mapping of High-Potential Areas for Apiculture Development

Introduction

Beekeeping is an agricultural practice that encompasses various facets which are susceptible to influence from environmental and geographical factors. One critical aspect is the location of the apiary, which requires careful selection to guarantee the safety and optimal productivity of bee colonies. (Estoque & Murayama, 2010; Amiri, Shariff, & Arekhi, 2011; Triantomo, Widiatmaka, & Fuah, 2016) When choosing the ideal location for an apiary, several key factors need to be considered. Firstly, the surrounding environment and its floral resources greatly impact the availability and diversity of nectar and pollen for the bees. (Di Pasquale et al., 2013) The presence of abundant and diverse floral sources contributes to the nutritional well-being of the colonies, enabling them to produce high-quality honey, beeswax, and other bee-related products. Additionally, a diverse floral environment ensures a more balanced diet for the bees, supporting their overall health and vitality. (Di Pasquale et al., 2013) Secondly, environmental factors such as climate and weather patterns are crucial considerations in apiary location selection. Honeybees have specific temperature and humidity requirements for optimal functioning. (Hou et al., 2016) Selecting a location with a climate that aligns with the natural preferences of honeybees helps minimize stress on the colonies. It is important to consider factors such as temperature ranges, rainfall patterns, wind exposure, and microclimates when determining the suitability of a location for beekeeping. (Středa et al., 2011) Furthermore, the geographical characteristics of the chosen location can significantly impact the success of the apiary. Factors such as topography, elevation, and proximity to water sources play important roles. (Sarı et al., 2020) For instance, areas with gentle slopes can provide natural drainage and prevent waterlogging, which can be detrimental to the health of the colonies. Proximity to water bodies, such as rivers or lakes, ensures a readily available water source for the bees, supporting their hydration needs and honey production. (Galbraith et al., 2017) Overall, the careful selection of the apiary location is essential for beekeepers to ensure the safety and optimal productivity of their bee colonies.

MCDM or MCDA are widely recognized acronyms representing multiple-criteria decision-making and multiple-criteria decision analysis. MCDA focuses on the organization and resolution of decision and planning problems that involve multiple criteria. Its primary objective is to provide support to decision-makers who encounter such complex problems. (Majumder, 2015) MCDSs are a subset of MCDA, serving as the practical tools to implement MCDA methodologies effectively. In the context of site selection for apiary locations in beekeeping, by assessing and analyzing various factors it significantly impacts the success and productivity of bee colonies and offers several benefits and capabilities. MCDSs can incorporate climate data such as temperature, rainfall, humidity, and seasonal patterns. For example, areas with moderate temperatures and adequate rainfall throughout the year might be prioritized as they provide ideal conditions for bee colonies to thrive. MCDSs enable the evaluation of floral resources in potential apiary locations. Areas with a rich variety of flowering plants that offer a consistent source of food for bees are desirable for sustaining healthy colonies and maximizing honey production. MCDSs can assess land use patterns in potential apiary locations. Factors such as the proximity to agricultural areas, forests, or natural habitats can influence the availability and quality of forage resources for bees. Areas with minimal exposure to pesticides and other agricultural chemicals, as well as a diverse range of vegetation, are generally preferred to support the health and well-being of bee colonies. Adequate water sources are crucial for the survival and functioning of honeybee colonies. MCDSs can consider factors like proximity to rivers, lakes, or other water bodies, ensuring that apiary locations have convenient access to clean and reliable water sources. This helps meet the hydration needs of the bees and supports other essential hive activities. MCDSs assist beekeepers in evaluating the prevalence of pests, diseases, and parasites in different areas. Factors such as Varroa mite infestation rates, incidence of honeybee pathogens, or the presence of other harmful pests can be considered. Therefore, this method offers two significant outcomes. Firstly, it provides suitability scores to different locations based on weighted criteria, allowing beekeepers to quantitatively measure their relative suitability for beekeeping activities. These scores facilitate objective decision-making by enabling comparisons and rankings of locations. Secondly, it promotes objective decision-making in beekeeping by systematically considering multiple factors. It reduces reliance on subjective judgment and biases, providing a transparent and data-driven approach to decision-making. MCDMA approaches encompass a wide range of techniques, such as Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW), and Multi-Objective Optimization, among others. (Maris et al., 2008)

Saaty (1980) introduced the Analytical Hierarchy Process (AHP), a sophisticated decision-making framework that takes into account the relative importance of individual criteria. AHP is founded on three core principles: decomposition, comparative evaluation, and the synthesis of priorities. (Maris et al., 2008) Decomposition is the first principle, involving the structured breakdown of a complex decision problem into a hierarchical framework. At the pinnacle of this hierarchy is the overarching goal or objective one seeks to attain. Below this goal, a set of criteria is identified. These criteria serve as the pivotal factors that need consideration when evaluating various alternatives to achieve the primary goal. In essence, decomposition creates a structured hierarchy that organizes and categorizes the components of the decision problem. Comparative evaluation is the next step in AHP. It entails comparing these criteria and sub-criteria in pairs. Decision-makers assign relative weights or importance values to each criterion by systematically comparing them to one another. This comparison is often done using a scale, such as the Saaty scale, which quantifies the degree of importance. Decision-makers determine whether one criterion is significantly more important than another, slightly more important, or of equal importance. This pairwise comparison process is conducted for all criteria and sub-criteria. This process entails inputting the pairwise comparison matrix and obtaining the resultant relative weights. The Pairwise Comparison Matrix serves as a straightforward means to interpret the weightage of each criterion. This interpretation is achieved by assessing the preference scale between two distinct criteria, utilizing values ranging from 1 to 9, as exemplified in Table 1.

Table 1. Scale for AHP comparisons (Saaty, 1980)

Intensity of Importance	***Description***
1	Equal importance of both elements
3	Weak importance of one element over another
5	Essential or strong importance of one element over another
7	Demonstrated importance of one element over another
9	Absolute importance of one element over another
2,4,6,8	Intermediate values between two adjacent judgements

The final principle is the synthesis of priorities. In this step, AHP combines the results of all the pairwise comparisons to calculate the overall priorities or weights for each criterion and sub-criterion. This synthesis takes into account the judgments made during the comparative evaluation phase. The outcome is a structured prioritization of criteria, with higher priority attributed to those criteria that were deemed more important relative to others. These prioritized criteria are then used as the basis for making well-informed decisions. Alternatives are evaluated and ranked based on how effectively they perform in relation to the weighted criteria. These principles work in tandem to offer a systematic approach for understanding and addressing complex decision-making challenges. Additionally, AHP introduces the concept of a consistency rate, which assesses the coherence of overall weights and priorities. The AHP method calculates a consistency ratio, aiming for a value less than 0.1 to demonstrate the consistency of weights and priorities. (Sarı et al., 2020) Consequently, AHP proves to be an invaluable tool for unraveling intricate problems, it helps break down the problem into manageable parts, establish the relative importance of criteria, and ultimately enable the selection of the best alternative based on a systematic and transparent evaluation process.

AHP is particularly useful for MCDA in GIS, as it helps prioritize and weigh these criteria to identify the best locations for various purposes. This scoring process forms the basis for suitability mapping, which plays a crucial role in visualizing and analyzing the results obtained from the MCDS evaluation. Suitability mapping utilizes GIS (Geographic Information System) technology, which is a powerful tool for managing, analyzing, and visualizing spatial data. GIS enables beekeepers to integrate various geospatial datasets, including climate data, land cover types, topography, and other relevant information, into the mapping process. By employing GIS, suitability mapping creates maps that provide a spatial representation of the suitability scores assigned to different locations for beekeeping. These maps employ color coding or gradient shading to depict areas with optimal conditions, ranging from highly suitable (e.g., dark green) to less suitable (e.g., light green or yellow) or unsuitable (e.g., red). This visual representation allows beekeepers to quickly identify and prioritize areas that offer the greatest potential for successful beekeeping contributing to the sustainable growth and development of the apiculture sector by maximizing the productivity and well-being of honeybee colonies.

2. Materials and Methods

Research area

This study was performed within the administrative limits of the Bouira Province (fig 1), which was established as part of the administrative restructuring in 1974, it is located in northern Algeria, 35.94° N to 36.57° N of latitude, and 3.34° E to 4.67° E of longitude. The total surface area is 4,724 km^2. The average elevation of the province is approximately 500 m above sea level, but there are several notable peaks that rise much higher. The highest point in the province has an elevation of 2 308 meters. It is made up of twelve administrative districts (daïras) and forty-five municipalities and is bordered by The Djurdjura mountain range to the north, The provinces of M'sila and Médéa to the south, The provinces of Bejaia and Bordj Bou Arreridj to the east, The provinces of Boumerdes and Blida to the west. (DSA Bouira, 2020) Bouira Province is characterized by a hot and dry climate in the summer and cold and rainy weather in the winter. The average annual rainfall is 660 mm in the north and south regions. Temperatures range between 20 and 40 °C from May to September and between 2 and 12 °C from January to March.

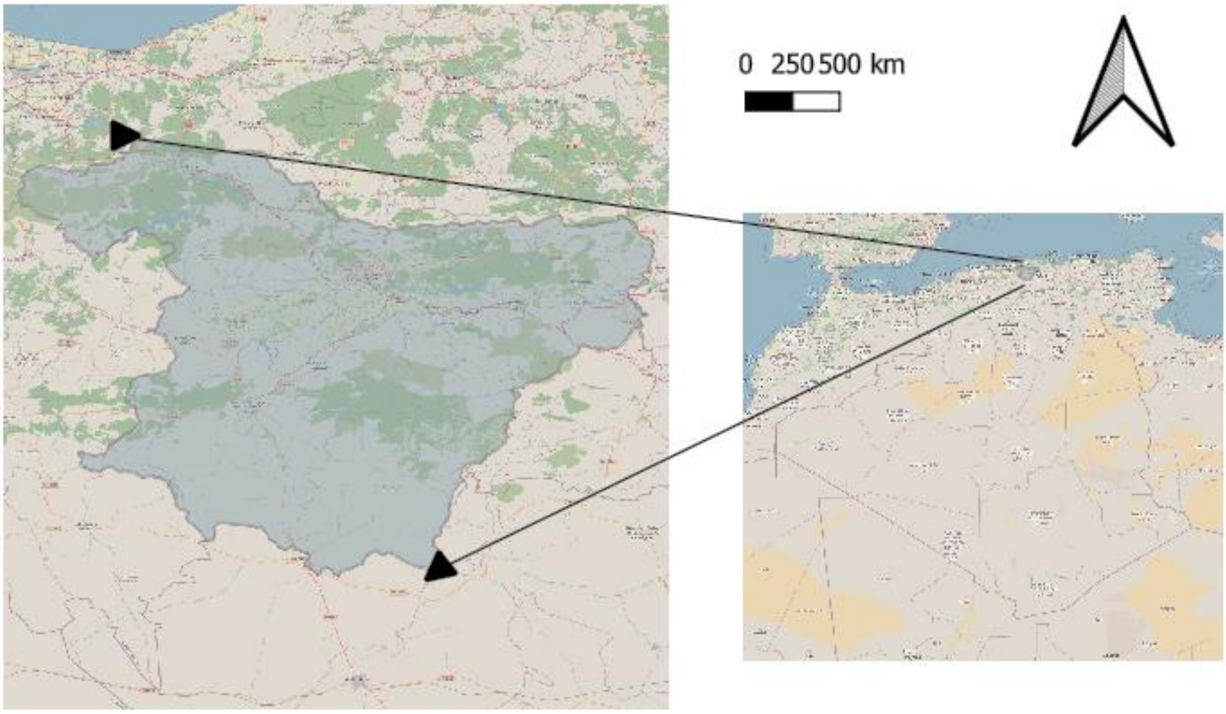

Figure 1. Map of the study area (wilaya of Bouira) built with QGIS.

Survey-Based Selection of Factors for Generating a Map of Suitable Locations for Beekeeping

In our work, a survey was conducted to select the factors to be considered in generating a map of suitable locations for beekeeping in different regions of the Bouira province. The survey was conducted using 38 questionnaires (Annex 1), where respondents were asked to mention the criteria, they believed were important for selecting suitable beekeeping sites. They were then instructed to rank these criteria in order of importance.

Several methods were employed as part of this survey, including interviews with beekeepers, consultations with experts in the field, and analysis of existing data. The survey aimed to gather insights and perspectives from experienced beekeepers and industry professionals to identify the key factors that contribute to successful beekeeping operations.

The findings from the survey provided valuable input for selecting the factors that would be included in the generation of the map. Factors such as climate conditions, floral resources, land use patterns, water availability, and pest and disease prevalence were among those considered based on the feedback and recommendations obtained from the survey participants.

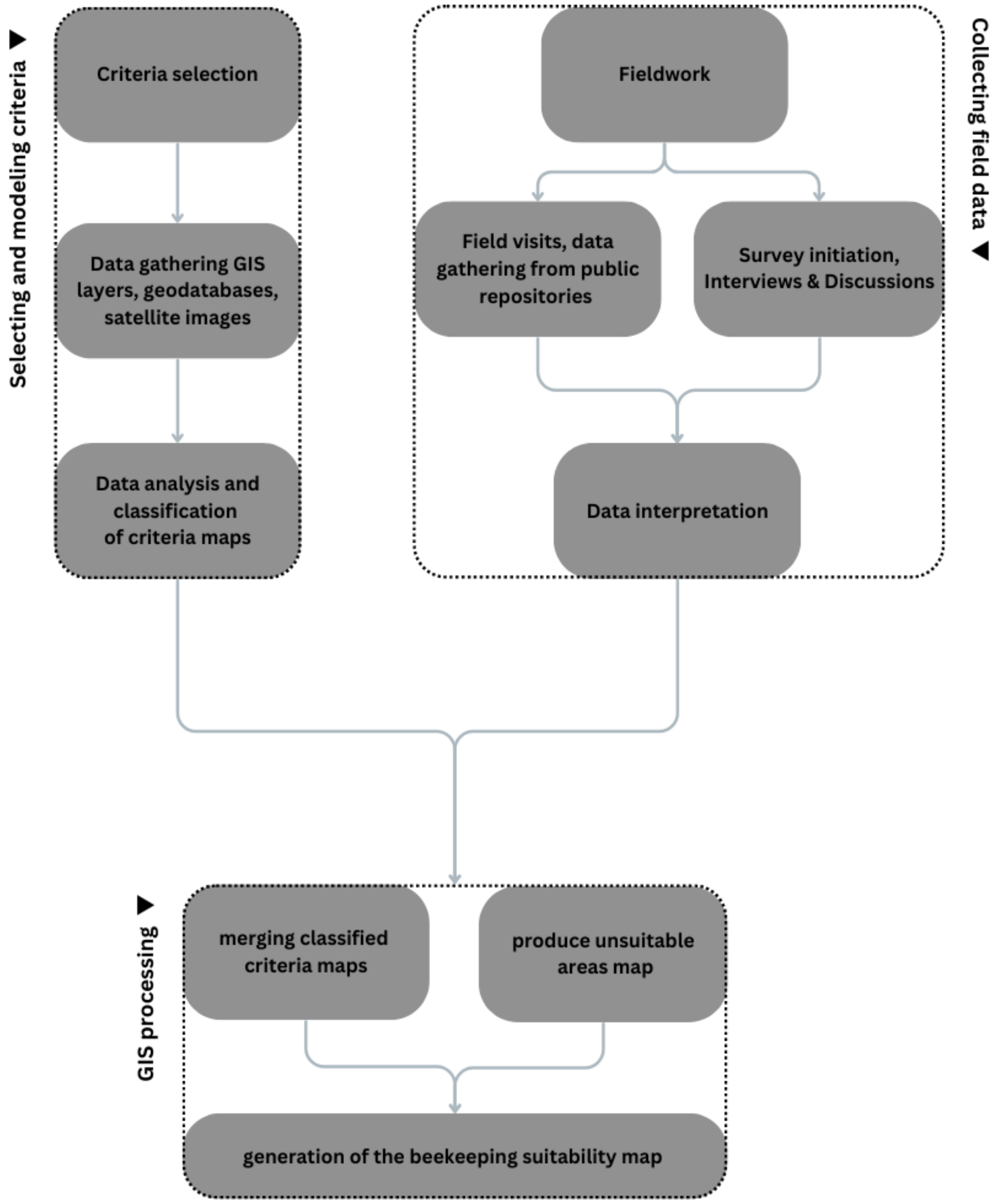

Figure 2. Proposed framework for assessment of suitable beekeeping sites in Bouira.

Presentation of Ain Aloui Apicultural Cooperative:

As part of our research, we completed a 30-day internship at the Ain Aloui Agricultural Cooperative, which is situated 15 kilometers west of Bouira. This cooperative is specifically focused on apiculture (beekeeping) activities.

Created in 2000 in accordance with Decree No. 96/459, which establishes the regulations for agricultural cooperatives, the CASSAB (Cooperative for Supply, Marketing, Transformation, and Storage of Beekeeping Products) has a set of objectives. These include the sourcing of beekeeping products and equipment, the marketing, processing, and storage of beekeeping products, and providing assistance to its member amateur beekeepers in various apicultural operations. These operations encompass hive visits, feeding, artificial swarming, honey harvesting, and scientific dissemination. We had the opportunity to visit several facilities that enabled the cooperative to fulfill the diverse demands for beekeeping products and other apiary-related resources, ensuring the satisfaction of its members' needs.

The CASSAB facilities:

There is a carpentry workshop with a production capacity of 10,000 empty beehives per year.

Figure 3. Carpentry Workshop

A beehive assembly workshop and its components.

Figure 4. Assembly Workshop.

Another workshop for embossing with a processing and transformation capacity of 200 quintals of wax per year.

Figure 5. Embossing Workshop.

A storage facility equipped with all the necessary equipment for honey extraction and maturation, with a capacity of 10 tons per year.

Figure 6. Honeybee Equipment Processing Room for Commercialization.

An exhibition room dedicated to showcasing and selling beekeeping equipment.

Figure 7. Beehive Placement Sites

There is an administrative block comprising of offices, as well as a meeting room that doubles as a training venue for beekeepers in the Bouira province.

Additionally, there are two plots of land spanning a total area of 3 hectares, dedicated to beekeeping activities and beekeeping operations.

Spatial Data Acquisition:

Recent studies on beekeeping suitability, Maris et al., (2008); Estoque & Murayama, (2010); Amiri & Shariff, (2012); Abou-Shaara et al., (2013); Camargo et al., (2014); Femandez et al., (2016) and Zoccali et al., (2017) used elevation, slope, aspect, distance to water, distance to roads, pollen-nectar resources, and flora criteria to generate beekeeping suitability maps.

In this research, a set of criteria was identified and chosen based on the earlier survey. These selected criteria, including annual rainfall, slope, proximity to roads and water sources, land use, altitude, and aspect, were utilized to create the beekeeping suitability map.

To generate data on slope, elevation, aspect, and water resources, we utilized SRTM (Shuttle Radar Topography Mission) images. These images are digital elevation models that explicitly represent physical elements such as the hydrographic network, mountain ridges, slope breaks, structural features, and their apparent or actual discharges. The SRTM images were obtained from the USGS (United States Geological Survey) Earth Explorer data portal (https://earthexplorer.usgs.gov/).

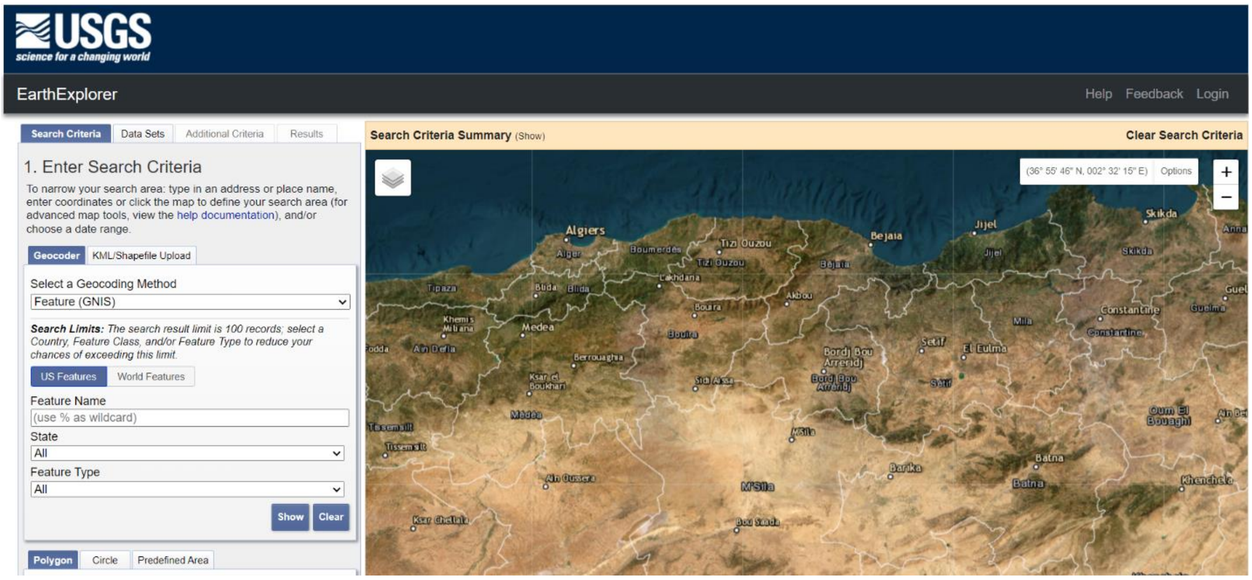

Figure 8. Earth Explorer Platform Interface.

Regarding the data related to land use and road networks, the information was generated from OpenStreetMap (OSM). OpenStreetMap is an open-source mapping platform that provides detailed and up-to-date geospatial data contributed by a global community of mappers. The land use and road network data for the study were obtained from OpenStreetMap, ensuring comprehensive and reliable information for the analysis.

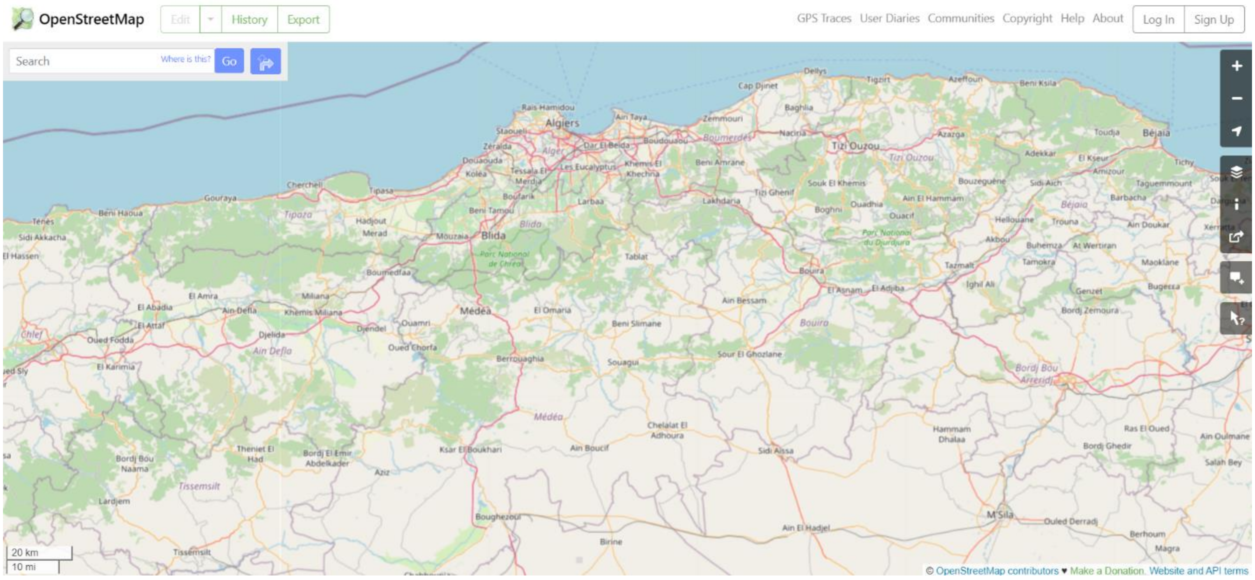

Figure 9. OSM Interface (OpenStreetMap Interface).

Use of (GIS) for Spatial Data Analysis and Processing:

To conduct a comprehensive analysis and multi-criteria assessment of suitable beekeeping locations, two GIS software tools were utilized in this study: QGIS and ArcGIS. The acquired raw data was imported into these GIS platforms for further processing and analysis.

Georeferencing of Data:

Prior to conducting accurate analysis and processing of both raster and vector data, it was necessary to perform georeferencing procedures. This involved aligning all the data to a common coordinate system. In our study, the data was georeferenced to the UTM Zone 31N coordinate system, with EPSG code 32631 (Figure 10), which is widely used for the geographical region covering Algeria.

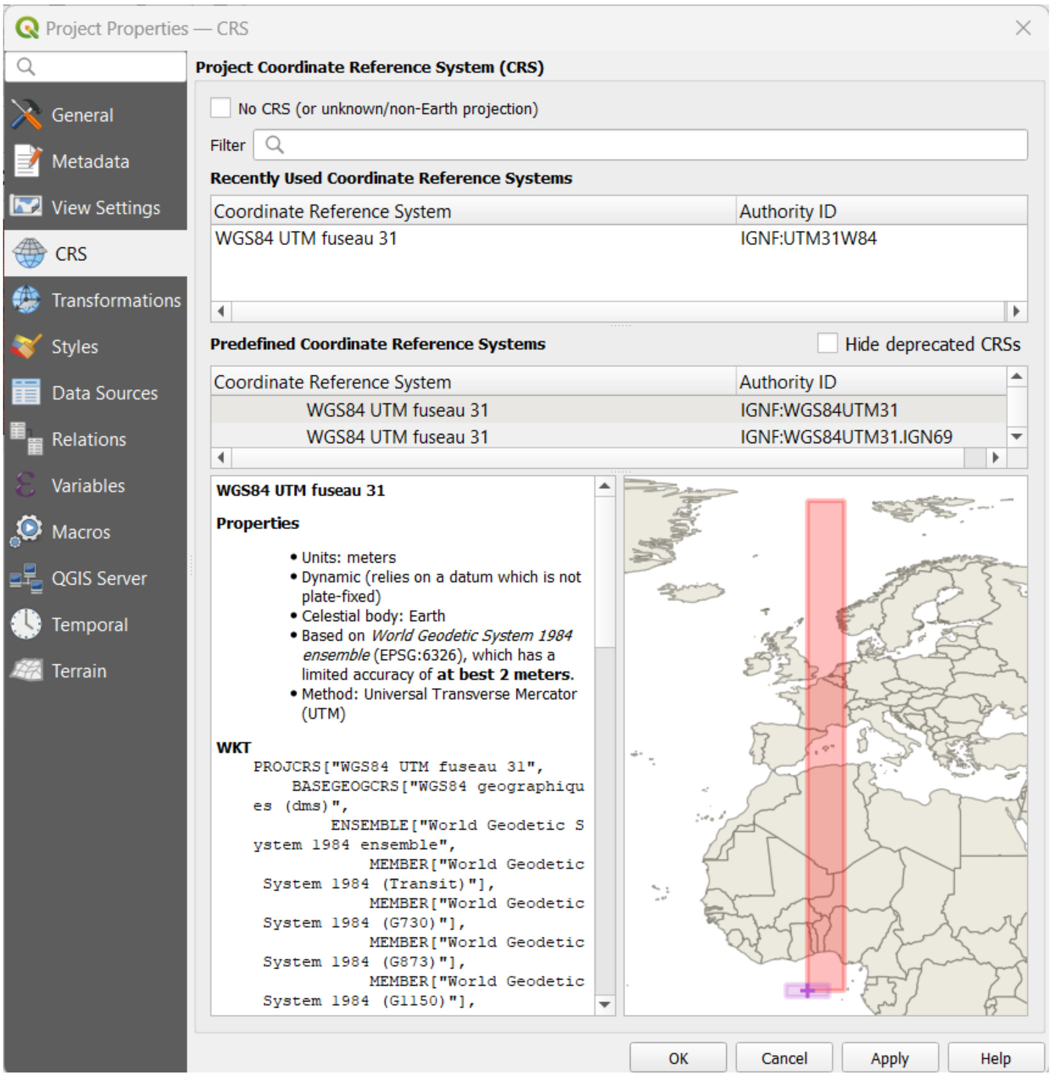

Figure 10. Reprojection Dialogue Table.

3. Results and discussions

Our map development involved a progression through three key phases: establishing a database, conducting spatial and multicriteria analysis, and undergoing a validation process. Subsequent to the survey and various analyses carried out using the previously mentioned methods, we obtained results that were translated into map formats to enhance the presentation of our work.

Multi-criteria Decision Making Using the Analytic Hierarchy Process: The survey included beekeeping experts and professionals as well as teachers from the SNVST faculty, encountered in the regional beekeeping cooperative and all around Bouira. This allowed us to identify a range of criteria that were selected for the study. AHP pairwise matrix was used to calculate the weights of criteria by using ranking values from 1 to 9, and a weight was assigned to each criterion (Table 2&3).

Table 2: *Ranking factors.*

Criteria	*Ranking*
Annual rainfall	**1**
Landcover	**2**
Distance from water	**3**
Slope	**4**
Distance from roads	**5**
Aspect	**6**
Altitude	**7**

Table 3: Decision Matrix.

	1	2	3	4	5	6	7
1	1	2	3	5	6	7	9
2	0.5	1	3	7	8	8	9
3	0.33	0.33	1	4	6	7	8
4	0.20	0.14	0.25	1	2	4	3
5	0.17	0.12	0.17	0.50	1	3	4
6	0.14	0.12	0.14	0.25	0.33	1	3
7	0.11	0.11	0.12	0.33	0.25	0.33	1

Table 4: *AHP weights.*

Criteria	*Weight*
Annual rainfall	**33,70%**
Landcover	**31,00%**
Distance from water	**18,00%**
Slope	**6,80%**
Distance from roads	**5,10%**
Aspect	**3,20%**
Altitude	**2,10%**

The resulting weights are based on the principal eigenvector of the decision matrix:

Principal eigen value = 7.606

Eigenvector solution: 7 iterations, delta = 2.9E-9

1 The map of suitable locations for beekeeping in relation to rainfall:

Rainfall plays a crucial role in beekeeping by directly affecting the availability of nectar, pollen, and water – all vital resources for bee colonies health and productivity.Additionally, it helps maintain natural water sources, reducing the need for bees to seek water from less suitable sources.

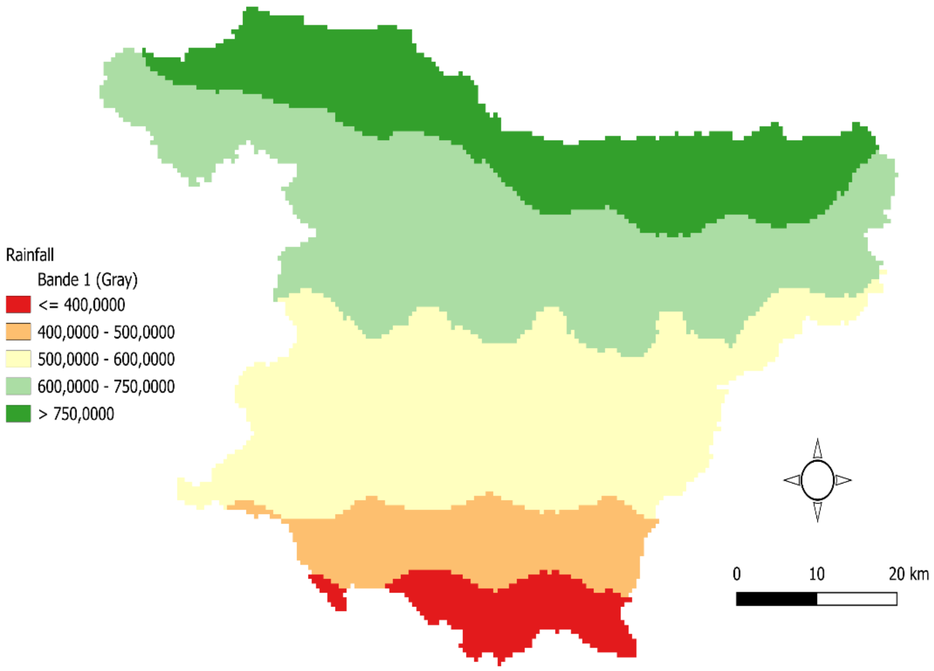

Figure 11. Annual rainfall Distribution Map of Bouira.

2 The map of suitable locations for beekeeping in relation to landcover:

The presence of flora is considered the second most crucial factor in determining appropriate locations for establishing beehives, as indicated by spatial experts. Emphasizing the significance of natural plant diversity, preference is given to forests and natural vegetation areas.

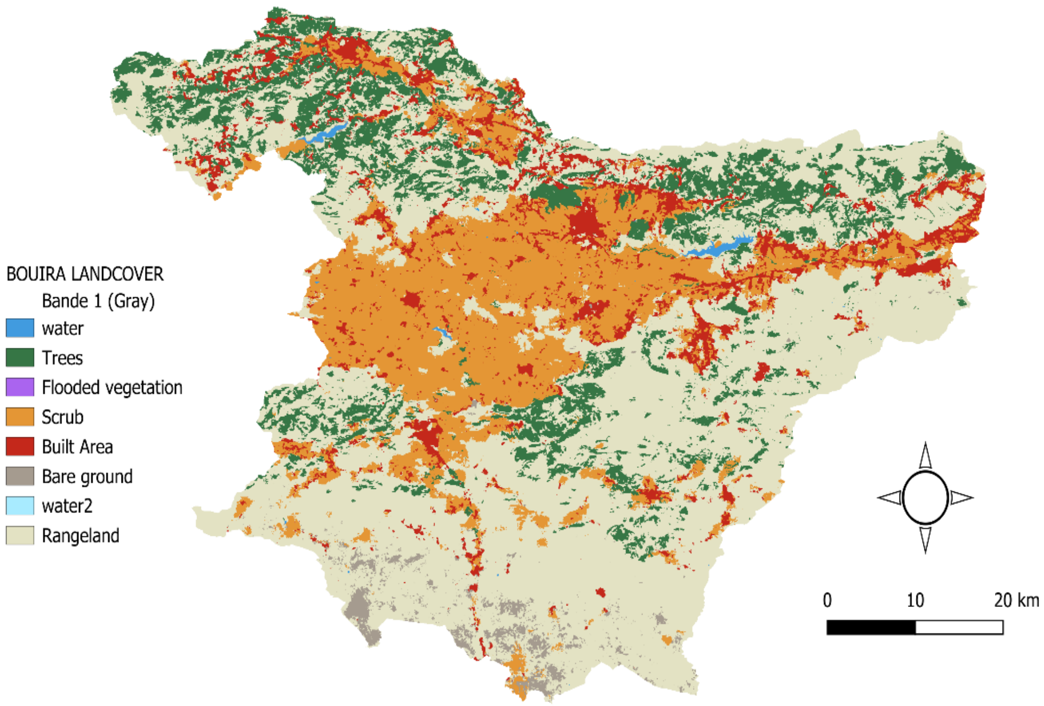

Figure 12. The Landcover map of the Bouira region.

3 The map of suitable locations for beekeeping in relation to water resources:

Water resources are crucial for bees to find an adequate water supply, which they use for colony cooling during hot periods and for diluting honey for their own consumption during extreme conditions. Bees collect water from various sources within a radius of 6 km. However, bodies of water are considered constraints because colonies cannot be placed directly on them. In our work, these constraints were not taken into consideration but will be addressed in future research.

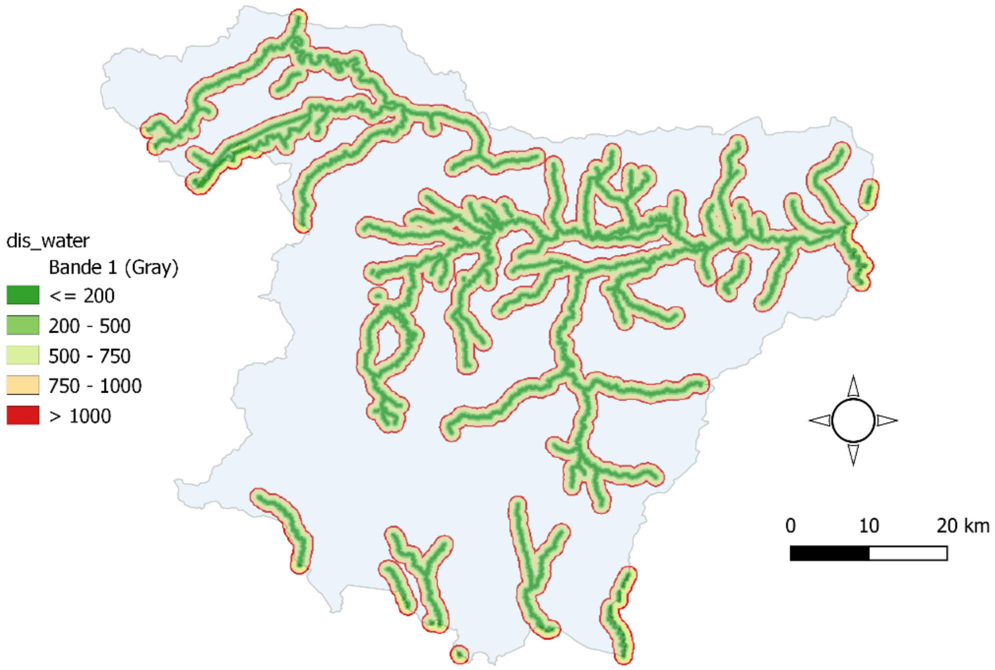

Figure 13. Hydrological Map of Rivers and Surface Water in Bouira Province.

4 The map of suitable locations for beekeeping in relation to slope:

The terrain slope plays a crucial role in selecting appropriate sites for beekeeping. It should facilitate logistical operations, drainage of rainwater, and the take-off of bees. On average, beehives are located on slopes with an inclination of 22.3°.

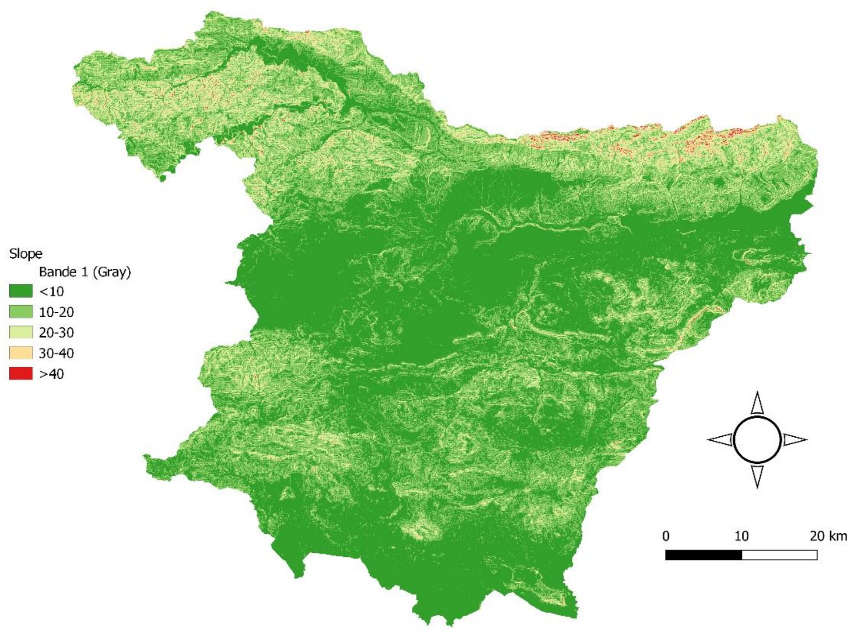

Figure 14. Slope map of the Bouira province.

5 The map of suitable locations for beekeeping in relation to the distance from roads:

The distance from roads plays a vital role in the evaluation and monitoring of beehives by beekeepers. It is worth noting that certain beekeepers choose to establish their hives away from urban areas and roadways in order to reduce greenhouse gas emissions, air and noise pollution, and exhaust fumes. Figure 15 showcases the road network in the Bouira region.

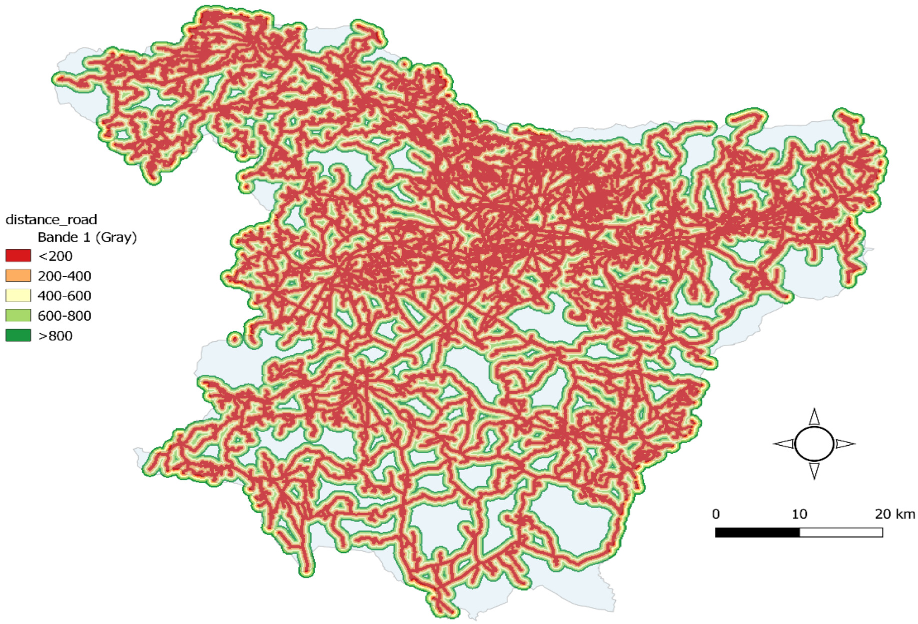

Figure 15. Road Network Map of Bouira Province.

6 The map of suitable locations for beekeeping in relation to aspect:

The aspect of a beehive refers to its positioning in relation to the sun and prevailing weather patterns. A well-considered aspect can significantly enhance the efficiency of beekeeping operations and the well-being of the bees themselves. The inclusion of the aspect criterion is crucial for assessing directional factors. When deciding on suitable locations for beehives and their orientation, beekeepers commonly favor positions facing South, South-East, or South-West. This orientation is chosen to maximize exposure to daylight, while simultaneously providing protection from the colder North winds.

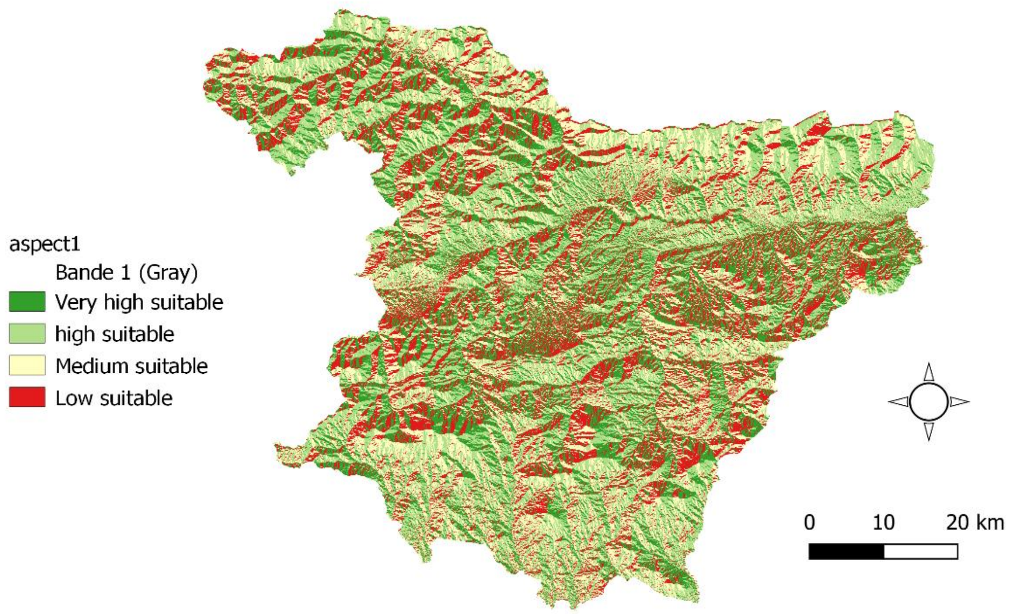

Figure 16. Aspect map of the Bouira province.

7 The map of suitable locations for beekeeping in relation to altitude:

Elevation, referring to the height above sea level, is a critical criterion that significantly influences the local flora and marks the seasonal commencement of beekeeping activities in our study area. Beyond an altitude of 1600 meters, we observe a decline in honey production yield and efficiency, primarily attributed to the challenging meteorological conditions and persistent winds. These higher altitudes pose distinct challenges for beekeepers, impacting both the quantity and quality of

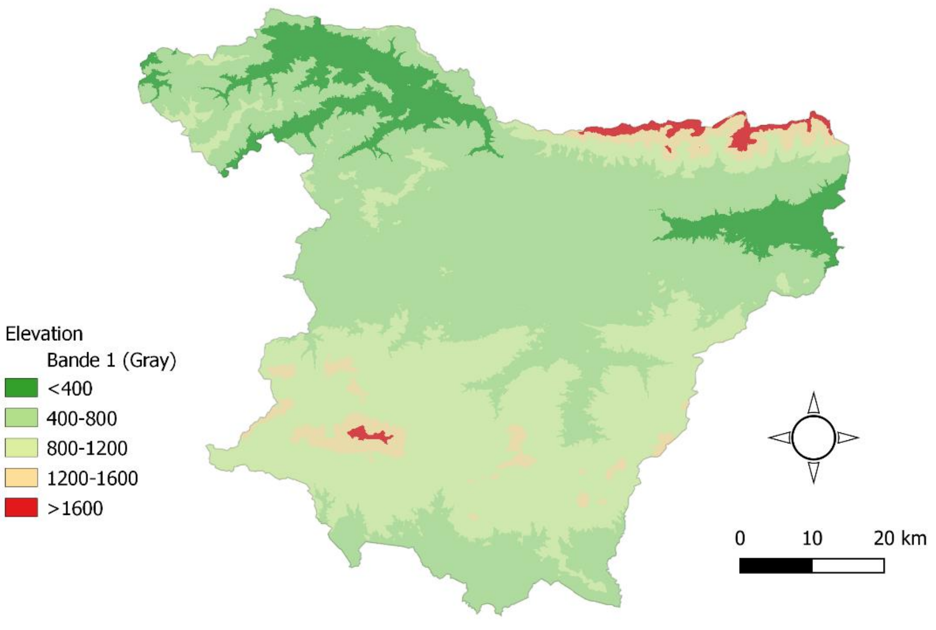

Figure 17. Elevation map of the Bouira province.

honey harvested. Consequently, understanding the interplay between elevation, weather patterns, and beekeeping practices is essential for optimizing honey production in our region.

Every criterion undergoes subsequent reclassification within ArcGIS software, based on pre-defined classes as depicted in Figure 18. These layers and their associated classes are then integrated with assigned weights to produce the suitability map. Each figure represents the suitability values, ranging from highly suitable (green) to unsuitable (red), relative to each criterion.

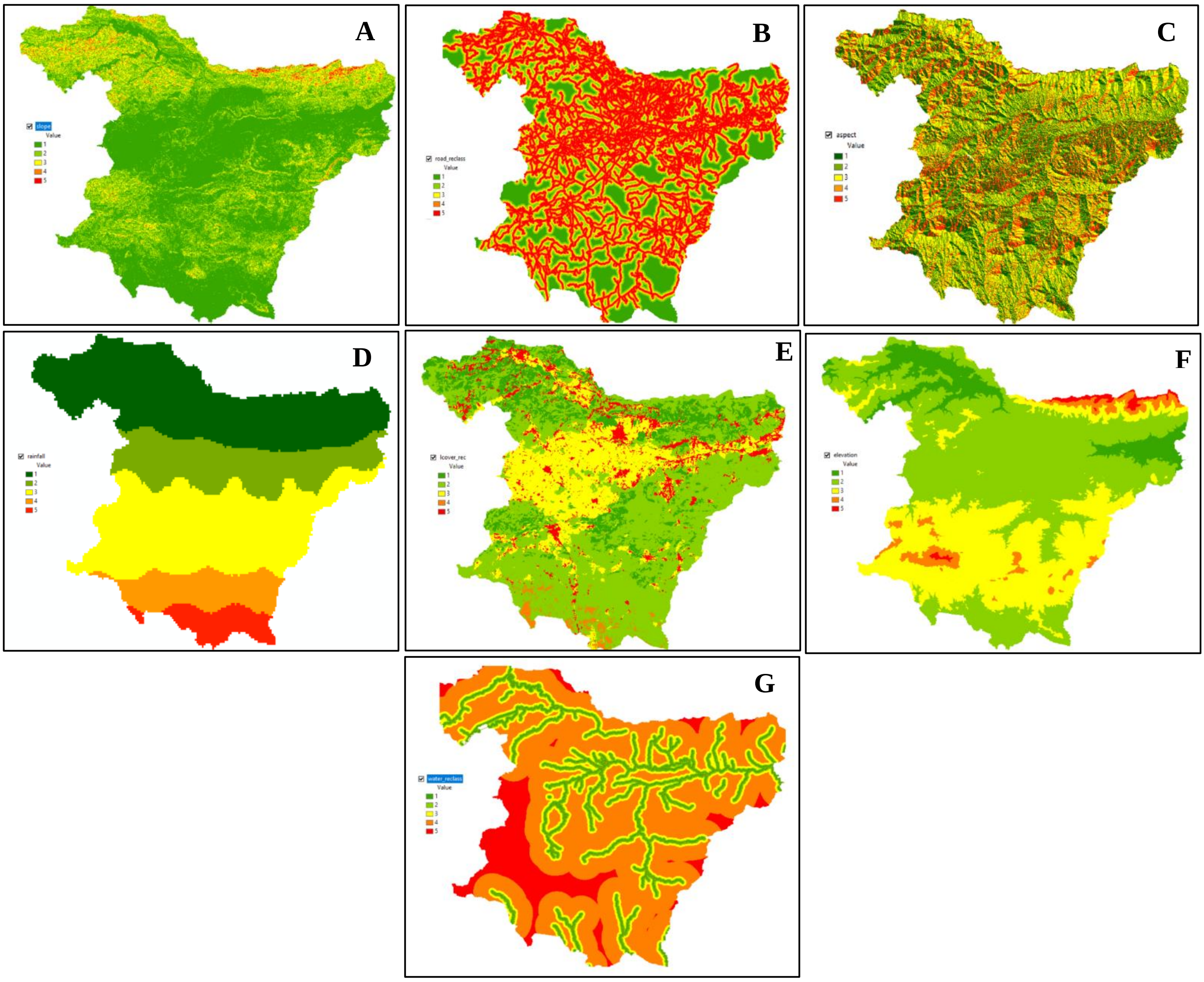

*Figure 18. redistributed maps of : **A** slope. **B** distance from roads. **C** aspect. **D** annual rainfall. **E** landcover. **F** elevation. **G** distance from water.*

8 Overlaying of Maps:

The overall suitability map was created by overlaying the five previously obtained maps. The final map of suitability levels is presented in Figure 19.

The beekeeping industry is experiencing significant growth due to the rising interest in hive-derived nutraceuticals, such as honey, propolis, pollen, and royal jelly.

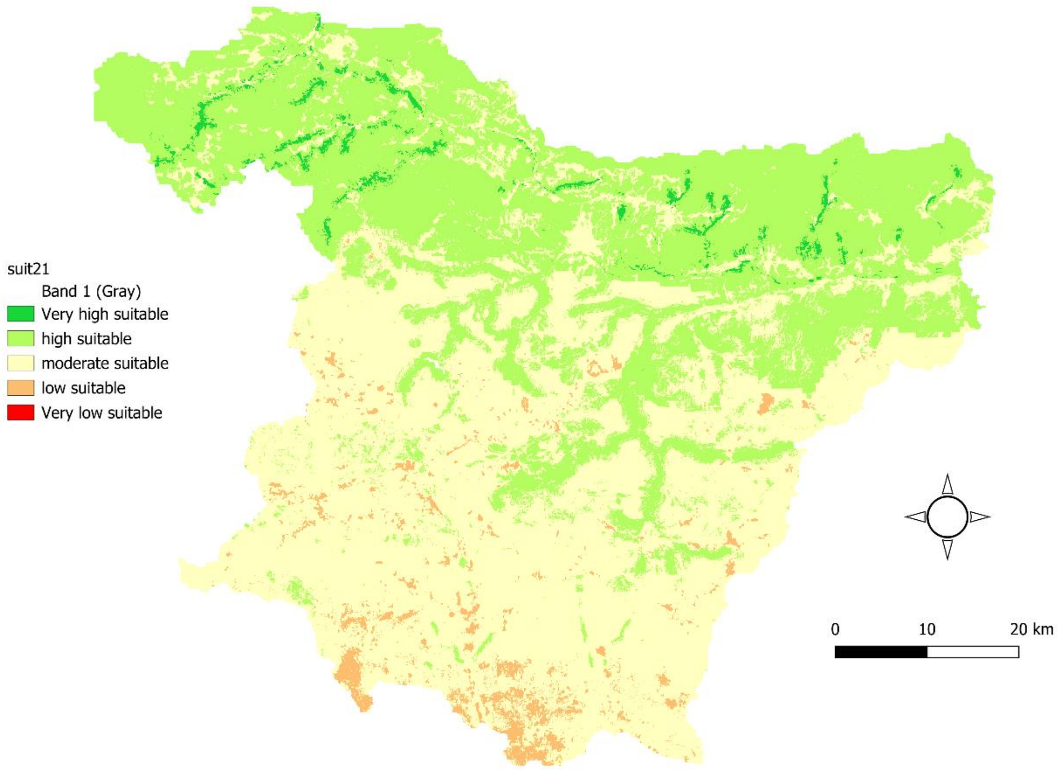

Figure 19. Beekeeping Site Suitability Map for the Bouira Region.

The map comprises five distinct classes, each representing a different level of suitability for beekeeping in the Bouira region:

a) Class 1, represented in red, indicates areas where beekeeping activity is not suitable, making up approximately 3.09% of the region. These areas pose significant limitations that render beekeeping impossible.

b) Class 2, represented as moderately unsuitable, encompasses areas where beekeeping is feasible but with severe limiting conditions. These conditions make it economically unviable, covering approximately 23.04% of the region.

c) Class 3, denoted as somewhat suitable, includes areas with fewer limiting conditions but lacking significant economic interest for beekeeping. This class accounts for approximately 48.86% of the region.

d) Class 4, classified as moderately suitable, represents areas where productivity values are still limiting, yet beekeeping activity is becoming economically feasible. These areas constitute approximately 24.97% of the region.

e) Class 5, depicted as highly suitable in green, signifies areas where beekeeping activity is economically viable and exhibits the highest levels of productivity. This class covers a minimal portion of the region, approximately 0.022%.

These distinct classes provide valuable insights into the varying degrees of suitability for beekeeping throughout the Bouira region.

Based on the final map, the optimal locations for placing beehives in Bouira province are primarily concentrated in three regions: the northeastern region (e.g., Hizer...), the northwestern region (e.g., Ain Bessam...), and the central area (e.g., Ain Laloui...). These areas showcase the highest suitability for beekeeping activities, as indicated by the comprehensive evaluation conducted.

Areas where beekeeping is not possible accounted for 3.09% of the total area. On the other hand, economically feasible areas for beekeeping, such as cultivated lands and forested areas, represented 48.86% of the regional surface. Transition zones between these categories accounted for 24.97% of the area.

This study has highlighted the significance of Bouira as a region with great potential for beekeeping, as it has been identified that approximately 0.022% of the total area exhibits high to very high suitability for honey production. This finding emphasizes the presence of specific areas within Bouira that offer favorable conditions for successful beekeeping and the production of high-quality honey.

Conclusion

The determination of bee requirements and the establishment of optimal intervals for decision-making based on alternative beekeeping sites are complex yet crucial processes. Despite certain limitations encountered in this study, efforts were made to enhance the accuracy of the project by incorporating additional factors such as weather conditions, solar radiation, aspect, slope, elevation, proximity to water resources, and distance from roads.

The integration of Geographic Information System (GIS) technology with multicriteria analysis methods provides substantial potential for spatial decision support in the context of beekeeping planning. By considering all relevant parameters, this approach has enabled the identification of suitable locations for beekeeping in the Bouira province.

The primary objective of this research was to identify alternative areas that exhibit favorable conditions for beekeeping, utilizing the combined methodologies of GIS and Analytic Hierarchy Process (AHP). The findings indicate that the most suitable locations for establishing beehives in the Bouira province are predominantly concentrated in the northeastern, northwestern, and central regions. Notably, areas where beekeeping is deemed infeasible constitute a modest 3.09% of the total surface area.

Furthermore, the study underscores the significant potential of Bouira as an important region for beekeeping activities, as approximately 0.022% of the area exhibits high or extremely high suitability for honey production. These results contribute valuable insights.

General Conclusion
And recommendations

Conclusion

In conclusion, this thesis focused on two key aspects of the apicultural sector in Bouira. The first part examined the beekeeping production systems employed by local beekeepers. The findings revealed that modern hive systems are predominantly utilized, reflecting an awareness of the importance of hive protection against pests and diseases. The implementation of appropriate measures such as the use of medicines and vaccines demonstrated a commitment to maintaining healthy colonies and ensuring sustainable beekeeping practices.

The second part of the thesis involved the development of a GIS-based mapping framework to identify high-potential areas for apiculture development in Bouira. Through the integration of various criteria including land use, climate, water resources, solar radiation, road proximity, slope, elevation and aspect, a comprehensive map was created. This map highlights the regions that are most suitable for beekeeping activities, offering valuable guidance for prospective beekeepers, policymakers, and stakeholders involved in the development and management of the apicultural sector.

By combining the insights gained from the examination of beekeeping production systems and the GIS-based mapping analysis, this thesis has contributed to a deeper understanding of the apicultural landscape in Bouira. The thesis findings provide valuable information for beekeepers to enhance their practices and make informed decisions regarding hive management and disease control. Moreover, policymakers and stakeholders can utilize the final map to strategically allocate resources and support the sustainable growth and development of the apicultural sector in Bouira.

Overall, this thesis serves as a valuable resource for the apicultural community in Bouira, providing insights into beekeeping production systems and offering a comprehensive mapping framework to identify suitable regions for apiculture development. It is hoped that the findings and recommendations presented in this thesis will contribute to the promotion of a thriving and sustainable apicultural sector in Bouira, fostering economic growth, environmental preservation, and improved livelihoods for beekeepers and related stakeholders.

In light of the comprehensive analysis conducted in this thesis on the beekeeping production systems and the suitability mapping for apiculture in Bouira, it is evident that there are opportunities for further development and improvement in the apicultural sector. The findings and conclusions presented in this study provide valuable insights into the current state of beekeeping practices in Bouira, as well as the identification of regions with high potential for apiculture development.

Building upon the conclusions drawn from this research, this section outlines several key recommendations aimed at enhancing the practices and sustainability of the apicultural sector in Bouira.

Further Research on Beekeeping Production Systems: In order to deepen the understanding of beekeeping production systems in Bouira, it is recommended to conduct further research on specific aspects such as hive management techniques, honey extraction methods, and the impact of different hive designs on honey production and bee health. This research will provide more detailed insights and practical recommendations for beekeepers in the region, contributing to the enhancement of their practices.

Long-term Monitoring of Beekeeping Systems: To ensure the long-term sustainability of beekeeping practices in Bouira, it is advisable to establish a comprehensive and systematic monitoring program. This program should encompass key parameters including honey yields, colony health, and the prevalence of pests and diseases. By collecting and analyzing data over an extended period, it will be possible to assess the effectiveness of current practices and identify areas where improvements can be made to optimize beekeeping outcomes.

Educational and Training Programs: It is recommended to develop educational and training programs tailored specifically for beekeepers in Bouira. These programs should focus on essential topics such as hive management, disease prevention, sustainable beekeeping practices, and the utilization of modern technologies in beekeeping. By providing beekeepers with access to comprehensive knowledge and training, they can enhance their skills, improve hive productivity, and contribute to the overall development and advancement of the apicultural sector in Bouira.

Collaboration and Knowledge Exchange: Encouraging collaboration and facilitating knowledge exchange among beekeepers, researchers, policymakers, and stakeholders in Bouira is crucial for the growth and progress of the apicultural industry. This can be achieved by organizing workshops, conferences, and online forums that provide platforms for sharing experiences, best practices, and innovative ideas. Fostering a supportive community of knowledge exchange will not only enhance the understanding of beekeeping practices but also foster a collaborative environment that promotes the sustainable growth and advancement of beekeeping in the region.

Policy Development and Support: Engaging with policymakers and relevant authorities is vital in developing policies that support the apicultural sector in Bouira. It is recommended to advocate for the allocation of resources, financial incentives, and the establishment of regulatory frameworks that promote sustainable beekeeping practices, environmental conservation, and the development of markets for bee products. Collaborating with government agencies and organizations will ensure the effective implementation and enforcement of these policies, further strengthening the apicultural sector.

Public Awareness and Consumer Education: Raising public awareness about the importance of bees and the significant role of beekeeping in Bouira is essential. This can be accomplished through various outreach programs, workshops, and educational campaigns that target the general public. The objective is to educate the community about the benefits of beekeeping, honey production, and the crucial role of bees in pollination services. By fostering appreciation for bees and their products, a supportive consumer base can be cultivated, which will contribute to the sustainability and growth of the local apicultural sector.

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Annexes

Questionnaire on beekeeping systems and management

Questionnaire on beekeeping systems and management

This questionnaire is part of the preparation of a master's thesis on

Beekeeping Suitability Mapping: A Multi-Criteria Decision Support System Approach

@gmail.com Changer de compte

Non partagé

what is your name?

Votre réponse

what is your gender?

- [ ] male
- [ ] Female

how old are you?

Votre réponse

What is your educational background?

Votre réponse

1.What is your experience with beekeeping?

- [ ] Novice
- [ ] Intermediate
- [ ] Expert
- [ ] Autre : ____________

2.How many hives do you currently manage?

- [ ] 1-10
- [ ] 11-50
- [ ] 51 or more
- [ ] Autre : ____________

3.How often do you feed your hives?

- [ ] Daily
- [ ] Weekly
- [ ] Monthly
- [ ] Rarely
- [ ] fortnightly
- [ ] Per season
- [ ] Never

Site suitability

What factors do you consider when selecting a site for your hives?

Votre réponse

How important is each of the following factors in determining the suitability of a site for your hives? (Rank on a scale of 1-4, with 1 being the most important) *

	1	2	3	4
Climate	○	○	○	○
Vegetation	○	○	○	○
Pest and disease pressure	○	○	○	○
Human impact	○	○	○	○

Do you use any tools or resources to determine the suitability of a site for your hives?

- ☐ yes
- ☐ no
- ☐ if yes, please specify:
- ☐ Autre :

Have you noticed any changes in the suitability of your current beekeeping site over time?

- [ ] yes
- [ ] no
- [ ] if yes, please specify:
- [ ] Autre : ______

Do you think that the availability of resources, such as water and flowering plants, affects the suitability of a site for beekeeping?

- [ ] Strongly agree
- [ ] Agree
- [ ] Neutral
- [ ] Disagree
- [ ] Strongly disagree

How important is access to quality and affordable beekeeping equipment and supplies in determining the suitability of a site for beekeeping?

- [ ] Very important
- [ ] Somewhat important
- [ ] Neutral
- [ ] Not very important
- [ ] Not important at all

Do you think that the presence of other beekeepers in the area affects the suitability of a site for beekeeping?

- [ ] Strongly agree
- [ ] Agree
- [ ] Neutral
- [ ] Disagree
- [ ] Strongly Disagree

How important is access to beekeeping education and training opportunities in determining the suitability of a site for beekeeping?

- [ ] Very important
- [ ] Somewhat important
- [ ] Neutral
- [ ] Not very important
- [ ] Not important at all

Have you ever participated in a beekeeping cooperative or association?

- [ ] Yes
- [ ] No

What additional information would you find useful in determining the suitability of a site for beekeeping?

Votre réponse

beehive health assessment and pest control

Have you encountered any challenges in your current beekeeping operations? (check all that apply)

- [ ] Climate variability
- [ ] Pest and disease pressure
- [ ] Human impact (such as urbanization, pollution, or pesticide use)
- [ ] Lack of suitable vegetation
- [ ] Other (please specify)
- [ ] Autre : ______

How do you assess the health of your hives?

- [ ] Visual inspections
- [ ] Monitoring of honey production
- [ ] Monitoring of bee activity levels
- [ ] Other (please specify)
- [ ] Autre : ______

Have you noticed any changes in the health of your hives due to changes in the availability of resources (such as water and flowering plants)?

- [ ] yes
- [ ] no
- [ ] If yes, please describe:
- [ ] Autre : ______

Have you noticed any changes in the health of your hives due to changes in the local climate (such as temperature, precipitation, or humidity)?

- [ ] Yes
- [ ] No
- [ ] If yes, please describe:
- [ ] Autre : ____________

Have you ever had to treat your hives for pests or diseases?

- [ ] Yes
- [ ] No

How do you protect your hives from pests and diseases? (check all that apply)

- [ ] Chemical treatments
- [ ] Physical barriers
- [ ] Monitoring and early detection
- [ ] Other (please specify)
- [ ] Autre : ____________

Have you ever experienced colony losses in your hives?

- [ ] Yes
- [ ] No

How many hives have have you lost?

Votre réponse

What do you believe were the causes of the colony losses? (check all that apply)

- [ ] Pests and diseases
- [ ] Lack of resources (such as food and water)
- [ ] Climate change
- [ ] Autre :

How have colony losses affected your beekeeping operations and profitability?

- [ ] important impact
- [ ] a certain impact
- [ ] Minimal impact
- [ ] No impact

What measures do you take to prevent colony losses in your hives? (check all that apply

- [ ] Regular monitoring of hive health
- [ ] Providing adequate food and water
- [ ] Protecting hives from pests and diseases
- [ ] Other (please specify)
- [ ] Autre :

transhumance

Have you ever relocated your hives due to suitability concerns?

- [ ] Yes
- [ ] No

Have you ever practiced transhumance with your hives?

- [ ] Yes
- [ ] No

If yes, how often do you move your hives?

- [ ] Annually
- [ ] Every other year
- [ ] Occasionally as needed
- [ ] Autre : ______

How does transhumance affect your honey production?

- [ ] Significant increase
- [ ] Some increase
- [ ] No change
- [ ] Some decrease
- [ ] Significant decrease

How does transhumance affect the health of your hives?

- [ ] Significant improvement
- [ ] Some improvement
- [ ] No change
- [ ] Some decline
- [ ] Significant decline

What are the biggest challenges you face when practicing transhumance? (check all that apply)

- [ ] Logistics of moving the hives
- [ ] Finding suitable locations
- [ ] Protecting hives from pests and diseases
- [ ] Cost of transportation
- [ ] Other (please specify)
- [ ] Autre : ____________

Which areas of the Bouira region do you think would be the most suitable for beekeeping?

Votre réponse ____________

The survey analysis code for RStudio:

```
# set the working file directory
setwd("C:/Users/Slash/Desktop/Article/apis/analysis")

# Install and load the psych package
install.packages("psych")
library(psych)

install.packages("FactoMineR")
library(FactoMineR)

install.packages("missMDA")
library(missMDA)

install.packages("missForest")
```

```
library(missForest)

#Import the data
library(readxl)
data <- read_excel("C:/Users/Slash/Desktop/Article/apis/data.xlsx")
View(data)
str(data)
data$Gender
data$`tools used to determine the suitability site`
table(data$Experience)
table(data$`challenges in your current operations`)
region <- table(data$Region)
prop.table(region)
describe(data$Age)
summary(data)

#Descriptive analysis for numerical variables
numerical_variables <- c("Age", "hives number")
numerical_stats <- summary(data[, numerical_variables])
cat("Descriptive Statistics for Numerical Variables:\n")
print(numerical_stats)

# Frequency distribution for categorical variables
categorical_variables <- c("Gender","Educational Level", "Experience", "hives number", "hives managed", "hives feed", "factors to select a site", "tools used to ss", "changes in the ss", "water & flowering plants 4 ss", "Equipment & supplies 4 ss", "competition & suitability", "Beekeeping education & suitability", "coop participation", "additional info ss", "challenges in your current operations", "health assesement", "resources availability on HH", "changes in the local climate on HH",
    "hives treatment", "hives protection", "colony losses", "CL profitability", "measures to prevent CL", "moving hives due to suitability concerns", "T.H",
    "frequency of T.H", "T.H and honey production", "T.H and health", "challenges during T.H", "climate 4 suitability", "vegetation 4 suitability", "PDP 4 suitability", "Human imp. 4 suitability", "colony losses cause", "n hives lost", "most suitable areas in Bouira"
)
categorical_freq <- sapply(data[, categorical_variables], table)
cat("\nFrequency Distribution for Categorical Variables:\n")
print(categorical_freq)

# Plotting the results

# Demographic analysis

# Age distribution
ggplot(data, aes(x = Age)) +
  geom_histogram(binwidth = 5, fill = "skyblue", color = "black") +
  labs(title = "Age Distribution", x = "Age", y = "Frequency")
```

```
# Age distribution
ggplot(data, aes(x = Age)) +
  geom_histogram(aes(y = ..count.. / sum(..count..) * 100), binwidth = 5, fill =
"skyblue", color = "black") +
  labs(title = "Age Distribution", x = "Age", y = "Percentage")

# Gender distribution
ggplot(data, aes(x = Gender, fill = Gender)) +
  geom_bar() +
  labs(title = "Gender Distribution", x = "Gender", y = "Count") +
  scale_fill_manual(values = c("male" = "lightblue", "female" = "pink"))

# Gender distribution
ggplot(data, aes(x = Gender, fill = Gender)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Gender Distribution", x = "Gender", y = "Percentage") +
  scale_fill_manual(values = c("male" = "lightblue", "female" = "pink"))

# Calculate gender frequencies
gender_freq <- table(data$Gender)

# Create a pie chart for gender distribution
gender_pie <- ggplot(data, aes(x = "", fill = Gender)) +
  geom_bar(width = 1) +
  coord_polar("y") +
  labs(title = "Gender Distribution", fill = "Gender") +
  theme_void() +
  theme(plot.title = element_text(hjust = 0.5)) +
  guides(fill = guide_legend(title = "Gender"))

# Display the pie chart
print(gender_pie)

# Define the order of educational levels
edu_levels_order <- c("university", "high school", "Middle school", "Elementary
School", "unschooled")

# Create a bar chart for educational level distribution
educational_level_chart <- ggplot(data, aes(x = reorder(`Educational Level`, -
as.numeric(factor(`Educational Level`, levels = edu_levels_order))), fill = `Educational
Level`)) +
  geom_bar() +
  labs(title = "Educational Level Distribution", x = "Educational Level", y = "Count")
+
  scale_fill_brewer(palette = "Set3") +
  scale_x_discrete(labels = function(x) gsub("_", " ", x))
```

```
# Display the bar chart
print(educational_level_chart)

# Educational level distribution
ggplot(data, aes(x = `Educational Level`, fill = `Educational Level`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Educational Level Distribution", x = "Educational Level", y =
"Percentage") +
  scale_fill_brewer(palette = "Set3")

# Participation in a beekeeping cooperative or association
ggplot(data, aes(x = `participation cooperative or association`, fill = `participation
cooperative or association`)) +
  geom_bar() +
  labs(title = "Participation in Beekeeping Cooperative or Association", x =
"Participation", y = "Count") +
  scale_fill_manual(values = c("no" = "gray", "yes" = "green"))

# Participation in a beekeeping cooperative or association
ggplot(data, aes(x = `participation cooperative or association`, fill = `participation
cooperative or association`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Participation in Beekeeping Cooperative or Association", x =
"Participation", y = "Percentage") +
  scale_fill_manual(values = c("no" = "lightgray", "yes" = "green"))

# Experience distribution
ggplot(data, aes(x = `Experience`, fill = `Experience`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Experience Distribution", x = "Experience", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# Hive losses distribution
ggplot(data, aes(x = `colony losses`, fill = `colony losses`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Hive Losses Distribution", x = "Colony Losses", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# Colony losses distribution
ggplot(data, aes(x = `colony losses`, fill = `colony losses`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Colony Losses Distribution", x = "Colony Losses", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# hives feed distribution
ggplot(data, aes(x = `hives feed`, fill = `hives feed`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "hives feed Distribution", x = "hives feed", y = "Percentage") +
```

```
  scale_fill_brewer(palette = "Set3")

# factors to select a site distribution
ggplot(data, aes(x = `factors to select a site`, fill = `factors to select a site`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "factors to select a site Distribution", x = "factors to select a site", y =
"Percentage") +
  scale_fill_brewer(palette = "Set3")

# tools used to determine the suitability site distribution
ggplot(data, aes(x = `tools used to determine the suitability site`, fill = `tools used to
determine the suitability site`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "tools used to determine the suitability site Distribution", x = "tools used
to determine the suitability site", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# changes in the suitability of current beekeeping site distribution
ggplot(data, aes(x = `changes in the suitability of current beekeeping site`, fill =
`changes in the suitability of current beekeeping site`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "changes in the suitability of current beekeeping site", x = "changes in the
suitability of current beekeeping site", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# water and flowering plants for suitability distribution
ggplot(data, aes(x = `water and flowering plants for suitability`, fill = `water and
flowering plants for suitability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "water and flowering plants for suitability", x = "water and flowering
plants for suitability", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# Equipment and supplies for suitability distribution
ggplot(data, aes(x = `Equipment and supplies for suitability`, fill = `Equipment and
supplies for suitability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Equipment and supplies for suitability distribution", x = "Equipment and
supplies for suitability", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# competition and suitability distribution
ggplot(data, aes(x = `competition and suitability`, fill = `competition and suitability`))
+
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "competition and suitability distribution", x = "competition and
suitability", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")
```

```
# Beekeeping education and suitability distribution
ggplot(data, aes(x = `Beekeeping education and suitability`, fill = `Beekeeping education and suitability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) + scale_fill_manual(values)+
  labs(title = "Beekeeping education and suitability distribution", x = "Beekeeping education and suitability", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# participation cooperative or association distribution
ggplot(data, aes(x = `participation cooperative or association`, fill = `participation cooperative or association`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "participation cooperative or association distribution", x = "participation cooperative or association", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# participation cooperative or association distribution
ggplot(data, aes(x = `participation cooperative or association`, fill = `participation cooperative or association`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "participation cooperative or association distribution", x = "participation cooperative or association", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# additional information useful in determining the suitable site distribution
ggplot(data, aes(x = `additional information useful in determining the suitable site`, fill = `additional information useful in determining the suitable site`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "additional information useful in determining the suitable site distribution", x = "participation cooperative or association", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# challenges in your current operations distribution
ggplot(data, aes(x = `challenges in your current operations`, fill = `challenges in your current operations`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "additional information useful in determining the suitable site distribution", x = "challenges in your current operations", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# assessment  the health distribution
ggplot(data, aes(x = `assessment  the health`, fill = `challenges in your current operations`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "assessment  the health distribution", x = "assessment  the health", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")
```

```
# changes in the hives health and resources availability distribution
ggplot(data, aes(x = `changes in the hives health and resources availability`, fill =
`changes in the hives health and resources availability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "changes in the hives health and resources availability", x = "changes in
the hives health and resources availability", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# changes in the health of your hives due to changes in the local climate distribution
ggplot(data, aes(x = `changes in the health of your hives due to changes in the local
climate`, fill = `changes in the hives health and resources availability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "changes in the health of your hives due to changes in the local climate",
x = "changes in the health of your hives due to changes in the local climate", y =
"Percentage") +
  scale_fill_brewer(palette = "Set3")

# hives treatment  for pests or diseases distribution
ggplot(data, aes(x = `hives treatment  for pests or diseases`, fill = `hives treatment  for
pests or diseases`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "hives treatment  for pests or diseases", x = "hives treatment  for pests or
diseases", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# hives protection from pests and diseases distribution
ggplot(data, aes(x = `hives protection from pests and diseases`, fill = `hives protection
from pests and diseases`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "hives protection from pests and diseases distribution", x = "hives
protection from pests and diseases", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# hives protection from pests and diseases distribution
ggplot(data, aes(x = `hives protection from pests and diseases`, fill = `hives protection
from pests and diseases`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "hives protection from pests and diseases distribution", x = "hives
protection from pests and diseases", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# colony losses  with operations and profitability distribution
ggplot(data, aes(x = `colony losses  with operations and profitability`, fill = `colony
losses  with operations and profitability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "colony losses  with operations and profitability distribution", x = "colony
losses  with operations and profitability", y = "Percentage") +
```

```
  scale_fill_brewer(palette = "Set3")

# measures  to prevent colony losses distribution
ggplot(data, aes(x = `measures  to prevent colony losses`, fill = `measures  to prevent colony losses`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "measures  to prevent colony losses distribution", x = "measures  to prevent colony losses", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# moving hives due to suitability concerns distribution
ggplot(data, aes(x = `moving hives due to suitability concerns`, fill = `moving hives due to suitability concerns`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "moving hives due to suitability concerns distribution", x = "moving hives due to suitability concerns", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# transhumance distribution
ggplot(data, aes(x = `transhumance`, fill = `transhumance`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "transhumance distribution", x = "transhumance", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# frequancy of transhumance" distribution
ggplot(data, aes(x = `frequancy of transhumance`, fill = `frequancy of transhumance`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "frequancy of transhumance", x = "frequancy of transhumance", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# Transhumance and honey production distribution
ggplot(data, aes(x = `Transhumance and honey production`, fill = `Transhumance and honey production`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Transhumance and honey production distribution", x = "Transhumance and honey production", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# challenges during transhumance distribution
ggplot(data, aes(x = `biggest challenges during transhumance`, fill = `biggest challenges during transhumance`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "biggest challenges during transhumance", x = "biggest challenges during transhumance", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")
```

```
# Transhumance and health distribution
ggplot(data, aes(x = `Transhumance and health`, fill = `Transhumance and health`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "Transhumance and health", x = "Transhumance and health", y =
"Percentage") +
  scale_fill_brewer(palette = "Set3")

# rank climate for suitabilitydistribution chage numbers to most very less important
ggplot(data, aes(x = `rank climate for suitability`, fill = `rank climate for suitability`))
+
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "rank climate for suitability", x = "rank climate for suitability", y =
"Percentage") +
  scale_fill_brewer(palette = "Set3")

# rank Vegetation for suitability
ggplot(data, aes(x = `rank Vegetation for suitability`, fill = `rank Vegetation for
suitability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "rank Vegetation for suitability", x = "rank Vegetation for suitability", y =
"Percentage") +
  scale_fill_brewer(palette = "Set3")

# rank Pest and disease pressure for suitability
ggplot(data, aes(x = `rank Pest and disease pressure for suitability`, fill = `rank Pest
and disease pressure for suitability`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "rank Pest and disease pressure for suitability", x = "rank Pest and disease
pressure for suitability", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# colony losses cause
ggplot(data, aes(x = `colony losses cause`, fill = `colony losses cause`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "colony losses cause", x = "colony losses cause", y = "Percentage") +
  scale_fill_brewer(palette = "Set3")

# most suitable areas in Bouira
ggplot(data, aes(x = `most suitable areas in Bouira`, fill = `most suitable areas in
Bouira`)) +
  geom_bar(aes(y = ..count.. / sum(..count..) * 100)) +
  labs(title = "most suitable areas in Bouira", x = "most suitable areas in Bouira", y =
"Percentage") +
  scale_fill_brewer(palette = "Set3")

# Load required packages
library(cluster)
```

```r
# Load required packages
install.packages(arules)
library(arules)

# Convert your data to transactions format
transactions <- as(data_subset, "transactions")

# Perform association rule mining
rules <- apriori(transactions, parameter = list(supp = 0.1, conf = 0.8))

# Print the discovered rules
inspect(rules)

# Correlation matrix
cor(data[, c("Experience", "hives.number", "colony.losses")])

# Correlation heatmap
library(ggplot2)
library(reshape2)
cor_data <- cor(data[, c("Age", "hives number")])
ggplot(melt(cor_data), aes(Var1, Var2, fill = value)) + geom_tile()

# Compare mean values of a numerical variable across different categories
tapply(data$Age, data$`hives number`, mean)

# Compare frequency distributions of a categorical variable across different categories
table(data$`Educational Level`, data$Gender)
table(data$`Educational Level`, data$Experience)
table(data$Experience, data$transhumance)
table(data$Experience, data$`hives feed`)

# Simple linear regression
lm_model <- lm(data$`hives number` ~ data$Experience + data$Age, data = data)
summary(lm_model)

# Simple linear regression
lm_model <- lm(data$`hives number` ~ data$Experience, data = data)
summary(lm_model)

# Multiple linear regression
lm_model <- lm(data$`number hives lost` ~ Experience + hives number + Age, data =
data)
summary(lm_model)

# Perform PCA
pca <- prcomp(data[, c("hives number", "Age", "rank climate for suitability", "rank
Vegetation for suitability", "rank Human impact for suitability" )], scale. = TRUE)
```

```
# Summary of PCA results
summary(pca)

# Scree plot
plot(pca, type = "l", main = "Scree Plot")

# Biplot
biplot(pca, scale = 0)

# Scores and loadings
scores <- pca$x  # PCA scores
loadings <- pca$rotation  # PCA loadings

# Perform Cluster Analysis (e.g., K-means clustering)
cluster <- kmeans(data[, c("Age", "hives number", "rank climate for suitability")],
centers = 3)

# Cluster membership
cluster$cluster

# Cluster centroids
cluster$centers

# Create a contingency table
table(data$Experience, data$`tools used to determine the suitability site`)  # Replace
"Variable1" and "Variable2" with the names of your categorical variables

# Perform chi-square test of independence
result <- chisq.test(data$`Educational Level`, data$`hives feed`)  # Replace
"Variable1" and "Variable2" with the names of your categorical variables
result

# Fit multinomial logistic regression model
install.packages("nnet")
model <- multinom(data$`hives number` ~ data$Gender+ data$`hives feed` +
data$Experience, data = data)
summary(model)
```