

**THE EFFECT OF APIARY MANAGEMENT PRACTICES ON HONEY
YIELDS IN KENYA AND THE MODERATING EFFECT OF BEE SPECIES**



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076182

MASTER OF MANAGEMENT IN AGRIBUSINESS

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**A DISSERTATION SUBMITTED FOR THE FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF MANAGEMENT IN AGRIBUSINESS AT
STRATHMORE BUSINESS SCHOOL.**

MAY, 2025

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ABSTRACT

A large proportion of Kenya can be classified as Arid and Semi-arid lands which have been identified as suitable conditions for beekeeping. Despite this geographical advantage, the country is still far from reaching its honey production potential with the varying level of honey yields. The purpose of this study was to investigate the effect of apiary management practices on honey yields in Kenya and the moderating role of bee species. Specifically, the study's objectives were to examine the effect of apiculture's colony management practices, socioeconomic management practices and environmental management practices on honey yields and to explore the moderating effect of bee species on the relationship between apiary management practices and honey yields in Kenya. The target population of interest was 135 members of the Apiculture Platform of Kenya who are directly involved in beekeeping. This study was guided by the research philosophy of post-positivism and applied a descriptive cross-sectional research design. With the aid of IBM SPSS version 20 software, descriptive and inferential statistical analysis was used to analyze the primary data together with regression analysis to determine the relationship among the study's variables. The findings showed that only apiculture's colony management practices had a significant impact on the variation of honey yields. Apiculture's socioeconomic and environmental management practices had a weak relationship with honey yields; stakeholders are encouraged to evaluate how they can get more out of these practices to increase honey yields. This study was limited by its target group being a beekeeper's association therefore the results of the research study cannot be generalized to the whole of Kenya. The honey yield data was collected over two seasons in one year. The data on honey production was self-reported. Suggested areas for further research include: the use of an experimental research design to investigate the effects of apiculture's colony management practices on honey yields, qualitative techniques in the use of apiculture's socioeconomic management practices, and an experiment to compare precision apiculture systems performance with conventional apiculture colony management practices.

Key Words: *Apiary, Bees, Colony, Dearth, Honey, Internet of Things, Monitoring, Precision Apiculture, Yields.*

DEDICATION

This dissertation is dedicated to my father and mother, Dr. G. Maranya and Dr. J.M. Adogo, for constantly being there for me while conducting this study. I appreciate your encouragement and patience.



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CONTENTS

DECLARATION	ii
ABSTRACT.....	iii
DEDICATION.....	iv
ACKNOWLEDGEMENTS.....	v
CONTENTS.....	vi
LIST OF FIGURES	x
LIST OF TABLES.....	xi
LIST OF APPENDICES.....	xiii
ABBREVIATIONS IN FULL.....	xiv
KEY-WORD DEFINITIONS.....	xv
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background to the study	1
1.1.1 Honey Yields in Africa and Kenya.....	2
1.1.2 Apiculture’s Socioeconomic Management.....	4
1.1.3 Apiculture’s Colony Management.....	6
1.1.4 Apiculture’s Environmental Management.....	7
1.2 Problem Statement.....	8
1.3 Research Objectives.....	9
1.3.1 General Objective.....	9
1.3.2 Specific Objectives	9
1.4 Research Questions.....	10
1.5 Significance of the study.....	10
1.5.1 Beekeepers	10
1.5.2 Extension Officers	10
1.5.3 Policymakers.....	11
1.6 Scope of the Study	11
1.7 Chapter Summary	11
CHAPTER TWO: LITERATURE REVIEW.....	12
2.1 Introduction.....	12
2.2 Theoretical Review	12

2.2.1. Foraging Theory.....	12
2.2.3 Adaptive Management Theory	13
2.3 Empirical Review.....	16
2.3.1 Apiculture’s Colony Management Practices and Honey Yield	16
2.3.1.1 Supplementary Feeding	16
2.3.1.2 Queen Bee Manipulation	18
2.3.1.3 Frequency of Hive Inspection.....	19
2.3.1.4 Pest and Diseases Management	21
2.3.1.5 Precision Colony Management	23
2.3.2 Apiculture’s Socioeconomic Management Practices and honey yields in Kenya.....	26
2.3.3 Apiculture’s Environmental Management Practices and Honey Yields.....	27
2.3.4 Moderating effect of bee species on the association between apiary techniques and honey yields.	29
2.4 Research Gaps.....	31
2.5 Conceptual Framework.....	34
2.6 Operationalization of Variables	35
2.7 Chapter Summary	36
CHAPTER THREE: RESEARCH METHODOLOGY	37
3.1 Introduction.....	37
3.2 Research Philosophy.....	37
3.3 Research Design.....	38
3.4 Population	38
3.5 Data Collection Method.....	39
3.6 Research Quality.....	39
3.6.1 Validity of Instruments	39
3.6.2 Reliability of Research Instruments.....	40
3.6.3 Pilot Test	41
3.7 Data Analysis	41
3.8 Diagnostic Tests.....	42
3.8.1 Normality Test	42
3.8.2 Multicollinearity Tests	42
3.8.3 Heteroscedasticity	42
3.9 Ethical Issues	43

3.10 Chapter Summary	43
CHAPTER FOUR: PRESENTATION OF RESULTS	44
4.1 Introduction.....	44
4.2 Response Rate.....	44
4.3 Demographic Analysis.....	44
4.4 Descriptive Statistics.....	46
4.4.1 Descriptive Analysis of Apiculture’s Socioeconomic Management Practices.....	46
4.5.2 Descriptive Analysis of Apiculture’s Colony Management Practices.....	50
4.5.3 Descriptive Analysis of Apiculture’s Environmental Management Practices.....	52
4.5.4 Descriptive Analysis of Honey Production and Bee Species	54
4.5 Diagnostic Tests.....	56
4.5.1. Normality Test	56
4.5.2. Multicollinearity Test.....	57
4.6 Inferential Statistics	57
4.6.1. Correlation Results.....	57
4.6.2. Relationship between Apiculture’s Socioeconomic Management Practices and Honey Yields.....	58
4.6.3. Relationship between Apiculture’s Colony Management Practices and Honey Yields.....	60
4.6.2. Relationship between Apiculture’s Environmental Management Practices and Honey Yields.....	62
4.8. Regression Coefficient Model – Equation I.....	64
4.9. Regression Coefficient Model – Equation II	65
4.10 Chapter Summary	67
CHAPTER FIVE: SUMMARY, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS.....	68
5.1 Introduction.....	68
5.2 Summary of main findings.....	68
5.3 Discussion of Findings.....	68
5.3.1 Apiculture’s Socioeconomic Management Practices Effect on Honey Yields.....	69
5.3.2 Apiculture’s Colony Management Practices Effect on Honey Yields.....	70
5.3.3 Apiculture’s Environmental Management Practices Effect on Honey Yields.....	71
5.3.4 The Moderating Effect of Bee Species on The Relationship between Apiary Management Practices and Honey Yields.	72

5.4 Conclusions.....	73
5.5 Contribution of the Study.....	74
5.6 Recommendations.....	74
5.6.1 Beekeepers.....	74
5.6.2 Extension Officers.....	75
5.6.3 Policymakers.....	75
5.7 Limitations of the Study.....	75
5.8 Suggestions for Further Research.....	76
REFERENCES.....	77
APPENDICES.....	102



LIST OF FIGURES

Figure 1.1 Top Honey Producers (FAO, 2023)	1
Figure 1.2 Top Honey Producers Africa (FAO, 2023)	3
Figure 1.3 Kenya Production (Kenya National Bureau of Statistics, 2025)	3
Figure 1.4 Predictors of Honey Yields (Schouten, 2020)	6
Figure 2.1 Cognitive Map Questions (Albayrak et al., 2018)	15
Figure 2.2 Cognitive Fuzzy Map (Albayrak et al., 2018)	15
Figure 2.3 Honeybee Species in Africa (Senior, 2021)	30
Figure 2.4 Conceptual Framework (Researcher 2025)	34
Figure 4.1 County Apiary Location	46
Figure 4.2 Group Participation Heatmap	46
Figure 4.3 Funding Sources For Beekeeping Growth	48
Figure 4.4 Supplementary Feed	50
Figure 4.5 Apiary Environment	53
Figure 4.6 Apiary Proximity to Forests, Farmland and Water Bodies	53
Figure 4.7 Bee Species Encountered	56

LIST OF TABLES

Table 2.1 Summary of Research Gaps.....	32
Table 2.2 Operationalization of Variables	35
Table 3.1 Cronbachs Alpha Scores	40
Table 3.2 Kaiser-Meyer-Olkin KMO-Bartlett's Test.....	40
Table 4.1 Response Rate.....	44
Table 4.2 Summary of Demographic Statistics	45
Table 4.3 Group Participation.....	47
Table 4.4 Socioeconomic Activities	48
Table 4.5 Hive Type and Quantity.....	49
Table 4.6 Pest Prevalence	50
Table 4.7 Colony Practices	51
Table 4.8 Colony practices 2	52
Table 4.9 Environmental Practices	54
Table 4.10 Honey Production.....	55
Table 4.11 Honey Production DIstribution.....	55
Table 4.12 Tests of Normality	57
Table 4.13 Correlation of Variables.....	57
Table 4.14 Correlation in Objective 1.....	58
Table 4.15 Regression Output for Objective 1	59
Table 4.16 Correlation in Objective 2.....	60
Table 4.17 Regression Output of Objective 2.....	61
Table 4.18 Correlation in Objective 3.....	62

Table 4.19 regression Output of Objective 3 63

Table 4.20 Regression Output Equation I..... 64

Table 4.21 Regression Output Equation II 66



LIST OF APPENDICES

Appendix I Facilitation Letter.....	102
Appendix II Ethics Approval.....	103
Appendix III Research Licence	104
Appendix IV Questionnaire	105
Appendix V Multicollinearity test	113
Appendix VI Histogram.....	114



ABBREVIATIONS IN FULL

ANOVA –	Analysis of Variance
ASAL –	Arid and Semi-Arid Land
APK –	Apiculture Platform of Kenya
CCD –	Colony Collapse Disorder
FAO –	Food and Agricultural Organization of the United Nations
GDP –	Gross Domestic Product
GIS –	Geographical Information System
GOK –	Government of Kenya
ICIPE –	International Centre of Insect Physiology and Ecology
IOT –	Internet of Things
KALRO –	Kenya Agricultural and Livestock Research Organization
KES –	Kenyan Shilling
KIRDI –	Kenya Industrial Research and Development Institute
KTBH –	Kenya Top Bar Hive
NBI –	National Beekeeping Institute
PAS –	Precision Apiculture System
USA –	United States of America
USD –	United States Dollar

KEY-WORD DEFINITIONS

- Apiary:** A collection of beehives, specifically used for honey production; a location where bees are housed. It provides a space for beekeepers to oversee and tend to the hives. (Merriam-Webster, 2024).
- Apiculture:** A different term for beekeeping. Apiculture is the management of honeybee colonies with the aim to produce honey, propolis, beeswax, and for pollination (Crane, 1990).
- Colonization:** The action by bees of establishing themselves in an area such as a hive from which they will grow their population and return to from foraging (Winston, 1987).
- Dearth:** A scarcity or lack of something. Seasons in which there is a scarcity of flora, more so pollen and nectar for bees, can be referred to as a dearth period (Graham, 2015).
- Internet of Things:** It is the internet connection that allows computing devices embedded in common objects to send and receive data (Lynn et al., 2020).
- Monitoring:** The systemic collection of information and analysis of something over time (Smisiter, 2017).
- Precision Agriculture:** A method of farming that relies a lot on data, it monitors crucial parameters to tailor crop/animal management strategies to get the best yields (Thorp, 2015).
- Precision Apiculture:** This is a beekeeping colony management strategy whose foundation is the monitoring of each beehive's characteristics using information technology to minimize resources and maximize bee productivity (Danieli et al., 2024).

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Humans have been managing honeybees for numerous millennia with the objective of harvesting honey, venom, propolis, beeswax, and royal jelly in addition to providing pollination services (Sperandio et al., 2019). Apiary management therefore refers to the beekeepers' work activities that promote optimal production of bee products and services. These activities include hive selection and placement, supplementary feeding, disease and pest management, queen bee manipulation, forage planting, harvesting bee products, and swarm control (Gratzer et al., 2021).

According to statistical data, global honey output in 2021 was estimated at 1.77 million metric tons, which was 41% greater than in production 2000; 1.25 million metric tons and 5.4% lower than the peak of 1.87 million metric tons attained in 2017 (Popescu et al., 2023). China, Russia, Turkey, USA, Iran, Ukraine, United Republic of Tanzania, India, Mexico, Brazil, Canada, Argentina, Spain, and the Republic of Korea were the top producers of honey in 2023, with 1,260,537 MT which is 71.13% of the world's total, produced collectively. These countries were listed in decreasing order of honey production output (FAO, 2023).

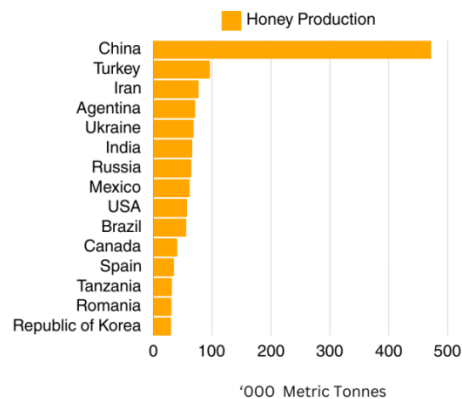


FIGURE 1.1 TOP HONEY PRODUCERS (FAO, 2023)

A global phenomenon with many facets, climate change has had a significant effect on many different ecosystems and creatures, including pollinators (Vercelli et al., 2021). There has been a major drop in bee populations and biodiversity as a result of climate change, which also affects insect pollinators' activity and efficiency according to Ouknin et al. (2023) making meeting food demands of a rapidly growing human population an even bigger challenge (Mumtaz et al., 2017).

Beekeepers concurred that providing additional feeding to the colonies is the most crucial management activity in response to the scarcity of nectar brought about by climate change (Vercelli et al., 2021).

In the past few years, bees worldwide have experienced an increase in mortality. In 2006, the USA first reported cases of Colony Collapse Disorder (CCD) (Neumann & Carreck, 2010). There have also been reports of a notable increase in CCD in South America. The primary causes of the honey bee losses have been identified in a comprehensive study conducted in five countries: Brazil, Uruguay, Chile, Argentina, and Venezuela is due to the widespread use of acaricides for treatment of ectoparasitic mite brought about by agriculture intensification (Maggi & Antúnez, 2016). According to a 2010-2013 study done in North Dakota, colonies exposed to foraging habitats with higher percentages of uncultivated land had lower colony death rates (Riciglianz et al., 2019).

The management practices used by beekeepers have a direct impact on managed hives. As a result, some improper management practices may have lethal effects on honeybees (Ensenbach S. , 2020). Examples include placing the hive in the shade or wind, which prevents the bees from seeing and orienting themselves, harvesting excessive amounts of honey, which deprives the bees of nutrition during the winter, using chemical pesticides to control varroa mites, moving the bee colonies frequently for hire to facilitate pollination, and monitoring the bees excessively on chilly days, which may result in cool brood (Oldroyd, 2007).

1.1.1 Honey Yields in Africa and Kenya

Apiculture in Africa is acknowledged as a minimal capital strategy to reduce poverty and provide those practicing it with a stable source of funds. Its affordability makes it easier for small-holder farmers to venture into beekeeping (FAO, 2021). Honey consumption in Africa is estimated to be three times the amount produced (Châtel, 2017). On the African continent, Ethiopia is the largest honey producer, other top producers are Tanzania, Angola, and Kenya respectively making Eastern Africa the continent's largest honey producing region (FAO, 2023).

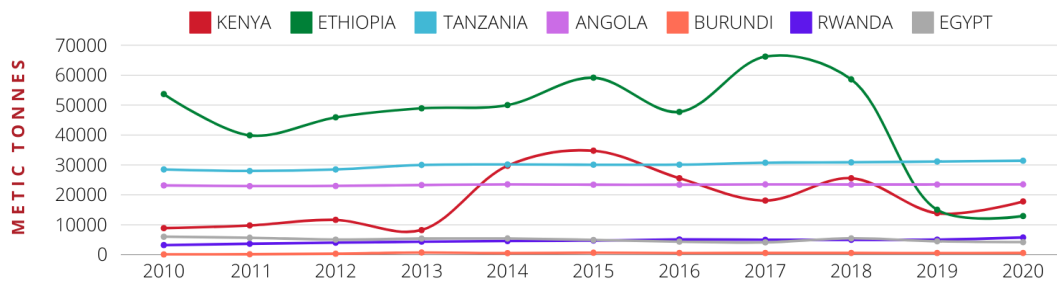


FIGURE 1.2 TOP HONEY PRODUCERS AFRICA (FAO, 2023)

Beekeeping accounts for more than half, 52%, of family incomes in Cameroon's Adamaoua savannah and Northwest Montane forests (Ingram & Njikeu, 2011). Even though beekeeping is economically beneficial to households, the top African countries have barely realized their production potential. Ethiopia, Africa's largest producer over the past few years has only achieved 10% of its production potential according to Nega & Eshete (2014) while the second largest producer on the continent, Tanzania has achieved 23% (Namwata et al., 2013). Other top-producing African countries such as Uganda (Amulen, 2017), Kenya (Carroll & Kinsella, 2013), and Ghana (Akamiti, 2020) have realized 1%, 25%, and 1% respectively of their estimated potential for annual honey production.

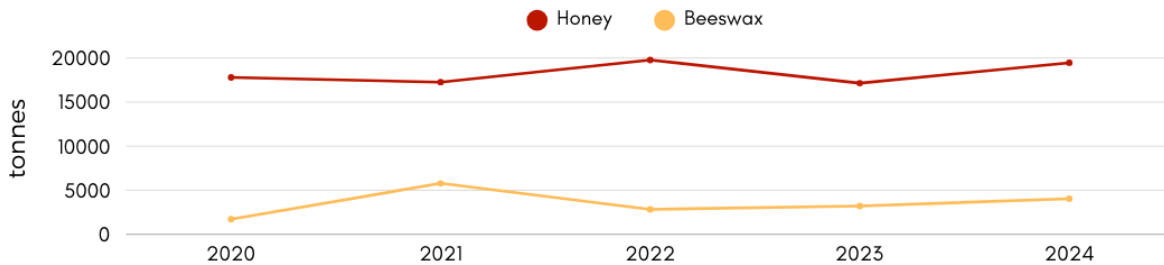


FIGURE 1.3 KENYA PRODUCTION (KENYA NATIONAL BUREAU OF STATISTICS, 2025)

Data from FAO Stats (2025) places Kenya as the 2nd largest producer of beeswax and 4th largest producer of honey in Africa. A publication by the Kenya National Bureau of Statistics (2025) as illustrated on Figure 1.3 shows Kenya's honey production just below the 20,000t mark, well below the production potential of 100,000t noted by the Kenya Institute for Public Policy Research and Analysis (2019). Similarly, the market demand for honey is not met by the honey that is produced, which results in the importation of natural honey. Kenya has been a net importer of natural honey

over the years. According to UN-COMTRADE (2025), the figures show a trade imbalance between 2013 and 2021, with imports totaling US\$ 3,307.572 and exports totaling US\$ 2,542.457. This disparity in trade highlights a basic problem: Kenya produces less honey than is needed by households and businesses in sectors including food, medicine, and cosmetics (Machio & Kiptoo, 2024).

Apimondia, which is the International Federation of Beekeepers' Associations, has expressed concerns about Kenya's lack of policies to develop a modern beekeeping industry (Apimondia, 2019). The international body noted that policies on land use and biodiversity which are crucial in not only increasing the production of honey but also in addressing the welfare of the bee, have been stuck at the development stage. The latest attempts to regulate and formalize this industry were through Livestock Bill 2023 which sought to prescribe areas designated for beekeeping, registration of beekeepers, and the penalties for undertaking commercial beekeeping without licenses (Kilimo, 2023). This follows a previous attempt in the Livestock Bill 2021 which collapsed after a large outcry by beekeepers in Kenya terming the proposed law as punitive (Graduate Farmer, 2021).

1.1.2 Apiculture's Socioeconomic Management

Apiculture has cultural roots having been practiced for subsistence using log hives and indigenous knowledge (Ntenga & Mugongo, 1991). Kenya's first beekeeping development initiative was supported in 1967 by an Oxfam grant, which marked the start of the country's endeavor to promote apiculture (Wambua et al., 2016). In the Ministry of Agriculture, a new agricultural sector called The National Beekeeping Station was founded in 1970 with assistance from the Canadian government. The Kenya Bureau of Standards (KEBS) is responsible for developing standards on beekeeping equipment and products. Other government and international organizations in the country that work together to support the sector include Kenya Livestock Research Organizations (KARLO), ICIPE, Kenya Forest Service (KFS), and Kenya Industrial Research & Development Institute (KIRDI).

Today, majority of smallholder beekeepers work through community-based organizations (CBOs) or cooperatives, which pool resources for market access, hive construction, and training. It is noted by McMenamin et al.(2017) that the choice of type of hive is the primary management decision made by beekeepers. The three main hive types; Log hives, Langstroth and Kenya Top Bar vary

in cost and efficiency. While log hives typically cost \$4-10, they are more affordable and last longer (20 years), the modern hives Langstroth (\$50-70) and Kenya Top Bar (\$40) have moveable frames which allow better hive management with minimal colony interference. These modern hives are, however, more expensive and have a shorter lifespan of 8 years (McMenamin et al., 2017). This could imply that the economic status of beekeepers has a bearing on the type of hives chosen thus influencing quality and quantity of honey yielded.

While studies by Shackleton et al.(2011) note the beekeeping is a male dominated activity, progress made through non-governmental organizations through trainings, ground hive placements and introduction of stingless bees has seen more women participate (Mburu et al., 2017). These studies have influenced the development of beekeeping systems which are gender friendly, allowing more people to participate and contribute to more honey production. The honey production potential of Kenya can be achieved by getting new adopters into the apiculture sector in addition to exploring ways of making existing beekeepers more efficiently productive. Access to credit is also a socioeconomic factor hindering the expansion of beekeeping operations as beekeepers face upfront costs in terms of protective gear and machinery (Machio & Kiptoo, 2024). Socioeconomic management factors have been reported to have various effects on honey yields. For example, a study by (Raina et al., 2009) found that hive placements on the ground led to more women participation resulting in success for both genders. Cooperative membership has in some cases found to increase the quantity and price of honey produced (Serra & Davidson, 2020). While some scholars consider the level of education as a key socioeconomic factor in apiary management, results differ with Mubarik & Buyinza (2020) finding that the level of beekeeping training did not increase honey production.

In Kenya, a study by Chemwok (2016) showed that access to a beekeeping training center, membership to a cooperative, and the use of framed beehives such as Langstroth and Kenya Top Bar were the main factors that influenced honey production. While there has been extensive research on the adoption of beekeeping technologies in Kenya, a gap remains in examining the management practices of beekeepers as an avenue to increase their honey yields.

A report on apiary management activities and beekeepers' characteristics by Schouten (2020) shows how different studies have ranked the influence of these apiary management practices on honey yields; this has been highlighted on Figure 1.4 In addition other apiary management

practices used as variables in predicting the honey yields of various apiaries include; the type and number of bee hives, frequency of requeening, supplementary feeding, baiting for hive colonization, and number of extension service visits (Tolera & Takele, 2014). This paper builds on these two studies and (Chemwok, 2016) using the variables in Figure 1.4 in exploring their relationship with honey yields.

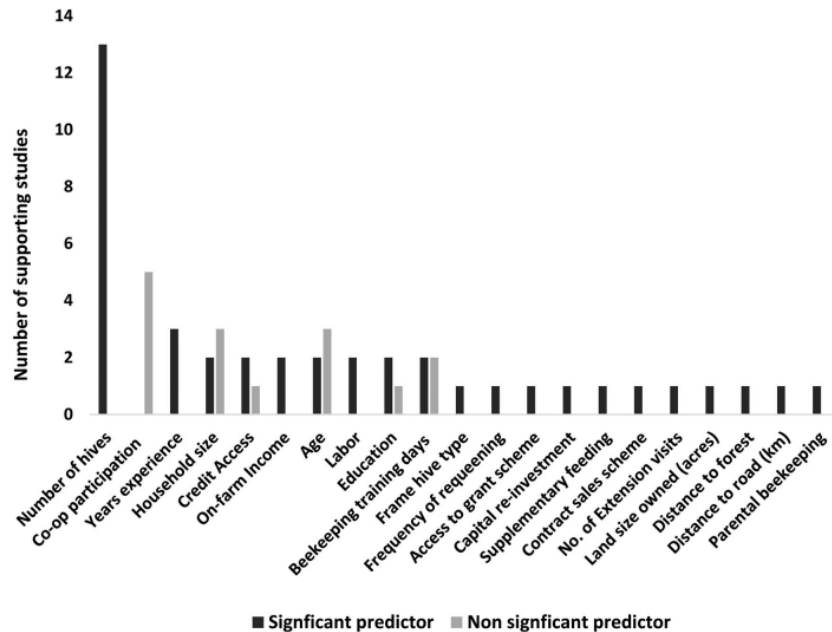


FIGURE 1.4 PREDICTORS OF HONEY YIELDS (SCHOUTEN, 2020)

1.1.3 Apiculture’s Colony Management

The term "apiculture colony management" describes the methodical procedures and methods used to preserve, track, and maximize the well-being, output, and sustainability of honeybee colonies (Winston, 1987). To guarantee that colonies flourish and generate the best possible honey harvests, this involves tasks like hive inspection, pest and disease control, queen rearing, swarm prevention, supplemental feeding, and adapting to seasonal changes (Bees for Development, 2022). To maintain bee populations and optimize apicultural outputs, effective colony management strikes a balance between ecological, biological, and operational aspects.

In a study by Okwee-Acai et al (2010), the findings showed bee farms that applied apiary management practices experienced better hive colonization rates 83.4% compared to those not

managed which had a colonization rate of 47%. Hive colonization, which is a significant step in growing an apiary's honey production capacity, was found to improve with the application of apiary management practices. The findings also showed that managed apiaries had a higher proportion of colonies classified as strong, 74%, compared to unmanaged apiaries with 6.1%. Colony strength influences the colonies' ability to gather pollen and nectar in honey production (Wilson, 2006).

In a report examining the primary issues that beekeepers face in Northern Africa, the quality of beekeeping products such as honey was greatly impacted by beekeepers' inadequate apiary colony management skills and their limited ability to monitor and control pests and diseases in beehives (Al-Ghamdi et al., 2016). Poor apiary colony management has also been listed as the leading cause of supply deficiency of honey (Kilimo, 2012). Compared to their European or Asian counterparts, African honey bees are more aggressive as reported by Kastberger et al. (2009), this forces beekeepers to typically open their hives for inspection after the sun has already set in order to avoid getting stung (Shackleton et al., 2011). This method of observation is considered intrusive as it disturbs the bees making them defensive; it is also time-consuming and causes stress to the bee colony (Zacepins et al., 2016).

Colony management practices such as queen bee manipulation (FAO, 2020) and supplementary feeding of bees (Shrestha, 2018) have been studied widely in relation to honey yields. Some studies have found their practice to increase honey yields while others such as (Szabo & Lefkovitch, 1989) differ. Furthermore, modern technology through precision beekeeping and use of sensors brings another attempt to better manage bee colonies for increased honey yields. The exploration of colony management practices builds on studies by (Bett , 2017) and (Haftu et al., 2018) which note pest management practices critical to determining honey output.

1.1.4 Apiculture's Environmental Management

One of the apiculture environmental management issues with beekeeping in Africa is the scarcity of honey plants owing to the reduction of forest areas caused by fire and deforestation. Honeybees use flower nectar as a key ingredient to produce honey (National Honey Board, 2022). As a result, beekeepers are compelled to move their hives around, which accelerates the transmission of illnesses among colonies (Abdelkader, 2020). Bees' productivity is increasingly affected by

environmental factors such as limited forage availability brought about by climate change and exposure to pesticides (Picknoll et al., 2021).

80% of Kenya is considered dry, Arid and Semi-arid lands. These areas have high prospects for apiculture due to the abundance of floras as documented by Apimondia (2019), despite this, the country produces approximately 25,000 MT of honey annually which is estimated to be only 25% of its production potential (Muma, 2019). Through commerce, the beekeeping sector supports the rural economy. The Kenya beekeeping sector is valued at millions of shillings and is crucial to the dry regions' economies. Bees are a part of Kenya's livestock subsector, which contributes 10% of the country's GDP with about 1.89% of the Livestock Sub-sector comes from beekeeping (Wambua et al., 2016).

Various scholars have investigated how different environmental conditions impact honey yields. For example, a study by Vaudo et al.(2011) and Invernizzi et al. (2011) compared honey production performance in apiaries close to farmlands with those in close proximity to natural forage such as forests. Other studies by de Graaf & Chemurot (2019) have investigated honey yields in different agroecological zones and as well as levels of floral diversity (Oluwaseyi et al., 2021). Furthermore, climate change, Colony Collapse Disorder and pesticide usage have been widely acknowledged to affect bee colonies worldwide. This study was therefore keen to evaluate the effects of these environmental factors on honey yields.

1.2 Problem Statement

80% of Kenya is considered dry, Arid and Semi-arid lands. These areas have high prospects for apiculture due to the abundance of flora (Apimondia, 2019). Apiculture is recognized as a minimal capital strategy to reduce poverty and provide those practicing it with a stable source of funds (FAO, 2021). Achievement of the country's honey production capacity, estimated at around 100,000 MT annually, would ideally have a great impact on rural communities and poverty alleviation efforts as beekeeping accounts for more than half of income earned by communities engaged in it (Ingram & Njikeu, 2011).

Despite the immense potential to be global leader in the sector, the country produces approximately 25,000 MT of honey annually which is estimated to be only 25% of its production potential (Muma, 2019). As a result, it estimated that Kenya relies on Tanzania, Uganda, Sudan and Congo for 80% of its honey needs (Ngomo, 2021). Data on honey imports and exports further shows

another problem, that Kenya produces less honey than is needed by households and businesses in sectors including food, medicine, and cosmetics (Machio & Kiptoo, 2024).

In a report examining the main problems faced by beekeepers, the quality bee products such as beeswax and honey were greatly impacted by beekeepers' inadequate apiary management practices and their limited ability to monitor and control pests and diseases in beehives (Al-Ghamdi et al., 2016). Poor apiary management has also been listed as the leading cause for the supply deficiency of honey (Kilimo, 2012). It is also noted by FAO (2023), that farmers are often trained in apiculture skills but lack further support on beehive management thus leading to poor quality honey fetching poor market prices. In addition to poor apiary management practices, climate change has greatly contributed to the low honey yields preventing the achievement of Kenya's production potential.

Numerous studies such as Nyamira et al. (2024), Bunde & Kibet (2013) Kiingwa (2019) and Muya et al., (2018) have focused on factors affecting adoption of beekeeping technologies in Kenya while a gap remains in examining the management practices of beekeepers as an avenue to increase honey yields. On the other hand, different studies have yielded contradicting results on how various apiculture management practices have influenced honey yields such as FAO (2020) and Szabo & Lefkovitch (1989) on queen bee manipulation, Hoover et al. (2022) and Gameda (2014) on type of supplementary feeding and Vaudo et al (2011) and Sande et al. (2009) on proximity to forests to name a few.

In response to the situation described above, this study examined how apiculture's socioeconomic, environmental and colony management practices that have a significant effect on honey yields. In doing so, beekeepers and stakeholders such as extension officers gain a better understanding of which apiary management practices to prioritize in increasing their honey yields and push the country towards achieving its potential.

1.3 Research Objectives

1.3.1 General Objective

The general objective of this study was to examine the effect of apiary management practices on honey yields in Kenya and to establish the moderating effect of bee species.

1.3.2 Specific Objectives

- i. To examine apiculture's socioeconomic management practices on honey yields in Kenya.

- ii. To examine apiculture's colony management practices on honey yields in Kenya.
- iii. To establish the effect of apiculture's environmental management practices on honey yields in Kenya.
- iv. To determine the moderating effect of bee species on the relationship between Apiary management practices and honey yields in Kenya.

1.4 Research Questions

- i. What is the effect of Apiculture's colony management practices on honey yields in Kenya?
- ii. What is the effect of Apiculture's socioeconomic management practices on honey yields in Kenya?
- iii. What is the effect of Apiculture's environmental management practices on honey yields in Kenya?
- iv. What is the moderating effect of bee species on the relationship between Apiary management practices and honey yields in Kenya?

1.5 Significance of the study

The results of the research study showed the most crucial apiary management practices that affect honey yields, the findings are of great use to the following groups:

1.5.1 Beekeepers

The findings from the study inform beekeepers on apiary management practices to prioritize based on their impact on honey yields. By understanding the effects of apiary management activities on honey yields, beekeepers are then able to appreciate their importance and therefore more likely to ensure their implementation. The study lays a foundation for the application of precision beekeeping, by reviewing literature on data-driven approaches to reducing beekeeping costs while increasing outputs.

1.5.2 Extension Officers

The findings are expected to be of use to the beekeeping sub-sector extension officers for understanding which improved apiary management practices beekeepers have challenges in

implementing. An understanding of current management practices informs extension officers on areas for improvement to tackle poor apiary management which has been listed as the leading cause of honey deficiency.

1.5.3 Policymakers

Parties in the planning and development of beekeeping in the livestock sector will find the results of this study useful in drawing policy interventions to increase the productivity of the country's apiaries. Since beekeepers are essential to the production of apiary goods, improving effective apiary management practices will strengthen the apiculture value chain. The study's empirical results will be a great contribution to the world of knowledge as more people work to better understand how to boost the productivity of our beekeeping resources.

1.6 Scope of the Study

This study set out to examine the apiary management practices carried out by the Apiculture Platform of Kenya (APK) whose beekeeping members formed the study's population. This is a group made up of 135 members across the country with the aim of sharing information and knowledge in the industry. The apiaries belonging to the organization's members are spread across Kenya in various geographical zones that inhabit the three main honeybee species used to analyze the moderating effect: *Apis mellifera litorea*, *Apis mellifera scutellate*, and *Apis mellifera monticola*. A descriptive cross-sectional research design was applied to study the effects of apiary management practices under three thematic areas; colony management, environmental management, and socioeconomic management on the honey yielded per bee colony. The period of the study was February to April 2025.

1.7 Chapter Summary

This chapter gives a background of the study, specifically giving a detailed discussion on the honey production landscape globally, regionally and locally. It also provides a breakdown of the key study variables, honey yields, apiculture socioeconomic management practices, apiculture environmental practices and apiculture's colony management practices. This section also outlines the problem statement, general objective, specific objectives, research questions, significance and scope of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter's goal was to discuss the inputs and contributions of researchers to better understand this study. The literature reviewed focuses on theoretical and empirical studies on apiary management practices and their impact on honey yields as guided by the objectives and research questions of this thesis.

2.2 Theoretical Review

Theories that serve as the basis for the analysis of different apiary management techniques are covered in this part.

2.2.1. *Foraging Theory*

This theory's inception can be linked to Kerbs & Stephens (1986) who analyzed the decision-making process undertaken by animals in search of food/prey. The theory had three main components; firstly, decision assumptions, this sought to select the forager's food alternatives for analysis. To solve the two primary issues of deciding which forage items to eat and when the animal will depart from the forage area, assumptions were established. This analysis further led to the development of diet models which studied the proportion of forage ingested by a particular species. Most diet models that are predicated on this premise calculate the best chance that a forager will seek out a particular food type after coming across it (Kerbs & Stephens, 1986). Secondly, currency assumptions, it was concerned how the various food/prey choices would be analyzed, for example the number of food particles captured at a given rate. Finally, constraint assumptions examined what restricts the animal's viable options. For instance, honeybees cannot tell the difference between red and grey, and a forager cannot feed for more than twenty-four hours at a time (Janetos & Cole, 1981).

Dempster & McFarland (1977) conducted a research program based on the theory to investigate how good animals are at doing their jobs. The study analyzed an animal's selection criteria within a specific set of food options. Caraco et al. (1980) used forage theory to study animal behavior and its correlation with different ecology while Cheverton (1985) determined the processes influencing

bumblebee migration between flowers by analyzing their forage motions under the premise that they maximize the rate of gain.

The tenants of this theory have been applied by Janssens et al. (2006) to forecast honey output in the southern region of Belgium from May to July using a simple approach model. In his analysis, all plants that are accessible to bees within a two-kilometer radius from the apiary could be foraged upon for pollen and nectar which are key honey production ingredients. The forage plants in this range were surveyed and mapped using GIS software to gather information on their area, density, and position. Additionally, information on the plants' nectar yield and flowering time was gathered (Picknoll et al., 2021). The theory assumes that honey production will decrease linearly with distance from forage desired by bees and that high-quality forage attracts more bees due to their pollen and nectar with increases honey making potential. The theory advocates environmental apiary management practices which have a focus on ensuring sufficient quality forage for improved honey production.

The input data on the forage density within area was used to calculate each hive's production potential, which was then added up to provide an estimate of the apiary's overall productivity (Picknoll et al., 2021). The researchers discovered this simple approach had overestimated honey harvests by more than a hundred times what was collected by the beekeepers. This was ascribed to its inability to sufficiently take into consideration the constraints imposed by foraging and the challenge of forecasting production for locations with a variety of flora. It was also noted that theory didn't take into consideration the effects of climate change, pollinator preferences, time taken to forage or the daily pattern of nectar secretion by each species.

In conclusion, forage theory advocates for the implementation of apiculture environmental management practices. This includes the planting of desirable forage, provision of water and reducing environmental impact such as pesticides that may harm bees. This is because the theory assumes that by availing these resources closer to the apiary, bees would spend less time and energy foraging, resulting in increased honey yields.

2.2.2. Adaptive Management Theory

Adaptive management theory proposed by Holling (1978) was developed to counter the assessments of environmental concerns which were often analyzed from a fixed review of an

independently designed policy. The theory promotes the creation of policies that integrate social, economic, and environmental knowledge both during the design phase and after they are put into effect. The implementation of adaptive management theory therefore moves from reactive assessments on what has already occurred to more time and effort spent on projecting and anticipating what is likely to occur. An integral part of the theory application is the incorporation of information from outside constituencies and the implementation of monitoring and remedial mechanisms during any management activity.

This theory advocates flexible and responsive management strategies that adapt to changing conditions. Applying adaptive management principles can help beekeepers adjust their practices based on real-time observations and outcomes, optimizing honey production. The cognitive maps prediction was developed by Albayrak et al (2018) utilizes tenants of the adaptive management theory by incorporating economic and social factors in addition to environmental management issues. The use of fuzzy cognitive maps takes into consideration an array of variables that impact honey production across different Turkish provinces. Fuzzy cognitive maps can be described as a technique for predicting complicated systems that make use of human experience and current knowledge.

The first step in the cognitive fuzzy application is to identify the stakeholders; these include beekeepers, agricultural development agencies and academics. The second step involves the identification of variables with a cause-effect relationship with the dependent variable which in this case was honey output. The population and health of bees, the quantity and quality of plants that provide nectar in the vicinity of the colonies, the age and fertility of the queen bees, the degree to which the bees have adapted their racial and morphological characteristics to the area, and whether or not agricultural spraying has been done in the area were all considered as factors that have an effect on the production of honey. Beekeepers then answer questions about their apiary management practices on honeybee colonies, their responses are then combined with meteorological data of their apiary locations and fed to an intelligent information website as shown in Figure 2.1

Choose the province: Ankara

What is the population size of adult worker bees?: Very small

What is the brood population size? (as surface area): Very small

How old is your queen bee?: Young

How much is the egg-laying capacity of the queen bee?: Very small

Is there any viral disease observed in the hive? To what extent?: No disease

Is there any fungal disease observed in the hive? To what extent?: No disease

Which race are your bees similar to in terms of morphological characteristics and ecotype?: Carniolan Bee

What is the race of your bees?: Carniolan Bee

How many years of experience do you have in beekeeping?(Year): Less than 1 year

Choose the hive type: Thermo Hive

What is the flight frequency of your worker bees?: Very Low

EVALUATE

FIGURE 2.1 COGNITIVE MAP QUESTIONS (ALBAYRAK ET AL., 2018)

The website would then analyze the data and produce an output of the expected honey production as shown in *Figure 2.2* C1-C17 represents apiary management practices and factors that affect honey yields. C18 is the predicted honey harvest.

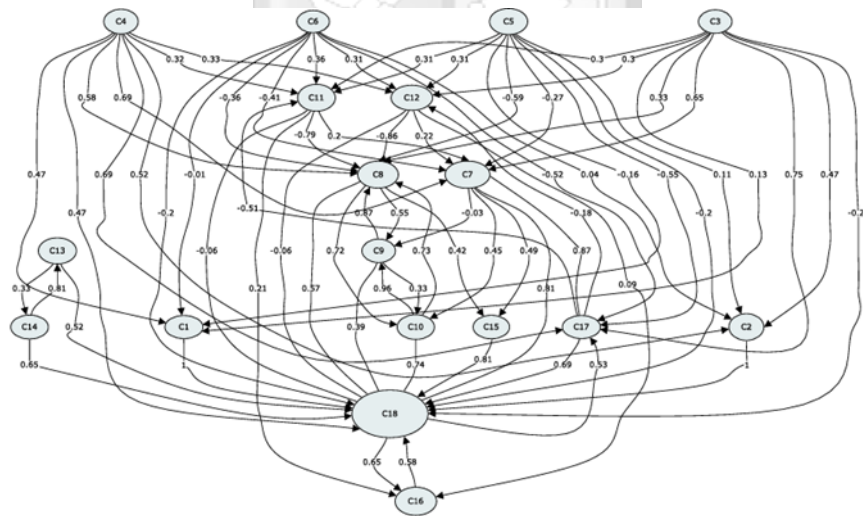


FIGURE 2.2 COGNITIVE FUZZY MAP (ALBAYRAK ET AL., 2018)

The cognitive fuzzy maps based on adaptive management theory builds on the simple approach used in forage theory which only considered environmental management practices by adding colony management practices specifically queen bee manipulation which impacts the number of worker bees, amount of brood and age of the queen bee. The model also adds socioeconomic management considerations such as the years of beekeeping experience and the type of hives used

as variables that influence honey output. The drawback of this cognitive map applying adaptive management theory was that it could only simply classify the honey production as low, weighing between 0 and 10 kilograms, medium, between 10 and 20 kilograms, or large, weighing more than 20 kilograms. Furthermore, a user is unable to investigate the impact of varying the decision variables such as the mix of species, plant area, and quantity on honey produced due to its limitations (Picknoll et al., 2021).

2.3 Empirical Review

This section investigates literature from past research on the application of various apiary management practices and their impacts on honey yields. The empirical review explores the findings of varied objectives, methods, locations, and durations in which researchers have continuously monitored apiary performance and management practices that influence it.

2.3.1 Apiculture's Colony Management Practices and Honey Yield

The daily tasks a beekeeper does on the bees to guarantee the best possible production of honey and other bee products like wax and propolis are known as colony management techniques (Bees for Development, 2022). These practices include supplementary feeding of bees, inspection of hives, queen bee manipulation, pest mitigation, and precision beekeeping. These practices all apply adaptive management theory by Holling (1978) which advocates for anticipation of events rather than reactive assessments.

2.3.1.1 Supplementary Feeding

Supplemental meals, including pollen, are important for both honey production and bee health. Honeybees need pollen and nectar to support the growth of their brood and enable them to go on foraging flights (Degrandi-Hoffman et al., 2008). When the natural pollen supply is insufficient to maintain bee health during lean seasons, Pakistani apiarists commonly feed their honeybee colonies maize, soybean, and gram flour (Ullah et al., 2021). The output of honey was significantly positively correlated with supplemental sugar-feeding (Shrestha, 2018).

Another study by Hoover et al. (2022) investigated the usage of protein supplements to feed honeybees and used the amount of brood capped as their measure of productivity. In another study by Gameda (2014), it demonstrated that, during dearth, bee colonies that were fed pea flour

considerably produced more brood than colonies supplemented with sugar. During dearth period, the average quantity of brood generated by bee colonies fed on the flour is $1274.3\text{cm}^2 \pm 195\text{cm}^2$, whereas the average amount produced by colonies fed on sugar solution was $924.8\text{cm}^2 \pm 163\text{cm}^2$.

The type of supplemental feed used had a substantial impact on honey production. Bees supplemented with sugar syrup had an average honey yield per colony of 21.3 kilograms while bee colonies that were fed chickpea flour generated a higher average honey yield of 26.8 kilogram per bee colony (Gemed, 2014). According to Vrndic & Mlaan (1999) who used a mix soy flour, milk powder, and molasses, as ingredients to make a pollen supplement and assessed its efficacy, the colonies produced more honey. The findings of Nabors (2000) and Matilla & Otis (2006) also indicate pollen supplements increased the quantity of honey harvested further corroborating the application of supplementary feeding to boost honey yields.

An experiment by Sultana et al (2024) examined five inexpensive supplemental nutrients as a management tactic to increase colony productivity: sugar, banana, pumpkin, maize flour, and rice flour syrups. Interestingly, despite sugar being the most preferred feed by bees, pumpkin syrup was the most cost-effective supplement, delivering a 50% cost reduction over sugar syrup and a 71.36%, 108.36%, and 58.73% increase in honey, brood, and pollen cell production, respectively. The effects of supplementary feeding on honey yields are further evidenced by research conducted in Ethiopia where colonies fed sugar syrups and protein diets yielded more honey than unfed colonies (Amera et al., 2024). Another study in the same country attributed poor feeding management as one of the reasons traditional beehives yielded a paltry 5-8kg per hive per year (Lango & Lomba, 2020).

When natural food is insufficient, like, in dry seasons, beekeepers in Kenya are frequently encouraged to turn to supplemental feeding. Sugar syrup, honey water, or supplements high in protein, such as pollen replacements, are examples of common feed. When natural resources are limited, these meals assist keep bee colonies healthy and productive, ensuring their survival and consistent output of honey (Gachago, 2023). While the practice of providing supplementary feeds to bees is encouraged, empirical research has not been undertaken in Kenya to measure this activity's effect on honey yields unlike studies in other regions discussed above.

From the empirical studies on supplementary feeding of bees, beekeepers in all regions should be keen on identifying dearth periods in their apiary locations and possibly providing extra feed. Supplementary feeding borrows from Adaptive Management theory by Holling (1978) which encourages proactive reaction to changing situations, beekeepers in areas with scarce forage who adapt and give their bees supplementary feed could possibly obtain increased yields. This is because it has been shown that this apiary management activity has been found to have a significant relationship with stronger brood which results in increased honey production.

2.3.1.2 Queen Bee Manipulation

Queen bee manipulation can be described as the process of replacing an existing queen bee with one with more desirable traits (Agriculture Victoria, 2024). The queen bee is a crucial member of the bee colony as it is the sole reproductive female whose main task is to lay eggs (TNAU, 2014). A new queen is required for the colony if the existing one's capacity to lay eggs is compromised, as this is the main criteria for assessing her productivity (FAO, 2020). This is because the queen's ability to lay eggs causes the colony's population to grow, which in turn increases honey production because more pollen and nectar can be collected by colony members. Usually, the worker bees will rear a new queen bee if the current queen bee does not lay eggs according to their required standard, failure to distribute pheromones or when the colony becomes queen-less as a result of her death (FAO, 2021).

In managing hives, beekeepers tend to observe characteristics of the queen bee to assess her productivity and make decisions if she needs replacement. In colony management, the beekeeper checks if queen bee's wings are clipped as this may cause her to limp thereby affecting her ability to lay eggs. The beekeeper also keeps track of the queen bees age which has a lifespan of 6 years (Schumus, 2022). This is important because a report by FAO (2020) notes that young queen bees swarm less and produce about 30% more honey than queen bees older than 2 years. It is, however, important to note that some young queens perform poorly while some older ones can produce a lot more eggs.

A study by Akyol et al. (2008) examined the effects of queen-bee age on bee colonies in Turkey, one of the leading honey-producing countries in the world. It discovered a substantial correlation between queen age and brood rearing, colony strength level, honey yields, and winter population decline. Additionally, the study discovered a strong positive association between brood production

($r = 97.5$) and honey yield and colony strength ($r = 99.5$). The researchers concluded that probably aged queens were the cause of Turkey's stunted honey production per colony because the young queens generated 150% more honey than the country as a whole. Another study by Fasasi (2010) in Nigeria compared a 24-day old queen bee with an 18-month-old one and found the younger queen had a higher production of brood than the older one leading to increased honey yields.

Researchers have tried to come up with optimum requeening schedules to increase honey production, however, this has been found to vary with each region (Delaplane, 1997). For example, in Alberta, Canada, honey production was not significantly different between beehives lead by one- or two-year-old queen bees (Szabo & Lefkovitch, 1989). In Greece, a seven-year study found that honey production was the same in colonies re-queened every one, two or three years but colonies left to re-queen themselves produced far less honey (Kostarelou-Damianidou et al., 1995). In Israel, honey yields were higher in colonies headed by 7-month-old queens compared to queens aged 20-months leading commercial beekeepers to requeen annually (Hauser & Lensky, 1994). It is implied that these researchers speak to Adaptive Management Theory by Holling (1978) using queen manipulation as a strategy to increase honey yields.

In temperate climates, most beekeepers mark the queen bee and change her when they feel there is a need to do so, however, due to the aggressive nature of the African honey bee, most African beekeepers do not open their hives to mark or replace the queen bee but instead rely on swarming and worker bees to carry out the re-queening process (FAO, 2020). This makes them miss out on the benefits of regular requeening that promotes rapid colony growth which increases honey production capacity. It is also important to note that some beekeepers practice commercial queen rearing, where they manipulate bees to create new queens which they then sell to beekeepers looking to replace existing queens. For this study, it is therefore important to identify whether beekeepers in Kenya carry out any queen manipulation in their colony management practices and compare their honey yields with beekeepers that do not.

2.3.1.3 Frequency of Hive Inspection

Beekeepers, researchers, technical assistants, and farmers routinely inspect their hives to keep an eye on the issues facing bees, evaluate brood health, check their food reserves, examine how the frames are attached to the hive wall, check for ripe honey, keep an eye out for pest and predator attacks, and search for disease indicators (African Union, 2016). In contrast to traditional bee

hives, modern and transitional hives feature moveable combs that make it simple for beekeepers to access and inspect their hives to monitor their bee populations.

Beekeepers carry out hive inspections on their bee colonies at various intervals. In a study by Guesh et al (2018) many respondents stated that they check their apiaries and honeybee colonies externally regularly (daily to weekly). Additionally, the findings demonstrated that most beekeepers examine apiaries and honeybee colonies from the outside. When most beekeepers visit their hives, they only carry out exterior inspection which includes observing the movement of the honeybee colonies in flight and to spot natural catastrophes and risks. Most beekeepers just happened to check their honeybee colonies internally when it was convenient for them. The beekeepers' external colony inspection of traditional and frame hives revealed no significant difference ($\chi^2= 2.625$, $p>0.05$). Nonetheless, there was a noteworthy distinction ($\chi^2= 49.180$, $p<0.01$) between frame hives and traditional beehives in the internal inspection that was conducted.

In other studies by Kerealem et al. (2009) and Gebretsadik & Negash, (2016) internal hive inspection was only conducted when a colony starts to weaken and during the honey harvesting season. This was mainly attributed to a lack of personal protective gear which causes stinging fears. Lack of frequent internal inspection was also attributed to the risk of a bee colony swarming away and poor understanding of the importance of regular beehive inspections. In addition, practically every beekeeper in the research said that they cleaned the area around their apiary and conducted external inspections to keep ants and other insect pests out of their hives (Gebremeskel et al., 2015).

According to research data presented by Lebedev (1979), the amount of honey harvested decreased with the increase of detailed hive inspections which involved removing and observing each frame. Beehives inspected every 6 days produced the least amount of honey at 20.3kg per colony while those inspected only 4 times in a season produced the most of honey at 29.2kg per colony. The removal and detailed inspection of each frame is found to significantly disrupt the honey-making process as bees must first repair any damaged parts limiting efforts to grow the brood and make honey (Honey Flow, 2021). The adaptation to optimal inspection frequencies for increased honey production speaks to the application of Adaptive Management theory by Holling (1978).

In another paper looking at hive inspection trends in Ethiopia, Lango & Lomba (2020), while acknowledging the importance of this practice in managing honey productivity, noted that many beekeepers only conducted external hive inspections and that those carrying out internal beehive inspections did so rarely. The paper also noted while there are many motivators for carrying out hive inspection, prevention of honey loss due to pest attack, was the top reason for conducting this apiary management activity. This study, however, did not empirically link the type or frequency of hive inspections to its effect on the honey yielded.

In Kenya, many researchers have noted the importance of frequent hive inspection to maintain healthy colonies and good honey production. Some researchers such as Musimba et al. (2016) recommend routine hive inspections, usually every 1-2 weeks during active seasons to keep an eye on food stores, sickness, queen activity, consistency in the brood, and honey readiness. By calming the bees with methods like smoking, inspections go more smoothly and the colony experiences less stress (Farming in Kenya Consultancy, 2024). Furthermore, a few obstacles have prevented the adoption of effective procedures that may increase the frequency of inspections and honey output in Kenya, such as inadequate training for farmers, restricted access to contemporary hives, and limited financial facilities (Hecklé et al., 2018).

Despite beehive inspection being a key activity in maintaining a colony's health through early detection of diseases and honey readiness, there has been no research empirically measuring the effect of hive inspections on honey yields in Kenya. This research would be key in establish optimal inspection frequency rates and establishing at which point the amount of hive inspections start to decrease the amount of honey produced by the colony.

2.3.1.4 Pest and Diseases Management

Several studies have listed pests and diseases as the leading constraint in honey production. Studies by Kerealem et al (2009), Beyene & Woldatsadik (2019), and Haftu et al. (2018) listed pests, predators, and diseases as the biggest constraint to honey production, it specifically listed ants, wax moth, and honey badgers as the leading cause of honey losses. A study done by Tesfaye et al (2017) to assess honeybee enemies in southern Ethiopia, beekeepers acknowledged the huge problem caused by pests and predators in their honey production. Among those surveyed, 50.3% reported the honey badger as a serious challenge causing loss to their honey and hive products.

Similarly, ants, mites, and beetles are the most troublesome pests that lower the amount and quality of honey collected, this is according to Bett (2017) who undertook a case study of Honey Care Africa in Trans Nzoia, Kenya. Both ants and beetles raided beehives for larvae and honey while taking soil into the hive mixing with honey and lowering its quantity and quality.

According to Kasina et al. (2024), Kimitei et al., (2024) and Mulwa et al. (2024) some common pests affecting bees in Kenya are hive beetles, wax moths, and varroa mites. The hive beetle is known for causing damage to honeycombs, stored honey, and pollen which results in discoloration and fermentation of honey. When attacked by this pest, bees tend to abandon their hive in search of a new home (Kasina et al., 2024). Detection of this pest is done visually through colony inspection where they can be seen running on the underside of the hive once opened. Prevention and control of this pest is through maintaining good hygiene around the apiary. A bottle trap containing an attractant; a concoction of water, vinegar, sugar, and a ripe banana peel can also be used to kill the hive beetle before it enters the beehive.

The wax moth is known for laying eggs in the combs where they hatch into caterpillars in 5-8 days. These caterpillars then aggressively feed on wax, brood, and honey cells which affects bee colony development (Kimitei et al., 2024). While the health of humans is not directly harmed by the pest, it causes a 100% loss in hive productivity by the destruction of combs and the consumption of bee pollen and wax which occasionally results in bees fleeing hives. Weak colonies are often predisposed to this pest further strengthening the need for queen manipulation in order to maintain strong colonies. Its presence is detected by a white silky trail found on the honeycombs. Its prevention and control is similar to hive beetles described above in addition to removing excess empty combs.

Varroa mites are tiny reddish-brown exterior parasites that live on adult honeybees feeding on their blood. These parasites breed on bee pupae growing in the brood causing deformity and weakening of honeybees in addition to spreading a variety of viruses (Mulwa et al., 2024). This results in crippled honeybees with damaged wings impairing forage activities for honey production. Infections occur when honeybees migrate from infected colonies into non-infected colonies or when bees raid infected hives for honey. This pest is known for inflicting the highest economic losses among all pests and diseases affecting bees globally (Genersch, 2010). Additionally, swarms and absconding colonies may disperse the Varroa mites throughout a region. Detection is carried

out by putting a sample of bees from a suspected colony in a container, pouring icing sugar on the bees, shaking the container, turning the container upside down then releasing the bees. The icing sugar is then poured on a white background where the pest will be observed.

The most notorious diseases infecting bees in Kenya are the European foul brood, deformed wing virus, and nosema diseases. Other pathogens that infect bee colonies include varroa destructor, black queen cell virus, and sac brood virus. It has been noted that bee diseases are not as serious as pests but have the potential to cause serious challenges with the increase of beekeeping activities in the country (Guantai et al., 2024). These diseases weaken bee colonies and reduce their capacity to forage and produce honey. Requeening of hives is suggested to strengthen genetic diversity to fight disease infection.

A study in Kenya by Onyango et al. (2018) done to gauge the awareness and responses of beekeepers to the pests and diseases discussed above, found that 95% had challenges with pests. While 90% of the surveyed respondents undertook some pest management against ants, beekeepers had no idea how to manage hive beetles, wax moths, and varroa mites. One of the leading reasons the other pests were a challenge in managing was due to poor identification since most honey harvesting is done at night. Pest and disease management as an apiculture colony management practice borrows from Adaptive Management Theory by Holling (1978) in anticipating through the laying of traps which has seen those practicing it have reduced honey losses.

The pests and diseases described in this section all have an impact on honey production as they all affect the productivity of honeybees. Each pest and disease have its suggested beekeeping management practice for prevention and control. This study will therefore seek to identify if the targeted beekeepers apply any of the suggested management practices and if it has any effect on honey yields compared to those who do not apply the practices.

2.3.1.5 Precision Colony Management

Precision agriculture in crop and livestock management entails the use of Internet of Things sensors to transmit and analyze vast amounts of data on crop and animal health. The sensors measure the physical parameters such as soil moisture, temperature, humidity, soil nutrition, pest and weed presence, plant chlorophyll content, weather, and send the collected data to a computing device. All the collected data is then analysed to produce agronomic recommendations such as,

which fertilizer to be applied, irrigation quantities, diseases or pest remedy. The timely reception and application of these recommendations are key to enhancing crop yields (Shafi et al., 2019). The USDA revealed that the operating profits of farmers applying precision agriculture is estimated at \$163 - \$272 per hectare higher than those who did not depending on the crop (Saiz-Rubio & Rovira-Más, 2020) demonstrating the financial impact data-driven precision methods can have on agriculture.

Precision agriculture's primary function in livestock farming is to make it easier to collect, process and analyse data so that the farmer is presented with solutions to farming challenges. This has been applied in monitoring water usage, counting eggs, weighing birds, controlling the environment where the livestock are kept, computerized feed systems, automatically detecting diseases, and measuring growth (Banhazi et al., 2012). Precision agriculture is an adaption to the technological advancements in other industries into agriculture for increased outputs which could be an inspiration from the application of adaptive management theory (Holling, 1978).

Precision Apiculture, a subset of Precision Agriculture, is centered on employing IoT-based technology to continuously monitor bees throughout their life cycle and production stage. This is accomplished without putting the bees through needless stress to minimize waste of resources and ensure the bees are as productive as possible. The goal of all these sophisticated instruments is to assist the beekeeper, who is still the most important component of proper apiary management, rather than to replace them (Zacepins et al., 2013). In addition to record-keeping, precision beekeeping enables the data analysis on hive weight, temperature, sounds & vibrations, humidity, as well as weather conditions to evaluate which beekeeping actions or scenarios contribute to the highest honey produced (FAO, 2021).

An important view on the interactions between bee colony health and the natural environment is provided by longitudinal data obtained from continuous hive monitoring. This data allows correlations between bee activities, such as changes in forager intensity, with changes in hive health and queen status, as well as with external factors, such as weather, nectar flow, or pesticide exposure (Meikle & Holst, 2014).

There is an opportunity to further explore the viability of precision apiculture to remedy Kenya's apiary management challenges in a quest to achieve the country's honey production potential. However, before going into building new technological solutions it would be prudent to first

identify which specific apiary management challenges face Kenyan beekeepers before applying precision apiculture.

Precision beekeeping is still a new and emerging management trend whose research results has not been easy to generalize as experiments have been conducted at different times, locations, with different beehive designs or even bee species subtypes (Hadjur et al., 2021). According to Catania & Vallone (2020) use of a precision apiculture system, honey production declines as wind speeds increase. This is evidence of decisional support provided by technology that could then inform the beekeeper of better hive placement for increased honey yields.

A pattern of hive weight change was established by Meikle & Holst (2014), a pattern of daily weight loss was associated with nectar drying; a process that leads to the production of honey. The hive weight pattern was then compared with time; loss of weight in the morning was associated with bees leaving the hive to forage for pollen and nectar with a hive weight gain observed in the afternoon and evening with bees returning to the hive (Hambleton, 1925). Another empirical study by Meikle et al (2008) examined the usage of continuous weight monitoring over the course of a month, recording data every quarter of an hour using a precision weight scale that was connected to a computer. The data collected linked the change in hive weight to infestation of mites which led to the bees abandoning the hive.

Infrared technology has also been used as a non-intrusive measurement of beehive temperature (Kviesis & Zacepins, 2015). This is best applied before dawn as there is maximum heat contrast between the beehive and the external environment. The use of this technology enabled rapid measurement of the bee colony population (Zacepins & Karasha, 2013). Colony population estimation can then assist in hive management, the beekeeper can make plans to split the hive, carry out requeening, anticipate swarming in cases where the population is large or to even add extra supers in the case of Langstroth bee hives for added honey yields.

Precision apiculture is a modern technological apiary management practice that can help beekeepers in carrying out the other colony management practices discussed in this chapter. While it is generally expensive to implement, more research is required on the impact of its application on apiary management and honey yields.

2.3.2 Apiculture's Socioeconomic Management Practices and honey yields in Kenya

Socioeconomic management practices can be described as an approach that considers both people and finances in its analysis for decision-making (Conbere & Heorhiadi, 2011). In apiary management, age is one factor found to influence beekeeping operations as only those aged 20-40 years have been found able to undertake harvesting activities compared to those above 50 years (Masuku, 2013). While influences beekeeping operations, the beekeeper's age has not been found to conclusively impact honey yields. On the other hand, beekeeper's experience has been listed in several studies such as Chemwok (2016) in Kenya, Masaku (2013) in Swaziland and Mubarik & Buyinza (2020) in Uganda as a factor that affects honey yields.

Gender has also been found to be a factor affecting honey production; this is due to the difficulty in harvesting brought about by bee stings, tree climbing and the sharing of household chores that may limit the involvement of women in apiary management activities (Dauda et al., 2019). Despite beekeeping being a male-dominated field, more women are joining this occupation proving its success in honey production relies more on knowledge, patience, and connection to nature than physical strength (UNDP, 2024). The use of beekeeping suits, smokers, and hive placement on stands or sheds rather than hanged on trees are some of the factors that have enabled more participation and success of both women and men in beekeeping (Raina et al., 2009).

The financial and economic aspect of management practices influence one's ability to select the type of beehive. In a publication by Adgaba et al. (2014), beekeepers who owned Langstroth beehives harvested a greater amount of honey than beekeepers who owned other beehive types. Further investigation showed a significant relationship between the average yearly production of honey and the kind of hives (Aksoy et al., 2018). In other studies, by Mbah (2012) and Tijani et al. (2011), the yearly revenue of apiarists increased significantly with the quantity of hives owned. Although it is not obvious that more hives will produce more honey, the quantity of hives should not be the sole measure of a beekeeping program's success. For example, in a study by Mubarik & Buyinza (2020), honey production rose with the expansion of hives up to 80 bee hives beyond which honey yields per hive began to decrease. This is because while larger-scale systems have the potential to give bigger yields and consequent income, they also demand more labor and input costs, and they depend on the availability of floral resources (Shrestha, 2018)

Education level has also been identified as a socioeconomic factor that has an impact on honey yields. One analysis by Dingtounda et al. (2024) discovered that beekeepers with higher education levels were more inclined to adopting improved beekeeping practices that resulted in better colony management and increased honey production. In a different study by Mubarik & Buyinza (2020) the level of beekeeping training did not translate to increased honey production; this was partly attributed to the laxity of beekeepers in applying the knowledge they had received. A study by Serra & Davidson (2020) found that cooperative membership remarkably raises both the price and quantity of honey. The research suggests that cooperatives enable beekeepers to adopt better practices and access markets more effectively, leading to higher honey yields. Cooperative membership also gave beekeepers access to beekeeping equipment such as bee suits which enabled them to harvest more honey (Rimui & Lufuke, 2024). While other studies by Deksisia et al (2024) and Chemwok (2016) have mentioned access and frequency of extension services as a socioeconomic factor affecting honey yields, this can be addressed through cooperative organization and membership. A lot of emphasis is usually put on colony management practices, however, from the extensive literature review discussed in this section, socioeconomic factors are also key in managing for improved honey yields. A combination of the application of colony management practices and an awareness of socioeconomic factors puts a beekeeper in a better position to increase their honey yields compared to those who do not apply.

2.3.3 Apiculture's Environmental Management Practices and Honey Yields

Environmental management practices significantly influence honey yields by affecting bee health, forage availability, and exposure to pesticides. Honeybees use flower nectar as a key ingredient to produce honey (National Honey Board, 2022). This apiary management practice applies forage theory by Kerbs & Stephens (1986) which considers an animal's decision-making process in its search for food.

The changes in land use have impacted the environment in which bees forage by reducing pollen and nectar supply leading to decreased honey yields (Picknoll et al., 2021). Deforestation, increased farming activities, and construction have all led to a decrease in forage resources leading to an increased amount of energy spent in search pollen and nectar. The increase in energy spent foraging not being commensurate with the energy gained has forced bees to deplete honey stores within the hive leading to decreased yields for the beekeeper (Tomlinson et al., 2017). It is highly

recommended that farmers and ranchers refrain from purposefully removing and burning shrubs during the dry season and at the beginning of the planting season. This is among the factors causing bees in impacted areas to swarm in quest for refuge where they may be sure to find food and water. In addition to destroying beehives on tree branches, these bush-fires have the potential to disrupt the honeybee calendar's next build-up phase (Oluwaseyi et al., 2021).

When comparing bee colonies in protected areas such as forests to those in farmlands, the quantity of combs containing bees, brood, and honey indicated a better performance of the former. Bee resources like natural homes and feed are lost when land is turned into agricultural land (Vaudo et al., 2011). For instance, studies have revealed that, in comparison to protected regions, farmlands with eucalyptus trees have greater rates of infection *nosema ceranae* (Invernizzi et al., 2011) and bee pests (Chemurot et al., 2018). The poor performance of honeybee colonies in farmlands as opposed to protected areas is compelling evidence in favor of preserving natural or semi-natural settings for beekeeping. A two-year study by Sande et al. (2009) looked into the logical hypothesis that hives closer to forests generate extra honey when compared to hives farther away, this obliquely implies proximity to a forest influences bee activity. However, the study's conclusions demonstrated that there was no appreciable variation in honey yield over the forest's distances. Forage theory by Kerbs & Stephens (1986) did not seem to hold in this instance as it would have been assumed proximity to more desirable forest foliage would have resulted in increased honey yields.

A study by de Graaf and Chemurot (2019) which looked at honey yields in different agro-ecological zones of Uganda, considered the relationship between altitude, season, dominant vegetation type, and honeybee colony performance. Seventy-four percent of the variation in the amount of honey gathered was explained by the linear regression model that was created. Altitude and honey yields showed a substantial negative correlation. This is because it is colder at higher elevations as studied by Hemp (2005), this forces bees to take more time warming the hive, this then limits their ability to forage resulting in poor colony performance at higher elevations. Season was the only predictor that substantially predicted the amount of honey harvested, however all other factors listed explained the amount of honey produced

In a different study, Oluwaseyi et al.(2021) examined how floral diversity affected the amount of honey produced in several regions of Nigeria. The study identified individual tree species foraged

by bees and grouped them into 13 families noting their abundance, frequency, density, dominance, and created an important value index (IVI). With an IVI of 22.93, *Mangifera indica* was the most significant species, prevalent (6.67), dominant (2.67), and has the greatest density (13.59). Variations in the study locations' flora and honey production quality were also presented showing Asa local government area having a floral structure producing the highest quality honey among the study areas.

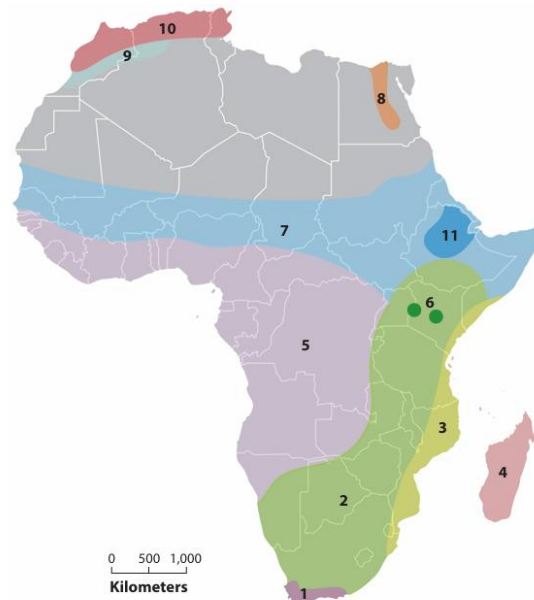
In Kenya, research conducted by Asiko et al. (2017) at the National Beekeeping Institute found that planting bee forage can sustainably grow the beekeeping industry. The planting of kales, sunflowers, and strawberries to boost bee forage during the dry season led to a 54% increase in colonized hives as bees will migrate to areas with adequate forage. Increased colonization rates brought about by environmental management directly contributes to an apiary's honey production capacity. It has also been noted that plants such as Mexican marigold and puff ball act as bee repellents and management should ensure that they are not planted close to apiaries as this can cause swarming and decrease honey yields (KALRO, 2023).

Climate change has caused a variation in temperature and rain patterns which has impacted forage patterns resulting in decreased honey production in ASAL Kenya (Akala et al., 2018). The case study done in Baringo County found that the impact of rainfall variability on plant phenology is a significant positive correlation which changes the flowering times of many food plants and the bees' feeding habits, which lowers honey output. Apiculture environmental techniques are required to lessen the impact of climate change on honey production. Empirical evidence discussed in this section has shown that beekeepers ought to manage pesticide usage, floral diversity, and hive placement as these practices all influence bee colony performance and honey yields.

2.3.4 Moderating effect of bee species on the association between apiary techniques and honey yields.

There are about 20,000 known species of bees, all known species of honeybees are found in the single genus *Apis*, which contains at least 44 subspecies with varied characteristics and honey production levels (Senior, 2021). For example, *Apis dorsata* are large in size, construct a single comb and produce about 36 kilograms of honey annually. *Apis florea* are among the smallest honeybees, they are rarely reared as they frequently swarm and produce about half a kilogram of honey per hive per year. *Apis cerana indica* builds multiple parallel combs and it is larger than

Apis florea but smaller than *Apis dorsata*, it yields about 6-8 kilograms of honey per colony annually. *Apis mellifera* has an average annual honey production of 25-40 kilograms per colony and is less prone to swarming (TNAU Agritech Portal, 2014). Figure 2.3 shows the distribution of *Apis mellifera* sub-species across Africa.



Geographic distribution of honey bee (*Apis mellifera*) subspecies in Africa based on morphoclusters identified by Hepburn & Radloff (43). (Location 1) *A. m. capensis*. (Location 2) *A. m. scutellata*. (Location 3) *A. m. litorea*. (Location 4) *A. m. unicolor*. (Location 5) *A.m. adansonii*. (Location 6) *A. m. monticola*. (Location 7) *A. m. jemenitica*. (Location 8) *A. m. lamarckii*. (Location 9) *A. m. sabariensis*. (Location 10) *A. m. intermissa*. (Location 11)

FIGURE 2.3 HONEYBEE SPECIES IN AFRICA (SENIOR, 2021)

Apis mellifera is found in Kenya in three subspecies whose quantity of yellow bands around the abdomen differs: *Apis mellifera litorea*, *Apis mellifera scutellata*, and *Apis mellifera monticola* (Raina & Kimbu, 2005). Geographical characteristics and climatic circumstances have an impact on their spread throughout the nation. The location of each subspecies is largely determined by elements like the terrain and weather patterns. The smallest subspecies of honeybee, *A.m. litorea*, is mostly found along the East African coast in low-altitude areas. In contrast, *A.m. monticola* is bigger, black, and found in hilly forest regions while *A.m. scutellata* is primarily found in savanna grasslands and has a yellowish tint (Frazier, 2024).

Honey output can be impacted by the foraging habits, disease resistance, and environmental adaptability of different bee species. In contrast to other subspecies, the Buckfast bee, a hybrid created for increased production and disease resistance, has been recognized for its exceptional

honey-gathering with some studies showing that they frequently give more honey (Ivancia et al., 2020). It is plausible to assume that the effectiveness of specific management strategies may differ depending on the species of bee, even though there is no direct research on the moderating influence of bee species. For instance, due to variations in behavior, physiology, or environmental adaptability, a management strategy that increases honey production in one species might not have the same impact in another. Therefore, optimizing management procedures to achieve increased honey yields requires an awareness of the unique requirements and traits of the bee species in question.

The identification of bee species in research is typically done through sample collection across different geographical locations followed by analysis since each species differs in abdomen band color, size, and cubital index (Raina & Kimbu, 2005). The collected samples are then verified against morphometric traits. Due to swarming brought about by seasonal pressure, hybridization of the three honeybee sub-species has been recorded in Kenya.

2.4 Research Gaps

Studies on supplementary feeding of bees have for the most part been conducted in locations that experience winter season as the bees are not able to go out and forage for pollen and nectar. This practice has however extended to other climatic regions due to the diminishing floral resources brought about by climate change and evidence that supplementary feeding of bees can increase honey production as detailed by Shrestha (2018). This study therefore sought to examine whether beekeeping members of the Apiculture Platform of Kenya who apply this practice as part of their colony management end up producing more honey than those who do not.

The report by FAO (2020) acknowledged that most African beekeepers do not practice any queen bee manipulation in their colony management practices primarily due to the aggressive nature of African bees. This made the beekeepers lose out on the benefits of requeening which leads to increased honey production. This study generalized the beekeeping attitudes of African beekeepers. It would therefore be of importance to study the specific views of Apiculture Platform of Kenya members towards this practice and report on whether those who carry out requeening have had the increased honey production benefits consistent to the (FAO, 2020) study.

The empirical studies on precision apiculture system by Kviešis and Zacepins (2015) and Meikle & Holst (2014) examine the development of smart hives and how they can improve colony management for increased honey production. This study on the other hand examined the perception of Apiculture Platform of Kenya members towards this relatively new apiary management technology and their interest in adopting it.

In the empirical review of socioeconomic management practices, the studies by Masaku (2013), Dauda et al. (2019), and Adgaba et al. (2014) acknowledge the influence of age, gender, and type of hive owned on the production of honey. These studies were conducted in Swaziland and Saudi Arabia respectively. In addition to these socioeconomic factors, this study sought to incorporate colony and environmental management practices and evaluated which category of apiary management practices have a greater effect on honey yields.

The study conducted by Albayrak et al. (2018) looked into the factors affecting honey yields in Turkey. While this study acknowledged the impact of apiary management practices on honey yields, it focused largely on environmental management practices with interest in the proximity to forage sources and forage quality in their analysis of factors affecting honey yields. The study used cognitive fuzzy maps as its methodology in determining the effects of the practices on honey production while this study used a regression model. A research gap also exists as this study sought to add other apiary management practices such as socioeconomic and colony management which has been found to influence honey yields. Furthermore, the study by Albayrak et al. (2018) had been conducted in Turkey, leaving a location research gap for a similar study to be conducted in Kenya.

TABLE 2.1 SUMMARY OF RESEARCH GAPS

Author	Topic of Study	Key Findings	Research Gap
(Ullah et al., 2021)	Nutritional effects of supplementary diets on brood development biological activities and honey production of <i>Apis mellifera</i>	Supplementary feeding of honeybees resulted in increased honey yields.	This study sought to establish whether supplementary feeding of bees as part of apiculture's colony management practices influences honey yields

			among Apiculture Kenya members.
(Albayrak et al., 2018)	Development of intelligent decision support system using fuzzy cognitive maps for migratory beekeepers.	Cognitive Fuzzy Maps were able to predict honey output based on an array of socioeconomic, environmental and colony management practices in Turkey.	This study sought to use a survey and regression of apiculture's socioeconomic, environmental and colony management practices to establish their effect on honey yields among Apiculture Kenya members.
(Masuku, 2013), (Chemwok, 2016)	Socioeconomic analysis of beekeeping in Swaziland: A case study of the Manzini Region, Swaziland Factors influencing Honey Production in Marigat, Baringo County - Kenya	Age and experience were found to be a significant socioeconomic factor that influenced beekeeping operations and yields.	This study sought to establish the effect of apiculture's socioeconomic, environmental and colony management practices to on honey yields among Apiculture Kenya members.
(Sande et al., 2009)	Proximity to a forest leads to higher honey yield: Another reason to conserve.	There is no relationship between proximity to forests and honey yields.	This study sought to establish whether proximity to forests among other environmental management factors have a relationship with honey yields among Apiculture Kenya members.

Researcher 2025

2.5 Conceptual Framework

According to Smyth (2004), a theoretical model under investigation and the connection between independent and dependent variables make up a conceptual framework. Figure 2.4 described below expresses the relationship the researcher feels exists between variables so as to examine the effects of apiary management practices on honey yields as described in the earlier chapters. The conceptual framework borrows from two theories; Foraging Theory by Kerbs & Stephens (1986) which speaks to the provision of environmental resources to bees to lessen energy consumption on foraging to increase time spent on production. This theory covers apiculture’s environmental management practices by considering the forest and water proximity as factors having influence on honey yields. The second theory, Adaptive Management Theory by Holling (1978) speaks to both apiculture’s socioeconomic and colony management practices as it advocates for the integration of social, economic and environmental policies as well as predictive and responsive management to changing conditions.

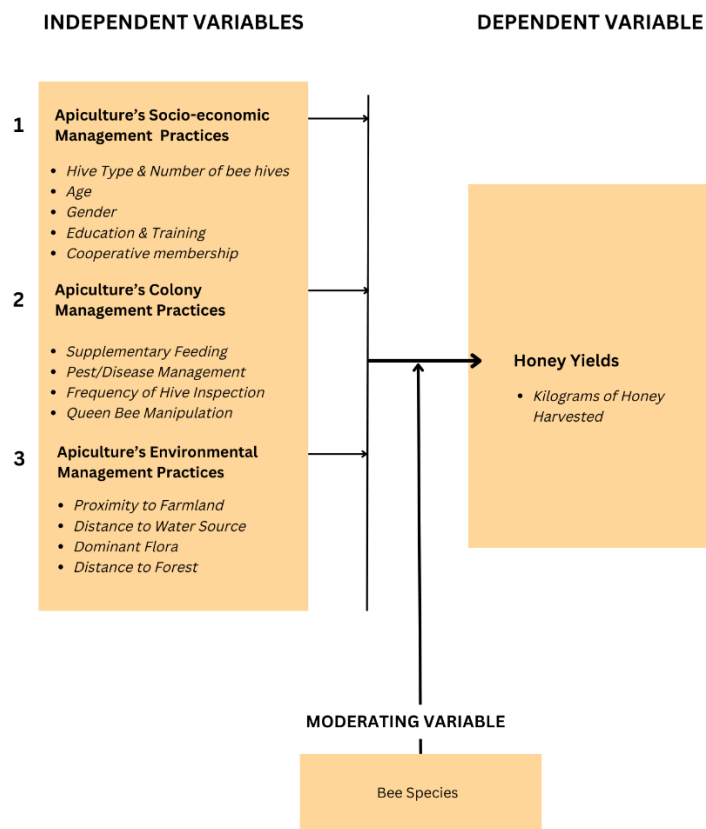


FIGURE 2.4 CONCEPTUAL FRAMEWORK (RESEARCHER 2025)

2.6 Operationalization of Variables

The operationalization and measurement of the independent and dependent variables outlined in Figure 2.4 were to be undertaken in the conduct of this dissertation, as indicated in Table 2.2.

TABLE 2.2 OPERATIONALIZATION OF VARIABLES

Identification	Variable Indicator	Data Collection Method	Source
Dependent Variable: Honey Yields	<ul style="list-style-type: none"> Honey harvested per bee colony 	Questionnaire	(Djurabaev & Rashidov, 2021), (Guesh et al., 2018) (de Graaf & Chemurot, 2019)
Independent Variables: Apiculture's Socio-economic Management Practices	<ul style="list-style-type: none"> Hive type Number of bee hives Beekeeping experience Age 	Questionnaire	(Schouten, 2020), (Adgaba et al., 2014), (Tijani et al., 2011), (Gebeyehu et al., 2010), (Minja & Nkumilwa, 2016).
Apiculture's Colony Management Practices	<ul style="list-style-type: none"> Supplementary Feeding Pest/Disease Management Frequency of Hive Inspection Queen Bee Manipulation 	Questionnaire	(Gebeyehu et al., 2010), (Wagner et al., 2019), (Nganso et al., 2023), (Guesh et al., 2018), (Shrestha, 2018).
Apiculture's Environmental Management Practices	<ul style="list-style-type: none"> Agro-ecological zone Dominant Flora Distance to water source Distance to Forest 	Questionnaire	(de Graaf & Chemurot, 2019), (Riciglianz et al., 2019), (Wagner et al., 2019) (Guesh et al., 2018)
Moderating Variable: Bee Species	<ul style="list-style-type: none"> <i>Apis mellifera scutellata</i> <i>Apis mellifera litorea</i> <i>Apis mellifera monticola</i> 	Scoring; 1 for <i>Apis mellifera scutellata</i> and 0 for other species.	(Frazier, 2024), (Senior, 2021), (TNAU Agritech Portal, 2014)

Source: (Researcher 2025)

2.7 Chapter Summary

This chapter discussed the theories establishing the foundation of this research study. These theories are foraging theory and adaptive management theory. It also reviewed previous studies undertaken by different scholars on topics such as supplementary feeding, queen bee manipulation, pest and disease management in beekeeping as well as socioeconomic and environmental apiculture management practices. This sections also provides the literature research gaps, the conceptual framework and operationalization of the study variables.



CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides a comprehensive summary of the techniques to be employed in completing the dissertation. It details the population of interest, the data collection procedure, the research philosophy, and the ethical considerations followed during the study.

3.2 Research Philosophy

According to Saunders et al. (2019), research philosophy is a set of presumptions and beliefs about how knowledge is developed. There are five types of research philosophies that can be used to guide a study though only one can be applied. The first is positivism, a research philosophy rooted in the belief that knowledge should be derived from empirical, observable, and measurable evidence, adhering strictly to scientific methods to ensure objectivity and universality (Comte, 1896). Positivism asserts that phenomena can be studied through systematic observation and experimentation, prioritizing quantifiable data and logical-deductive reasoning (Popper, 2002).

The second one is pragmatism philosophy which holds that ideas are only significant when they facilitate action (Kelemen & Rumens, 2008). This philosophy's research starts with a challenge and aims to provide practical answers that inform future procedures (Elkjaer & Simpson, 2011). The third one is interpretivism research philosophy which prioritizes understanding the subjective meanings, intentions, and contexts through which individuals construct their social realities, rejecting positivism's pursuit of objective laws (Creswell, 2007). Methodologically, it employs qualitative approaches such as interviews, ethnography, and discourse analysis to explore how people interpret their experiences, emphasizing co-creation of knowledge between researcher and participant.

The fourth philosophy is postmodernism, a study methodology that highlights the importance of language and power dynamics in challenging or upending the existing quo in terms of thought processes and providing a marginalized alternative viewpoint. Its value-driven research methodology and the researcher's radical reflexivity are like those of the interpretivism philosophy (Lyotard, 1984). The fifth and final research philosophy is critical realism which asserts that observable phenomena are shaped by underlying causal mechanisms and social structures (Bhaskar, 2008).

This study was guided by post-positivism research philosophy. This is influenced by the focus on discovering observable and measurable facts and regularities that can lead to production of credible and meaningful data (Saunders et al., 2019). It is also applied to look for causal relationships in the study in order to create law-like generalizations.

3.3 Research Design

The structure employed for data collection and its analysis is determined by research design as highlighted by Marczyk et al. (2010). Guided by post-positivism research philosophy, this study applied a descriptive-cross sectional research design which paints an accurate profile of the implementation of apiary management practices and their relationship with honey yields and the causal relationship between variables. The purpose of this study was descriptive research as it has been reported that descriptive research enables conclusions to be drawn about the state of phenomena regarding variables (Dannels, 2018). Descriptive research entails studying participants without altering their behavior as noted by Elle (2023), it was thus deemed appropriate. The descriptive survey approach was used in this study because it tabulates data on variable frequencies, analyzes them, and makes it simple to generate models of these associations and offers potential explanations for specific interactions between them. The descriptive design also allows researchers to paint a picture of the prevalence of a variable in a population, thus useful in identifying and generating hypothesis (Setia, 2016). This research strategy was a survey of the members of a beekeeper's association; an electronic questionnaire was used for data collection and quantitative analysis. Cross-sectional research designs are cost-effective and time efficient as data is collected at a single point in time as noted by Creswell (2014) but are therefore limited in their ability to establish causality (Polit & Beck, 2017). Cross-sectional designs provide a snapshot of relationships between variables at a specific time, aiding in understanding current states or behaviours (Wang & Cheng, 2020).

3.4 Population

The target population of interest in this research was the Apiculture Platform Kenya members. This is a group of 135 practitioners in the apiculture industry in Kenya (APK, 2024). The aim of this association is to share information on beekeeping, this includes new methods, equipment, honey sales, training, events, pest and diseases management, and everything bees (Apimondia,

2019). Research data was collected through a census, therefore there was no need for sampling.

3.5 Data Collection Method

In this research study, collection of data was done using a questionnaire. This data collection method was chosen as it aligns with the research design and philosophy described earlier. The questionnaire comprised closed-ended inquiries and a 5-point Likert scale which were drafted according to the research questions. Every section of the questionnaire focused on a sub-variable addressing the dependent variables and independent variables.

Two research assistants were recruited to assist in administering the survey to the target population. The survey was distributed electronically to the population using a web application link; QuestionPro. The pilot study was administered to 14 respondents who were members of the target population. These members were chosen through simple random sampling where random numbers were generated alongside the contacts provided. The members were then contacted based on the random numbers till 14 members had completed the questionnaire. The 14 members who participated in the pilot study were then removed from the contact list to ensure no new data was collected from them, the data from these respondents was also not included in the main study results. Pilot study data was subjected to construct validity and reliability assessment ensuring that the questions were well understood.

3.6 Research Quality

Research quality was achieved by ensuring techniques used can result in similar findings when applied by others wishing to conduct similar study.

3.6.1 Validity of Instruments

An investigation was carried out to seek whether the questions in the survey adequately address this study's objectives and whether the method of recording responses was appropriate. Consistency between constructs and data, which is crucial for representing the variables, is what is meant by validity Drost (2011). Construct validity examines the degree to which each question measures the occurrence of the matters the research wants to test; this was carried out through a pilot test. On the other hand, content validity evaluates if the queries in the measuring tool properly

respond to the research questions (Saunders et al., 2019). Content validity was established through consultation with the research supervisor.

3.6.2 Reliability of Research Instruments

According to Saunders et al (2019), a research instrument's reliability is its capacity to produce consistent results under a range of conditions and at different periods. Consistent findings should be achieved whether the questionnaire was filled out by the researcher, research assistants or field workers. A Cronbach's alpha score was calculated using the data collected from the pilot test. This is a tool used in internal consistency where the correlation of responses within a subgroup of questions is measured (Field, 2018). An alpha coefficient between 0 and 1 is generated with values above 0.7 regarded as being internally consistent therefore supporting that the research instrument is reliable.

TABLE 3.1 CRONBACH ALPHA SCORES

Variable	Cronbach Alpha Scores	Number of items
Apiculture's Socioeconomic Management	.717	6
Apiculture's Environmental Management	.724	5
Apiculture's Colony Management	.747	13
Honey Yields	.752	3

Source: Researcher 2025

Additionally, the Kaiser-Meyer-Olkin KMO-Bartlett's test of sphericity was used to evaluate the validity of the individual variables and the questionnaires. Shrestha asserts that KMO levels less than 0.5 are inadequate and that values closer to 1.0 are the most desirable. The analysis resulted in a KMO score of 0.588 which is adequate as shown in Table 3.2

TABLE 3.2 KAISER-MEYER-OLKIN KMO-BARTLETT'S TEST

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.588
Bartlett's Test of Sphericity	Approx. Chi-Square	296.080
	df	36
	Sig.	.000

Source: Researcher 2025

3.6.3 Pilot Test

The questionnaire was subjected to pre-testing; this was done to recognize items which require modification. A pre-test group of 14 respondents was used as this represents 10% of the population size of this research dissertation (Cooper & Schindler, 2011). This is done to ensure questions had similar interpretation to all respondents and to modify questions that were confusing or biased. To avoid contamination, data collected from the pilot test was not incorporated in the chief results, and new data was not collected from the pilot study participants.

3.7 Data Analysis

Descriptive statistics were used in the analysis of data collected. This was expressed in the form of averages, percentages and correlations where appropriate using analytical software and web applications such as Statistical Packages for Social Sciences (SPSS), QuestionPro and Microsoft Excel. Descriptive statistics have a goal to provide the variables being assessed with context. Inferential statistics were used to draw conclusions on the data collected through analysis of variance (ANOVA), and multivariate regression analysis applied to establish relationships of variables listed in the conceptual framework.

The regression models used:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon \dots \dots \dots (1)$$

$$Y = \beta_0 + \beta_1 X_1 * \Omega + \beta_2 X_2 * \Omega + \beta_3 X_3 * \Omega + \varepsilon \dots \dots \dots (2)$$

Where:

Y = Honey Yields

β_0 = Constant

X_1 = Colony Management Practices

X_2 = Socio-economic Management Practices

X_3 = Environmental Management Practices

Ω = Bee Species

ε = Error Term

β_1 , β_2 , and β_3 , are Beta coefficients used for measuring dependent variable's sensitivity (Y) to a change in one unit of independent variables X_1 , X_2 , and X_3 .

3.8 Diagnostic Tests

This study carried out three statistical tests: normality, multicollinearity, and heteroscedasticity to ascertain concurrence with the assumptions of the regression models.

3.8.1 Normality Test

The normality test sought to determine how a dataset with a normal distribution should be organized and assesses how well the random variable affects the dataset to produce an effective and normal distribution (Khatun, 2021). Skewness and kurtosis statistics were used in this study to analyze the distribution of the data to determine normality. If a variable's skewness and kurtosis values fall between -1 and 1, it is considered normal, this was further evaluated using the Shapiro-Wilks normality test, where the significance of the deviations from a normal distribution is tested (Matore & Khairani, 2020). There is no difference between the observed distribution and the expected normal distribution, if the test is not significant ($P > .05$), it is assumed that the distribution is normal (Hernandez, 2021).

3.8.2 Multicollinearity Tests

Using the gathered dataset, a multicollinearity test was performed to ascertain the degree of association between the predictor variables. Highly correlated independent variables with one or more additional independent variables, other things being equal, have a relatively large standard error (Allen, 1997). This was done prior to performing the regression analysis as the large standard error is bound to produce skewed results (Noora, 2020). Multicollinearity was calculated using Pearson's Correlation Coefficients where values below 0.8 show that collinearity was less likely to exist.

3.8.3 Heteroscedasticity

The term heteroscedasticity refers to unequal variances of variables among distinct groups, which causes varying accuracy levels of predicting the dependent variable across different levels of the independent variables under study (Saunders et al., 2019). To investigate heteroscedasticity in the

regression model, the Breusch-Pagan test was utilized through SPSS to determine the p-value. This test establishes if there is a relationship between the independent variable values and the regression model's variance of errors. Heteroscedasticity is presumed, and the homoscedasticity hypothesis is to be rejected if $p < 0.05$ (Zhou et al., 2017).

3.9 Ethical Issues

Ensuring the protection of the rights of those impacted by a study is the goal of ethical considerations (Kumar, 2019). All necessary approvals were sought before commencement of the study. An introductory letter was also shared with the respondents to assure them that the study is voluntary and academic. Before starting the research project, the researcher sought authorization and clearance from the Strathmore Scientific Ethical Review Committee, leadership of the Apiculture Platform Kenya, and the National Commission for Science, Technology, and Innovation. An assurance of confidentiality of the responses was also included in the research instruments while giving respondents the right to forfeit the study.

3.10 Chapter Summary

This chapter presented the research methods applied in conducting this study. It contains the research philosophy and research design which formed the overall guide in the execution of the study. The target population, data collection methods, research quality, data analysis, diagnostic test and ethical considerations are all included in this section.

CHAPTER FOUR: PRESENTATION OF RESULTS

4.1 Introduction

The results of the analysis of the data gathered from the surveys are presented in this chapter. The response rate, demographic data, descriptive statistics, and inferential statistics were all included in this section, presented under the themes described in the research objectives. This chapter also contains a regression model output showing relationships between the study variables in accordance with the conceptual framework.

4.2 Response Rate

This study targeted 135 respondents but managed to reach 88 resulting in a response rate of 65%. 14 of the targeted respondents answered completed the pilot study, no new data was collected from them, 26 of the targeted respondents declined to take part in the questionnaire while 7 withdrew midway through the study.

TABLE 4.1 RESPONSE RATE

Response	Total	Percentage
Completed	88	65%
Declined/Ignored	26	20%
Withdrew Midway	7	5%
Pilot Study	14	10%
Total	135	100%

Source: Researcher 2025

4.3 Demographic Analysis

From the collected data, majority of the respondents were male at 73.86% while female was 23.86% and 2.27% preferred not to disclose their gender. This clearly shows the male dominance in the apiculture association. The age group with the most respondents is 35-44 Years at 29.5% closely followed by 45-54 Years at 25%. The 18-24 age group had the least respondents at 5.7%. The results also indicate that the association is mostly made up of experienced beekeepers; respondents with over 7 years of experience in beekeeping accounted for 65.9% of the population.

TABLE 4.2 SUMMARY OF DEMOGRAPHIC STATISTICS

Category		Frequency	Percent	Cumulative Percent
Gender	Female	21	23.9	23.9
	Male	65	73.9	97.7
	Prefer not to say	2	2.3	100.0
	Total	88	100	
Age	18 - 24	5	5.7	5.7
	25 - 34	16	18.2	23.9
	35 – 44	26	29.5	53.4
	45 – 54	22	25.0	78.4
	55 – 64	12	13.6	92.0
	Above 65	7	8.0	100.0
	Total	88	100	
Education	No Formal Schooling	2	2.3	2.3
	Secondary School	10	11.4	13.6
	Vocational School	18	20.5	34.1
	Undergraduate	48	54.5	88.6
	Masters	5	5.7	94.3
	PhD	5	5.7	100.0
	Total	88	100.0	
Experience	0– 3 Years	12	13.6	13.6
	4– 7 Years	18	20.5	34.1
	8- 11 Years	24	27.3	61.4
	Over 11 Years	34	38.6	100.0
	Total	88	100.0	

Source: Researcher 2025

Beekeepers who responded had apiaries in locations spread across the country, while most beekeepers had their apiaries in only one location, 19% had bees in multiple counties. Figure 4.1 shows that Nakuru, Narok, Kajiado and Kitui as top locations for the association’s members. It is also important to note that the beekeeping respondents had apiaries in 38 out of 47 of the Kenyan counties.

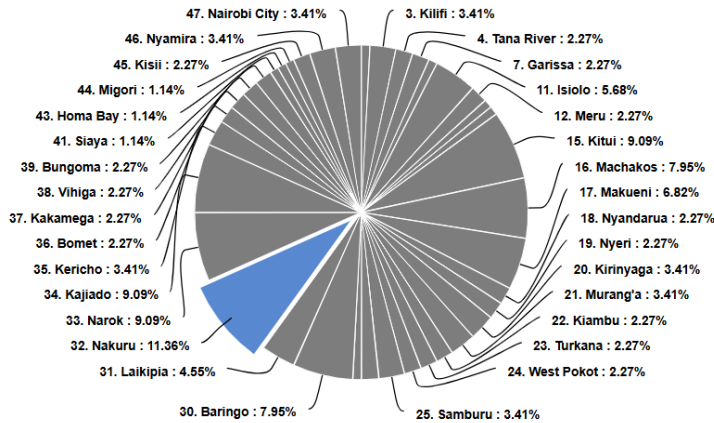


FIGURE 4.1 COUNTY APIARY LOCATION

4.4 Descriptive Statistics

The descriptive statistics were presented for each variable. Pie charts and a 5-point Linkert scale were used to present the data.

4.4.1 Descriptive Analysis of Apiculture's Socioeconomic Management Practices.

The research study's first objective is to examine apiculture's socioeconomic management practices effects on honey yields. A Linkert Scale of 1-5 measuring how often beekeepers of the association participated in apiculture related social activities: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Frequently, 5 = Always.

Statement	Never (1)	Rarely (2)	Sometimes (3)	Frequently (4)	Always (5)	Overall
Beekeeping Cooperative	18 20.45%	6 6.82%	12 13.64%	27 30.68%	25 28.41%	88 n = 88
Farmers Group	28 31.82%	18 20.45%	8 9.09%	20 22.73%	14 15.91%	88 n = 88
NGO Program	49 55.68%	10 11.36%	14 15.91%	8 9.09%	7 7.95%	88 n = 88
Savings Group	31 35.23%	8 9.09%	15 17.05%	16 18.18%	18 20.45%	88 n = 88

FIGURE 4.2 GROUP PARTICIPATION HEATMAP

Beekeeping Cooperative received most positive engagement at 59.3% ('Frequently' 30.69% + 'Always' 28.61%), only 20.45% responded 'Never' despite the study population being from an apiculture group. NGO Program received the least engagement with 55.88% "Never" (highest

negative response) and only 17.04% combined ‘Frequently’ + ‘Always.’ Participation in ‘Farmer’s Group’ showed moderate engagement at 38.64% combined ‘Frequently’ + ‘Always’ but 31.82% ‘Never.’ On the other hand, ‘Savings Group’ had mixed results at 39.28% combined ‘Frequently’ + ‘Always,’ but 35.23% ‘Never.’ The beekeeping cooperative is the most actively engaged group, while the NGO Program lags significantly. Farmers and Savings Groups show moderate participation, with Savings Group slightly outperforming Farmers Group.

TABLE 4.3 GROUP PARTICIPATION

Statement	N	Mean	Standard Deviation
Beekeeping Cooperative	88	3.398	1.482
Farmers Group	88	2.705	1.510
NGO Program	88	2.023	1.816
Savings Group	88	2.795	1.577

Source: Researcher 2025

Regarding economic and main source of income, ‘Beekeeping Activities’ formed the largest source of beekeeper’s incomes with 53.41% of the respondents selecting it, this was followed by ‘Other Farming Activities’ at 35.23% and ‘Non-Farming Activities’ at 11.36%. The primary source of financing for the beekeepers of this association is personal savings at 47.73%, highlighting a heavy reliance on self-funding. This was followed by ‘Family and Friends’ at 34.08% emphasizing the role played by informal networks. A more detailed description of sources of funding for apiculture expansion can be found in Figure 4.4

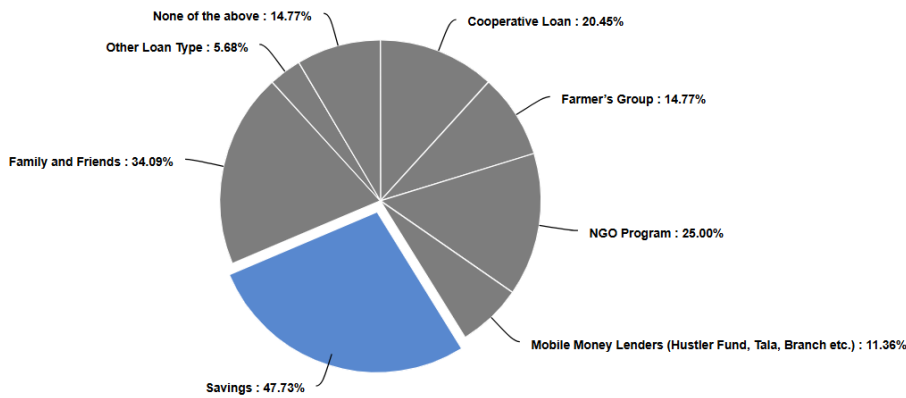


FIGURE 4.3 FUNDING SOURCES FOR BEEKEEPING GROWTH

A Linkert Scale of 1-5 measured perception of beekeeper's social activities in relation to the apiculture management practices; 1 = Strongly Disagree, 2 = Disagree, 3= Neutral, 4 = Agree, 5 = Strongly Agree. The average score was 3.27, a further breakdown of the scoring is detailed in below.

TABLE 4.4 SOCIOECONOMIC ACTIVITIES

Statement	N	Mean	Standard Deviation
Beekeeping training has given me the necessary skills to manage my apiary.	88	3.807	1.183
Engaging with other beekeepers has greatly increased my beekeeping skills	88	4.273	1.111
Access to finance has prevented me from growing my beekeeping operation.	88	2.943	1.457
Lack of beekeeping experience is the cause for my poor harvests.	88	2.136	1.315
I share or borrow my beekeeping equipment with other beekeepers.	88	2.830	1.440
My family members participate in my beekeeping operation.	88	3.375	1.216
Internet and social media have helped me improve my skills.	88	3.693	1.290
Field visits and extension services have helped me better manage my apiary.	88	3.102	1.398

Source: Researcher 2025

"Engaging with other beekeepers" scored the highest mean (4.27), nearing Strongly Agree, with low variability (SD = 1.11). This underscores the importance of community knowledge-sharing while "Beekeeping training provided necessary skills" also received strong agreement (Mean = 3.81), indicating perceived value in formal education. "Family members participate" (Mean =

3.38) suggests moderate familial support in operations on the other hand "Internet/social media improved skills" (Mean = 3.69) reflects a positive but varied reliance on online resources. "Field visits helped manage apiary" scored neutrally (Mean = 3.10), with high variability (SD = 1.40), indicating mixed experiences. In one of the phone interviews, one respondent shared the positive impact visiting model apiaries had to their operation compared to field visits from extension officers. "Share/borrow equipment" (Mean = 2.83) shows no strong consensus, highlighting diverse practices. "Access to finance prevented growth" (Mean = 2.94) leans slightly toward disagreement, but the high SD (1.46) suggests financial constraints affect some disproportionately. "Lack of experience causes poor harvests" (Mean = 2.14) is widely rejected, indicating most do not blame inexperience for low yields.

The type and number of beehives owned by the respondents was also collected and analyzed. Respondents only had the 3 most popular hives; Traditional Log Hive, Langstroth and Kenya Top Bar Hive. 'Other' type of hive had no respondents. Table 5.5 has a detailed breakdown of the hives owned by the beekeepers of this association. It was clear from the results that the beekeepers mostly owned Langstroth hives followed by Traditional Log Hives. In all hive types, ownership standard deviation was higher than the mean. The high standard deviation of 446.64, 1278.99 and 248.29 for log hives, Langstroth and KTBH respectively suggest that beehive ownership varies widely.

TABLE 5.5 HIVE TYPE AND QUANTITY

Hive Type	Count	Mean per Farmer	Std. Deviation	Median	Min	Max	N
Traditional Log Hive	12,585	143	446.639	.00	0	3000	88
Langstroth Hive	52,790	599.88	1278.981	72.50	0	8000	88
Kenya Top Bar Hive	8,838	100.43	248.288	2.50	0	1650	88

Source: Researcher 2025

4.5.2 Descriptive Analysis of Apiculture’s Colony Management Practices

The research study’s second objective is to examine apiculture’s colony management practices effect on honey yields. One of the investigations under colony management was supplementary feeding of bees, the results showed that 86.36% of the respondents did not provide any extra type of feed to their bees.

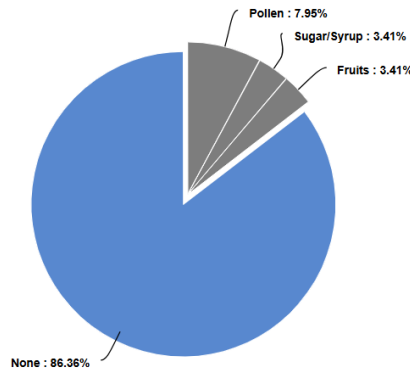


FIGURE 4.4 SUPPLEMENTARY FEED

Another crucial aspect of colony management investigated was the nuisance of pests, the most popular pest was the wax moth at 42.05% followed by Mites/Ants/Spiders at 28.41% and the Honey Badger at 11.36%. Respondents who answered other was 18.18% as shown in Table 4.6 Three respondents who were able to clarify which ‘other’ pest was a nuisance mentioned bush rats.

TABLE 4.6 PEST PREVALENCE

Answer	Count	Percent	20%	40%	60%	80%	100%
Wax Moth	37	42.05%					
Honey Badger	10	11.36%					
Mites/Spiders/Ants	25	28.41%					
Other	16	18.18%					
Total	88	100 %					
Mean 2.227	Variance: 1.396	Standard Deviation: 1.182	Standard Error: 0.126	Confidence Interval: [1.980 - 2.474]			

Source: Researcher 2025

A Linkert Scale of 1 – 5 measuring how often beekeepers of the association participated in said colony management practices; 1 = Never, 2 = Rarely, 3= Sometimes, 4 = Most of the time, 5 = All the time.

TABLE 4.7 COLONY PRACTICES

Statement	N	Mean	Standard Deviation
Bees are provided with extra feed to boost their forage stores.	88	1.568	1.285
Queen bee manipulation is a practice I undertake that is important in increasing my honey yields.	88	1.648	1.175
The area around my apiary and bee hives is cleaned.	88	3.420	1.337
I monitor the progress of my honeybees to check on their health and productivity	88	3.761	1.006
Internal beehive inspection is done during routine management.	88	2.318	1.023
I check on each queen bee's health and egg laying productivity.	88	2.011	1.160
Measures are taken to protect my bees from pests and diseases.	88	4.170	0.861
I keep records on harvests and major occurrences around my apiary	88	3.943	1.272

Source: Researcher 2025

Pest/Disease Control: Highest mean (4.17), nearing "All the time," with low variability (SD = 0.86). Nearly all beekeepers prioritize protective measures. Monitoring Health/Productivity: Second-highest mean (3.76), close to "Most of the time," indicating regular checks on bee health. Record-Keeping: Mean of 3.94, suggesting most keep harvest/occurrence records, though variability exists (SD = 1.27). Apiary Cleanliness: Mean of 3.42 ("Sometimes" to "Most of the time"), with moderate variability (SD = 1.34). Internal Hive Inspections: Mean of 2.32 ("Rarely" to "Sometimes"), showing infrequent detailed checks. Queen Health Checks: Mean of 2.01 ("Rarely"), indicating minimal focus on individual queen productivity. Extra Feeding and Queen Manipulation: Lowest means (1.57 and 1.65, near "Never"), with moderate variability. Most beekeepers avoid these practices. High SDs for cleaning (1.34) and record-keeping (1.27) reflect inconsistent adoption while low SDs for pest control (0.86) and monitoring (1.01) indicate widespread consensus on their importance.

A Likert Scale of 1-5 measured perception of beekeeper's colony management practices; 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree. The average score was 3.27, a further breakdown of the scoring is detailed in Table 5.8

TABLE 4.8 COLONY PRACTICES 2

Statement	N	Mean	Standard Deviation
Pests and diseases have significantly affected the amount of honey harvested.	88	3.659	1.285
I have all the equipment I need to take care of my bees and harvest honey.	88	3.023	1.295
The supplementary feed I give my bees changed the taste of honey harvested.	88	2.682	0.704
I would be interested in putting sensors on my hives to remotely monitor the progress of my bees.	88	3.057	1.334
The swarming of bees has greatly affected my apiary resulting in reduced honey harvest.	88	3.159	0.993

Source: Researcher 2025

"Pests and diseases affect honey harvest" (Mean = 3.66, near Agree), with moderate variability (SD = 1.29). This highlights a significant concern impacting productivity. "Have all needed equipment" (Mean = 3.02) is neutral, with high variability (SD = 1.30), indicating divergent experiences. Some lack essential tools. "Swarming reduces harvest" (Mean = 3.16) leans slightly toward agreement, but moderate consensus (SD = 0.99) suggests it's a moderate concern. "Interest in hive sensors" (Mean = 3.06) is neutral-to-positive, but high variability (SD = 1.33) reflects mixed willingness to adopt tech solutions.

4.5.3 Descriptive Analysis of Apiculture's Environmental Management Practices

The research study's third objective is to establish apiculture's environment management practices effect on honey yields. Farmland (39.77%) and Savannah Grassland (31.82%) together account for 71.59% of apiaries environments, indicating a strong preference for these environments. Likely reasons include abundant floral resources (e.g., crops, wildflowers) and favourable foraging conditions. Figure 4.5 describes the environment in which the association's beekeepers' apiaries are located.

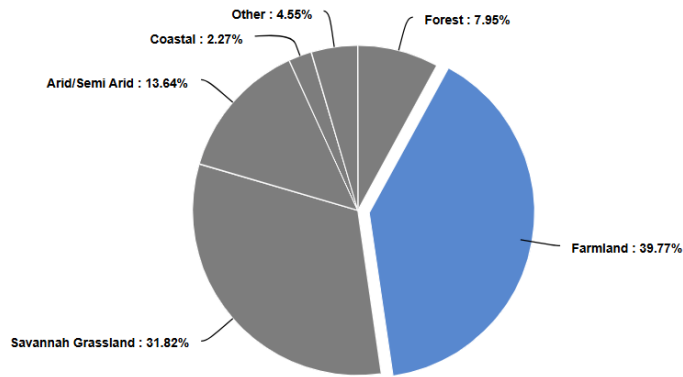


FIGURE 4.5 APIARY ENVIRONMENT

Arid/Semi-Arid Regions (13.64%) suggest adaptability of beekeeping practices to drier climates, possibly relying on drought-resistant flora or supplemental feeding. Forests (7.95%) and Coastal Areas (2.27%) are less common among members of this association. Other (4.55%) includes urban areas such as Nairobi City.

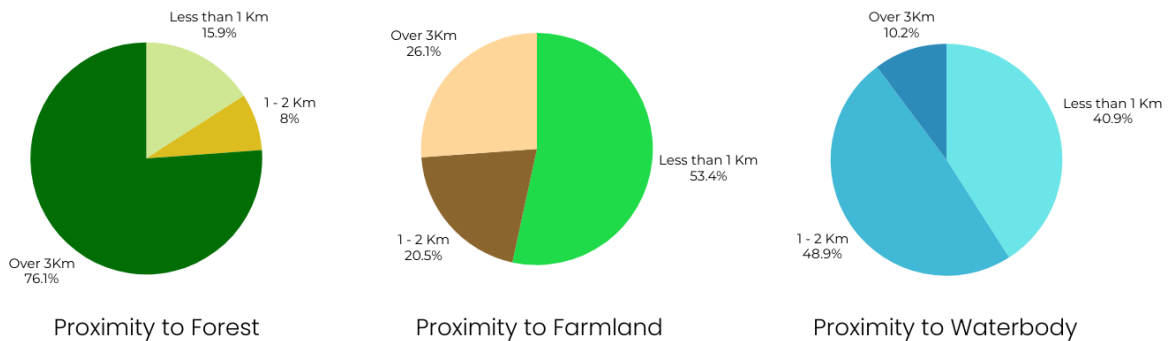


FIGURE 4.6 APIARY POXIMITY TO FORESTS, FARMLAND AND WATERBODIES

From Figure 4.6, 76.1% of apiaries are located over 3 km away from forests while only 15.9% are within one kilometre, suggesting limited forest accessibility. 53.4% of apiaries are within one kilometre from farmland, indicating strong reliance on agricultural areas for forage while on the other hand 26.1% are more than three kilometres away, possibly reflecting land-use conflicts or intentional separation. 48.9% are 1–2 km from water, with 40.9% within one kilometre, highlighting prioritization of water access for bee health. Only 10.2% are more than three kilometres from water, underscoring its critical role in apiary placement.

A Linkert Scale of 1-5 measured perception of beekeeper’s environmental management practices; 1 = Strongly Disagree, 2 = Disagree, 3= Neutral, 4 = Agree, 5 = Strongly Agree. Table 4.9 gives a breakdown of the results.

TABLE 4.9 ENVIRONMENTAL PRACTICES

Statement	N	Mean	Standard Deviation
Pesticides from nearby farms are a big problem for my bees	88	2.761	1.546
My bees always have enough forage from the surrounding environment.	88	4.091	0.942
The planting of trees and flowers around my apiary has helped increase the amount of bee products I harvest.	88	2.955	1.154
Climate change has affected the productivity of my bees	88	3.557	1.230
Extra water for bees is provided so that they don’t have to go looking far.	88	2.477	1.277
The environment around my apiary has very many types of plants, flowers, and trees.	88	3.295	1.176
The environment around my apiary mostly has one major type of plant, flower or tree.	88	2.739	1.300

Source: Researcher 2025

Forage Availability recorded ‘Strong Agreement’ (Mean = 4.09) that bees have sufficient forage, with low variability (SD = 0.94), indicating widespread confidence in environmental resources. Biodiversity resulted in moderate agreement (Mean = 3.30) that apiary environments have diverse plants, though variability exists (SD = 1.18). Climate change impact perception elicited highest concern (Mean = 3.56), leaning toward Agree, with moderate consensus (SD = 1.23). Beekeepers recognize its effect on productivity. Pesticide Impact: Near-neutral (Mean = 2.76), but high variability (SD = 1.55) reflects polarized views where some see pesticides as problematic, others do not. Water Provision: Low agreement (Mean = 2.48), near Disagree, suggesting minimal effort to provide supplemental water despite potential benefits.

4.5.4 Descriptive Analysis of Honey Production and Bee Species

This section represents data analyzed on quantities of honey produced over two seasons categorized based on the type of hive. Table 4.10 and Table 4.11 give a detailed description of honey production in 2024 by the beekeepers of this association.

TABLE 4.10 HONEY PRODUCTION

Hive Type	Season 1	Season 2	Total Honey Produced
Traditional Log Hive	53,549	15,420	68,969
Langstroth Hive	208,884	45,380	254,264
Kenya Top Bar Hive	41,886	17,723	59,609
Total Honey Produced	304,319	78,523	382,842

Source: Researcher 2025

Langstroth Hives outperformed others in Season 1, with a high mean of 2,373.68 kg and a maximum of 60,000 kg (likely an outlier). However, the median (177.50) shows most hives produced little, suggesting extreme skewness. All hive types saw reduced mean production in Season 2. For example, Langstroth dropped from 2,373.68 to 515.68. Large standard deviations (e.g., 7,179.22 for Langstroth Season 1) indicate significant spread due to outliers. Traditional Log and KTBH hives showed lower productivity, with means under 1,000 in both seasons.

TABLE 4.11 HONEY PRODUCTION DISTRIBUTION

		Statistics					
		Traditional Log Hives Season 1	Traditional Log Hives Season 2	Langstroth Hives Season 1	Langstroth Hives Season 2	KTBH Season 1	KTBH Season 2
N	Valid	88	88	88	88	88	88
	Missing	0	0	0	0	0	0
Mean		608.51	175.23	2373.68	515.68	475.98	201.40
Median		.00	.00	177.50	.00	.00	.00
Mode		0	0	0	0	0	0
Std. Deviation		2052.129	793.741	7179.217	1612.772	1516.737	763.901
Minimum		0	0	0	0	0	0
Maximum		10000	5400	60000	9500	9000	6500
Sum		53549	15420	208884	45380	41886	17723

Apis mellifera scutellata is the predominant subspecies encountered by beekeepers in their apiaries, followed by *monticola* and *litorea*. *Apis mellifera scutellata* (savannah grassland, yellowish tint) is overwhelmingly prevalent, accounting for 86.36% of observations (76 out of 88 respondents) as shown in Figure 4.7

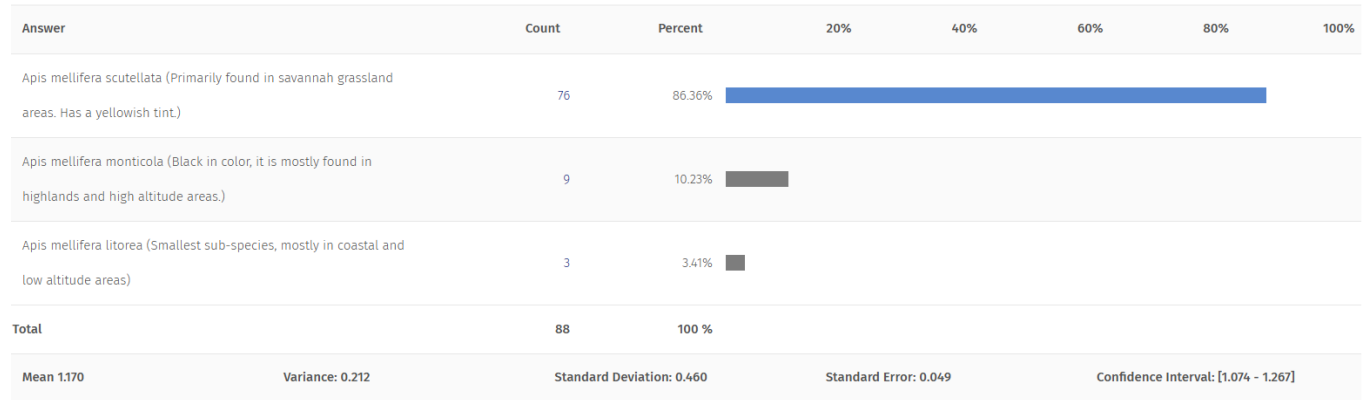


FIGURE 4.7 BEE SPECIES ENCOUNTERED

The statistical measures support the high prevalence of *scutellata* with low variability in the data. Possible implications could relate to regional habitat preferences of these subspecies, with *scutellata* thriving in savannah grasslands, *monticola* in highlands, and *litorea* in coastal areas.

4.5 Diagnostic Tests

Prior to carrying out analysis, the data was tested for normality, multicollinearity and heteroscedasticity.

4.5.1. Normality Test

Kolmogorov-Smirnov and Shapiro-Wilk tests were conducted to assess the normality of the dependent variable. While the skewness and kurtosis were within the range of -1 and 1 for a normal distribution, the p value is less than 0.05 which generally does not indicate a normal distribution. The histogram figure is found in Appendix VI.

TABLE 4.12 TESTS OF NORMALITY

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total Honey Yield	.324	88	.000	.477	88	.000

a. Lilliefors Significance Correction

Source: Researcher 2025

4.5.2. Multicollinearity Test

Pearson’s Correlation Coefficients were calculated on the predictor variables resulting in no value above 0.8, therefore instances of multicollinearity are less likely to exist (Noora, 2020). The table in *Appendix VI* shows the multicollinearity test results.

4.6 Inferential Statistics

The inferential statistics comprised of correlation and regression analysis results used to bring out the relationship between the dependent and independent variables.

4.6.1. Correlation Results

Pearson correlation was used to measure strength and direction of linear relationship between variables. The results are shown in Table 4.13

TABLE 4.13 CORRELATION OF VARIABLES

Correlations

		Apiculture's Socioeconomic Management Practices	Apiculture's Environmental Management Practices	Apiculture's Colony Management Practices	Total Honey Yield
Apiculture's Socioeconomic Management Practices	Pearson Correlation	1	.027	.272*	.052
	Sig. (2-tailed)		.804	.010	.628
	N	88	88	88	88
Apiculture's Environmental Management Practices	Pearson Correlation	.027	1	.425**	-.065
	Sig. (2-tailed)	.804		.000	.545
	N	88	88	88	88
Apiculture's Colony Management Practices	Pearson Correlation	.272*	.425**	1	.318**
	Sig. (2-tailed)	.010	.000		.003
	N	88	88	88	88
Total Honey Yield	Pearson Correlation	.052	-.065	.318**	1
	Sig. (2-tailed)	.628	.545	.003	
	N	88	88	88	88

*. Correlation is significant at the 0.05 level (2-tailed).

** . Correlation is significant at the 0.01 level (2-tailed).

Source: Researcher 2025

The correlation analysis reveals significant relationships between apiculture management practices and total honey yield. Colony Management Practices demonstrate a moderate positive correlation with Total Honey Yield ($r = 0.318, p < 0.01$), indicating that enhanced colony management directly associates with increased yield. Additionally, Colony Management Practices correlate strongly with Environmental Management Practices ($r=0.425, p < 0.01$) and weakly with Socioeconomic Management Practices ($r=0.272, p < 0.05$), suggesting environmental strategies and socioeconomic efforts may indirectly support yield improvements through better colony management. However, neither Socioeconomic Management Practices ($r=0.052, p=0.628$) nor Environmental Management Practices ($r = -0.065, p = .545$) show direct significant correlations with Total Honey Yield, implying their influence is mediated via colony practices. The lack of direct yield associations for socioeconomic/environmental practices highlights the central role of colony-specific interventions. These findings emphasize prioritizing colony management to optimize honey production, while integrating environmental and socioeconomic strategies as complementary supports.

4.6.2. Relationship between Apiculture’s Socioeconomic Management Practices and Honey Yields.

Regression analysis was used to ascertain the connection between honey yields and the socioeconomic management practices of apiculture. Both the ANOVA and Spearman's correlation were produced by the regression analysis. Table 4.14 displays the correlation results.

TABLE 4.14 CORRELATION IN OBJECTIVE 1

		Total Honey Yield	Apiculture's Socioeconomic Management Practices
Spearman's rho	Total Honey Yield	Correlation Coefficient	1.000
		Sig. (2-tailed)	.
		N	88
	Apiculture's Socioeconomic Management Practices	Correlation Coefficient	.240*
		Sig. (2-tailed)	.024
		N	88

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Researcher 2025

A statistically significant but weak correlation coefficient of 0.240 ($p < 0.05$) indicates that improved socioeconomic management practices are modestly associated with higher honey yields. The significance level (Sig. = 0.05) confirms the correlation is not due to random chance. While the link is statistically valid, the weak strength (0.24) suggests socioeconomic practices alone explain only a small portion of yield variability. Other factors (e.g., environmental conditions, pest management, hive type) likely play larger roles.

TABLE 4.15 REGRESSION OUTPUT FOR OBJECTIVE 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
1	.052 ^a	.03	-.009	9370.765		
a. Predictors: (Constant), Apiculture's Socioeconomic Management Practices, Dependent variable: Total Honey Yield.						
ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20714143.94	1	20714143.94	.236	.628
	Residual	7551766991	86	87811244.08		
	Total	7572481135	87			
a. Dependent Variable: Total Honey Yield. b. Predictors: (Constant), Apiculture's Socioeconomic Management Practices						
Coefficients						
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	
	B	Std. Error	Beta			
(Constant)	2248.985	4289.976		.524	.601	
Apiculture's Socioeconomic Management Practices	681.464	1403.086	.052	.486	.628	
a. Dependent Variable: Total Honey Yield						

Source: Researcher 2025

The above model's $R=0.052$ and $R^2=0.03$ indicate that socioeconomic practices explain less than 3% of the variance in honey yields. Standard error of 9,370.765 highlights poor accuracy in

estimating yields. $f=0.236$, $p=0.628$ (far above 0.05) confirms the model is not statistically significant. Socioeconomic practices do not meaningfully predict honey yields. Neither the constant term ($p=0.601$) nor the predictor ($p=0.628$) are significant. The predictor's standardized beta ($\beta=0.052$) confirms a negligible effect. The results also contradict the findings of Serra & Davidson (2020) who found elements such as cooperative membership to have a positive relationship with honey production. The findings of this study also contradict those of Chemwok (2016) in Kenya, Masaku (2013) in Swaziland and Mubarik & Buyinza (2020) who found age to be a factor that affects honey yields. The tenants of adaptive management theory by Holling (1978) in the form of seeking cooperative membership, education and training for increased yields does not hold as apiculture's socioeconomic management practices do not meaningfully predict honey yields.

The resultant model for the relationship between apiculture's socioeconomic management practices and honey yields:

$$HY = 2248.985 + 681.464 \text{ ASMP} + 9370.765$$

Where: HY= Honey Yields and ASMP = Apiculture's Socioeconomic Management Practices

4.6.3. Relationship between Apiculture's Colony Management Practices and Honey Yields.

Regression analysis was used to examine the relationship between honey yields and the colony management practices of apiculture. Both the ANOVA and Spearman's correlation were produced by the regression analysis. Table 4.16 displays the correlation results.

TABLE 4.16 CORRELATION IN OBJECTIVE 2

		Total Honey Yield	Apiculture's Colony Management Practices	
Spearman's rho	Total Honey Yield	Correlation Coefficient	1.000	
		Sig. (2-tailed)	.	
		N	88	
	Apiculture's Colony Management Practices	Correlation Coefficient	.530**	1.000
		Sig. (2-tailed)	.000	.
		N	88	88

** . Correlation is significant at the 0.01 level (2-tailed).

Source: Researcher 2025

A statistically significant correlation coefficient of 0.530 ($p < 0.01$) indicates a moderate positive association between improved colony management practices and higher honey yields. The p-value (.000) confirms the correlation is highly unlikely to be due to random chance. The strength of the correlation suggests that colony management practices (e.g., pest control, hive inspections, record-keeping) are meaningfully linked to productivity.

TABLE 4.17 REGRESSION OUTPUT OF OBJECTIVE 2

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
1	.318 ^a	.101	.091	8897.236		
a. Predictors: (Constant), Apiculture's Colony Management Practices, Dependent variable: Total Honey Yield.						
ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	764651007.1	1	764651007.1	9.659	.003
	Residual	6807830128	86	79160815.44		
	Total	7572481135	87			
a. Dependent Variable: Total Honey Yield. b. Predictors: (Constant), Apiculture's Colony Management Practices						
Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig
		B	Std. Error	Beta		
	(Constant)	-9547.440	4547.525		-2.099	.039
	Apiculture's Colony Management Practices	4677.084	1504.869	.318	3.108	.003
a. Dependent Variable: Total Honey Yield						

Source: Researcher 2025

From Table 4.17, $R=0.318$ and $R^2=0.101$ indicate that colony management practices explain 10.1% of the variance in honey yields. Adjusted $R^2=0.091$ accounts for sample size, confirming modest explanatory power. A standard error of 8,897.24 suggests variability in yields not captured by the model. $F=9.659$, $p=0.003$ confirms the model is statistically significant.

Colony management practices meaningfully predict honey yields. Colony Management Practices (B=4,677.08, p=0.003): A significant positive relationship, with a standardized beta ($\beta=0.318$) indicating a moderate effect size. The results of this section agree with Holling (1978) on the application of adaptive management theory as these practices have been found to be meaningful predictors of honey yields. The results also concur with Ullah et al., (2021), and Haftu et al.(2018) that supplementary feeding, and pest and disease management respectively are key determinants of honey yields.

The resultant model for the relationship between apiculture’s colony management practices and honey yields:

$$HY = -9547.440 + 4677.084 \text{ ACMP} + 8897.236$$

Where: HY= Honey Yields and ACMP = Apiculture’s Colony Management Practices

4.6.2. Relationship between Apiculture’s Environmental Management Practices and Honey Yields.

Regression analysis was used to examine the relationship between honey yields and the environment management practices of apiculture. Both the ANOVA and Spearman's correlation were produced by the regression analysis. Table 4.18 displays the correlation results.

TABLE 4.18 CORRELATION IN OBJECTIVE 3

		Total Honey Yield	Apiculture’s Environmental Management Practices	
Spearman's rho	Total Honey Yield	Correlation Coefficient	1.000	
		Sig. (2-tailed)	.	
		N	88	
	Apiculture’s Environmental Management Practices	Correlation Coefficient	.135	1.000
		Sig. (2-tailed)	.211	.
		N	88	88

Source: Researcher 2025

A correlation coefficient of 0.135 indicates a very weak positive association between environmental management practices and honey yields. The p-value (0.211) is greater than the conventional threshold of 0.05, meaning the correlation is not statistically significant. This

suggests the observed relationship could be due to random chance. Environmental management practices (e.g., planting trees,) do not show a meaningful link to honey yields in this dataset.

TABLE 4.19 REGRESSION OUTPUT OF OBJECTIVE 3

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
1	.065 ^a	.04	-.007	9363.558		
a. Predictors: (Constant), Apiculture's Environmental Management Practices, Dependent variable: Total Honey Yield.						
ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	32325652.83	1	32325652.83	.369	.545
	Residual	7540155482	86	87676226.53		
	Total	7572481135	87			
a. Dependent Variable: Total Honey Yield. b. Predictors: (Constant), Apiculture's Environmental Management Practices						
Coefficients						
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	
	B	Std. Error	Beta			
(Constant)	7417.102	5269.621		1.408	.163	
Apiculture's Environmental Management Practices	-.991.671	1633.184	-.065	-.607	.545	
a. Dependent Variable: Total Honey Yield						

Source: Researcher 2025

The regression analysis evaluates the impact of environmental management practices on honey yields. Key findings from the output: Relationship: $R=0.065$ and $R^2=0.04$ indicate that environmental practices explain less than 4% of the variance in honey yields. Negative Adjusted R^2 (-0.007): Suggests the model is worse than a baseline model with no predictors, implying overfitting or irrelevance of the predictor. Standard error of 9,363.56 reflects poor accuracy in estimating yields. $F=0.369$, $p=0.545$ (far above 0.05) confirms the model is not statistically significant. Environmental practices do not meaningfully predict honey yields. This

goes to also agree with the studies by Sande et al. (2009) which found proximity to forests as an insignificant factor in predicting honey yields. The results also show that the tenants of forage theory by Kerbs & Stephens (1986) do not hold as apiculture’s environmental management practices that advocate for extra planting of foliage and adding water sources did not have a meaningful relationship with honey yields.

The resultant model for the relationship between apiculture’s environmental management practices and honey yields:

$$HY = 7417.102 - 991.671 \text{ AEMP} + 9363.558$$

Where: HY= Honey Yields and AEMP = Apiculture’s Environmental Management Practices

4.8. Regression Coefficient Model – Equation I

The regression output of the three variables described in the conceptual framework is broken down in Table 4.20

TABLE 4.20 REGRESSION OUTPUT EQUATION I

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
1	.392	.153	.123	8735.824		
a. Predictors: (Constant), Apiculture’s Socioeconomic Management Practices, Apiculture’s Environmental Management Practices, and Apiculture’s Colony Management Practices.						
ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1162053325	3	387351108.2	5.076	.003 ^b
	Residual	6410427810	84	76314616.79		
	Total	7572481135	87			
a. Dependent Variable: Total Honey Yield. b. Predictors: (Constant), Apiculture’s Socioeconomic Management Practices, Apiculture’s Environmental Management Practices, and Apiculture’s Colony Management Practices.						
Coefficients						

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig
	B	Std. Error	Beta		
(Constant)	-465.009	6378.206		-.073	.942
Apiculture's Socioeconomic Management Practices	-796.946	1366.572	-.061	-.583	.561
Apiculture's Environmental Management Practices	-3814.972	1692.338	-.251	-2.254	.027
Apiculture's Colony Management Practices	6495.371	1704.978	.441	3.810	.000

a. Dependent Variable: Total Honey Yield

Source: Researcher 2025

The resultant model for the relationship between apiculture's social, environmental, colony management practices and honey yields:

$$HY = - 465.009 - 796.946 X_1 - 3814.972 X_2 + 6495.371 X_3 + 8735.824$$

Where: HY= Honey Yields and X_1 = Apiculture's Socioeconomic Management Practices, X_2 = Apiculture's Environmental Management Practices, and X_3 = Apiculture's Colony Management Practices.

This regression model evaluates the impact of socioeconomic, environmental, and colony management practices on honey yields. $R^2=0.153$ indicates that 15.3% of the variance in honey yields is explained by the three predictors. Standard error (8,735.82) reflects significant unaccounted variability in yields. ANOVA results: $F=5.076$, $p=0.003$ confirms the model is statistically significant, meaning at least one predictor meaningfully relates to yields. Colony management practices is a key predictor with a strong positive effect ($B=6,495.37$, $p<0.001$).

4.9. Regression Coefficient Model – Equation II

The fourth objective was to determine the moderating effect of bee species on the relationship between apiary management practices and honey yields. The moderating effect was calculated on SPSS where each predictor variable in Equation I was multiplied by Bee Species. The output is detailed in Table 4.21. Note that EMPBS = Environmental Management Practices * Bee Species,

SMPBS = Socioeconomic Management Practices * Bee Species, and CMPBS = Colony Management Practices * Bee Species.

TABLE 4.21 REGRESSION OUTPUT EQUATION II

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate		
1	.361 ^a	.131	.100	8853.212		
a. Predictors: (Constant), EMPBS, SMPBS, CMPBS.						
ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	988614500.248	3	329538166.749	4.204	.008 ^b
	Residual	6583866634.468	84	78379364.696		
	Total	7572481134.716	87			
a. Dependent Variable: Total Honey Yield. b. Predictors (Constant), EMPBS, SMPBS, CMPBS						
Coefficients						
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig	
	B	Std. Error	Beta			
(Constant)	5986.073	2515.348		2.380	.020	
SMPBS	-1101.822	867.345	-.228	-1.270	.207	
CMPBS	4928.126	1510.450	.816	3.263	.002	
EMPBS	-4029.803	1231.520	-.653	-3.272	.002	
a. Dependent Variable: Total Honey Yield						

Source: Researcher 2025

This model evaluates how bee species moderates the relationship between management practices and honey yields. The resultant model for the relationship:

$$HY = - 5986.076 - 1101.822 \text{ SMPBS} + 4928.126 \text{ CMPBS} - 4029.803 \text{ EMPBS} + 8853.212$$

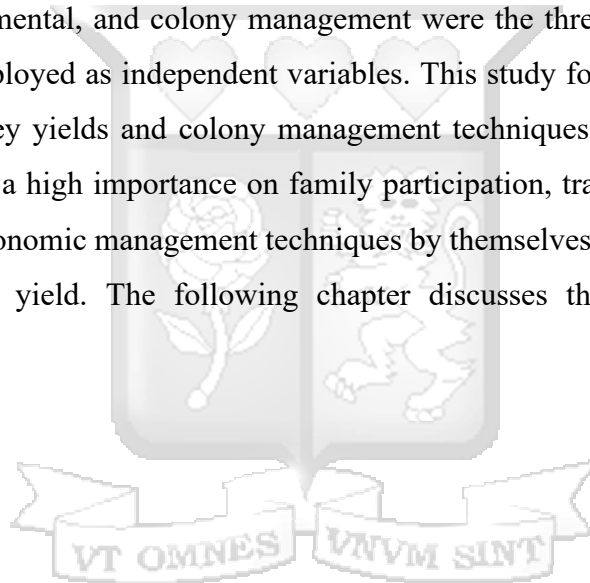
Where: HY= Honey Yields and **SMPBS** = Apiculture’s Socioeconomic Management Practices * Bee Species, **CMPBS** = Apicultures Colony Management Practices * Bee Species, and **EMPBS** = Apiculture’s Environmental Management Practices * Bee Species.

The model has moderate explanatory Power: $R^2=0.131$ indicates 13.1% of yield variance is explained by the interactions. Adjusted $R^2=0.100$ suggests limited improvement with added predictors. Standard error (8,853.21) reflects significant unexplained variability. ANOVA results

of $F=4.204$, $p=0.008$ confirms the model is statistically significant. CMPBS (Colony Management * Bee Species) has a strong positive effect ($B=4,928.13$, $p=0.002$). Assessment of the moderating effect of bee species on the relationship between apiary management practices and honey yields shows a decrease in the adjusted R^2 from .123 in 'Equation 1' to .100 in 'Equation II'. It also shows that the p value increased from 0.003 in 'Equation I' to 0.008 in 'Equation II', concluding that bee species negatively moderate the relationship between apiary management practices and honey yields.

4.10 Chapter Summary

This study investigated how honey harvests were affected by apiary management techniques. Socioeconomic, environmental, and colony management were the three apiculture management techniques that were employed as independent variables. This study found a substantial positive correlation between honey yields and colony management techniques used in apiculture. Even though beekeepers place a high importance on family participation, training, peer collaboration, and digital tools, socioeconomic management techniques by themselves only partially account for the variations in honey yield. The following chapter discusses the ramifications of these discoveries.



CHAPTER FIVE: SUMMARY, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter represents research findings derived from data collected to establish the effects of apiary management practices; socioeconomic, environmental and colony management on honey yields while also looking into the moderating effect of bee species. The research summary, discussions, conclusions, recommendations, and ideas for additional research are all included in this chapter.

5.2 Summary of main findings

The regression analysis findings revealed that only apiculture's colony management practices had a significant effect on honey yields whereas socioeconomic and environmental management practices had a weak and non-significant effect on honey yields. This places an emphasis on pest/disease management which was widely practiced. Although some colony management practices such as supplementary feeding and queen bee manipulation had low uptake, the potential for colony management practices to influence honey yields even more exist if these practices are implemented. Despite the widespread application of apiculture's socioeconomic management practices, this variable was observed to have a non-significant contribution to honey yields. Perhaps while beekeepers value these practices, more needs to be done for them to contribute to honey yields. Environmental management practices were found to have the least effect on honey yields while the use of bee species as a moderating variable showed that it negatively moderated the relationship between apicultures management practices and honey yields.

5.3 Discussion of Findings

The interpretation of the findings and a discussion of the findings in relation to the literature reviewed are included in this subsection. A combination of descriptive and inferential statistics was employed in the investigation. The following subsections provide details of the findings.

5.3.1 Apiculture's Socioeconomic Management Practices Effect on Honey Yields

From the study age, education, and gender, had a weak relationship with honey yields. These findings are agreement with Masaku (2013) but contradict the findings of Dauda et al. (2019) on the impact of gender on honey yields. Experience was found to have a positive relationship with honey yields, highlighting the importance of practical expertise in apiculture, this agrees with the studies by Chemwok (2016) and Mubarik & Buyinza, (2020).

The results from the study showed that The NGO Program is far less active than the beekeeping cooperative, which is the most active group. Participation is moderate for both the Farmers and Savings Groups, with the Savings Group outperforming the Farmers Group by a little margin. The results from a study done by Serra & Davidson (2020) found that cooperative membership remarkably raises both the price and quantity of honey. This study was however unable to conduct a similar analysis due to the difference in research design. The study showed that beekeeping members' financial access and extension services elicit mixed responses, and lack of experience is not seen as a primary issue.

Regarding the type and quantity of hives owned, Langstroth bee hives are the most popular among members of this association. Langstroth hive showed the strongest positive effect with each additional hive thereby increasing the honey yield. Traditional hives had a significant positive effect while Kenya Top Bar Hives had the weakest effect but still statistically significant. These findings agree with a publication by Adgaba et al. (2014) and Aksoy et al. (2018) which had found that beekeepers who owned Langstroth beehives harvested a greater amount of honey than beekeepers who owned other beehive types. The results also showed a weak application of adaptive management theory by Holling (1978), as apiculture's socioeconomic management practices were not meaningful predictors of honey yields.

Analysis of the findings revealed a statistically significant but weak correlation coefficient indicating that improved socioeconomic management practices are modestly associated with higher honey yields. The regression analysis also revealed that socioeconomic practices indicate that socioeconomic practices explain a very small amount of the variance in honey yields. While this was the case, beekeepers strongly value peer collaboration and training, while family involvement and digital tools play supportive roles. Perhaps beekeepers can re-evaluate the nature

of their apiculture socioeconomic practices and see what more value they can extract from these relationships to increase their honey yields.

5.3.2 Apiculture's Colony Management Practices Effect on Honey Yields

The results from this research showed that most of the respondents did not provide any extra type of feed to their bees. While supplementary feeding of honeybees is a common practice among apiarists in Pakistan to boost honey yields (Ullah et al., 2021), this practice is unpopular among members of this association. The few members that provide supplementary feed, have their apiaries located in areas commonly categorized as Arid/Semi-Arid. Studies done by Gameda (2014) were able to compare honey yields between hives fed on sugar syrup and chickpea flour, whereas in this study the responses on supplementary feeding were too few to evaluate their impact on honey yields.

An analysis of pest/disease management showed that pest control scored the highest mean, nearly all beekeepers prioritize protective measures. Monitoring health/productivity scored the second-highest mean, close to "Most of the time," indicating regular checks on bee health. Whereas a study by Tesfaye et al (2017) attributed honey badgers to major losses of honey, in this study the pest was only identified by 11.36% of the respondents as a major problem. This study's results contradict those of Bett (2017) whose respondents largely considered ants/mites/spiders as a major problem to honey production, as this study's respondents place Wax Moth as the major pest affecting honey production.

It was also observed from the results that beekeepers of this association prioritize pest/disease prevention and health monitoring but underutilize practices like queen management, internal inspections, and supplemental feeding. Record-keeping and cleaning are inconsistently adopted. Targeted training on undervalued practices (e.g., queen health, feeding) could perhaps enhance productivity, while standardized protocols for cleaning and record-keeping may reduce variability. From the results, equipment access varies, signaling a need for targeted resource distribution. Bee swarming is a moderate concern, while some beekeepers complained about losing colonies to swarm others heavily relied on swarming to grow their bee colonies. Interest in sensor technology for precision apiculture exists but may require further exploration to address hesitations.

Further analysis through Spearman's rho, a non-parametric measure of rank correlation, which assesses how well the relationship between the two variables can be described using a monotonic function suggested a moderate positive correlation between apiculture's colony management practices and honey yields. The regression model had a low r value, meaning about a little of the variance in honey yields is explained by colony management practices. Colony management practices have a significant positive relationship and moderate effect size on honey yields. Adaptive management theory by Holling (1978) was found to hold in the conduction of this research study Colony management practices significantly and positively influence honey yields, though their impact is modest.

5.3.3 Apiculture's Environmental Management Practices Effect on Honey Yields

The findings of the research study revealed that most member apiaries are closest to farmland, within one kilometer, fewer are more than three kilometers away, which could be a result of those areas not practicing farming as a dominant economic activity. The heavy proximity to farmland could also be due to apiaries being located close to members' homesteads where their location eases apiary inspection and management. The importance of water access for bee health is highlighted by the fact that nearly all apiaries are within two kilometers of waterbodies.

When comparing bee colonies in protected areas such as forests to those in farmlands, the study by Vaudo et al (2011) showed better honey production in forests. In this study, the members of this association had less inclination to forest beekeeping, possibly due to challenges like predators or management difficulties. The study done by Picknoll et al. (2021) attributed changes in land use to decreased honey yields through increased deforestation. The respondent of this study had majority of their apiaries close to farms. The study approach taken in this study is also not able to adequately compare honey yield performance of beekeepers close to forests versus those close to agricultural farms. Although this study's results on honey yields were based on one year and two seasons, the results were similar to a two-year study by Sande et al (2009) which also concluded that there was no appreciable variation in honey yield over the forest's distances.

The research data on apiculture's environmental management practices using a Linkert scale revealed that most association's members consider that their bees have sufficient forage, with low, indicating widespread confidence in environmental resources. This may partly explain the low desire among beekeepers to provide supplementary feed. The results had also showed moderate

agreement that apiary environments have diverse plants, and that climate change impact was of highest concern with most leaning towards Agree, with moderate consensus. The impact of pesticides is nearly neutral, but there is a lot of variation which indicates differing opinions. An experimental research design would be best placed to explore the impact of pesticide usage on honey yields over time.

The correlation and regression results both revealed there is no significant evidence that environmental management practices, as measured in this study, influence honey yields. Important conclusions drawn from the output show that less than very little of the variation in honey yields can be explained by environmental practices. Foraging theory as advanced by Kerbs & Stephens (1986) was found not to be applicable in this study. While minor improvements in practices may align with slightly higher yields, the effect is negligible. Future studies should isolate specific environmental interventions and account for confounding variables to better understand their impact.

5.3.4 The Moderating Effect of Bee Species on The Relationship between Apiary Management Practices and Honey Yields.

The results from the study showed high prevalence of scutellata with low variability in the data. Regional habitat preferences of these subspecies were evident and concurrent with observations made by Raina & Kimbu (2005) where *Apis mellifera* subspecies; scutellata thriving in savannah grasslands, monticola in highlands, and litorea in coastal area. This research study only asked respondents to select the most observed subspecies in their apiaries, this approach means that more than one subspecies could be present in an apiary. An experimental design would be more conclusive in comparing bee subspecies honey production performance in controlled environments. Specialized organizations such as the National Beekeeping Institute and ICIPE would be better placed to carry out this analysis due to their scientific expertise in studying variations in behavior, physiology, or environmental adaptability of bee species to develop a management strategy that increases honey production for each subspecies depending on the environment. This would mirror the study by Ivancia et al. (2020) which led to the development of the Buckfast bee, a hybrid species created for increased production and disease resistance.

Assessment of the moderating effect of bee species on the relationship between apiary management practices and honey yields shows a decrease in the adjusted R^2 in 'Equation 1' to

'Equation II'. It also shows that the p value increased from 'Equation I' to 'Equation II', concluding that bee species negatively moderate the relationship between apiary management practices and honey yields.

5.4 Conclusions

Examining how apiculture's socioeconomic management techniques affect honey output was the first objective. According to the study, there is little correlation between honey output and the socioeconomic management techniques used in apiculture. A small but statistically significant correlation value was found when the results were analyzed, suggesting a moderate relationship between higher honey yields and better socioeconomic management techniques. Additionally, the regression study showed that socioeconomic practices do not significantly affect honey yields. Despite this, beekeepers place a high importance on training, peer collaboration, digital tools and family participation which serve as supportive factors. To boost their honey production, beekeepers might want to enhance socioeconomic aspects of their apiculture and determine what additional benefits they can derive from these connections.

The second objective examined the relationship between apiculture's colony management practices and honey yields. The study showed a moderately positive correlation between apiculture's colony management practices and honey yields was suggested by the coefficient obtained from further analysis using Spearman's rho. The regression model indicated that colony management strategies account for roughly little of the variation in honey output. Colony Management Practices had a moderate effect on honey yields. Although they have little effect, colony management techniques have a considerable and favorable impact on honey output.

The third objective in this research study was to establish the effect of apiculture's environmental management practices on honey yields in Kenya. The study results revealed that there is no compelling evidence that environmental management techniques, as assessed in this study, have an impact on honey production, according to the correlation and regression data. Key findings from the data indicate that environmental practices account for very little variation in honey production. Even if little adjustments to procedures might result in somewhat improved yields, the impact is insignificant. To further understand their effects, future research should separate out certain environmental interventions and take confounding factors into consideration.

The fourth objective was to determine the moderating effect of bee species on the relationship between apiary management practices and honey yields. Assessment of the moderating effect of bee species on the relationship between apiary management practices and honey yields shows a decrease in the adjusted R^2 in 'Equation 1' to 'Equation II'. It also shows that the p value increased from 'Equation I' to 'Equation II', concluding that bee species negatively moderate the relationship between apiary management practices and honey yields.

5.5 Contribution of the Study

The dissertation contributes to the scholarly works of Ullah et al. (2021) and Shrestha (2018) by concurring through alternate methodology that supplementary feeding as colony management practice influences honey yields. While the report by FAO (2020) generalized attitudes towards queen bee manipulation, this study was able to examine the exact sentiments of this beekeepers' group towards the apiculture management practice. This study also contributes to literature developed by Kvišis and Zacepins (2015) and Meikle & Holst (2014) that examined the development of smart hives by first exploring the perception of this technology by members of the group. This then sets the foundation for future adoption and development of precision beekeeping. While the studies by Masaku (2013), Dauda et al. (2019), and Adgaba et al. (2014) acknowledge the influence of age, gender, and type of hive owned on the production of honey were studies were conducted in Swaziland and Saudi Arabia respectively; this research study's contribution is its findings that apicultures' socioeconomic management practices had a weak influence on honey yields. The study by Albayrak et al. (2018) looked into the factors affecting honey yields in Turkey. The study used cognitive fuzzy maps as its methodology in determining the effects of the practices on honey production while this study contributed by a different design of a survey and regression model.

5.6 Recommendations

5.6.1 Beekeepers

This study recommends beekeepers explore more colony management techniques such as queen bee manipulation and supplementary feeding based on the positive relationship colony management had with honey yields. Despite apiculture's socioeconomic management practices having a weak relationship with honey yields, this study recommends that beekeepers find ways

from getting more out of their social groups to increase honey yields. This could be through workshops, equipment sharing, hive ownership financing schemes among others. From the study, it is also recommended that beekeepers located near agricultural farms stay vigilant on pesticide application and how it may affect their apiary productivity.

5.6.2 Extension Officers

It has also been observed from the study that most respondents acknowledge the challenge of pests to their hive productivity. This paper therefore recommends more efforts geared towards sensitization hive protection from pests to increase honey yields. Disease monitoring coordination with cooperatives and county governments could also assist in colony management improvements. Extension officers could also partner with local leaders to protect natural habitats from deforestation and agrochemical misuse and encourage planting of indigenous plants to establish pollinator corridors. The results from the study showed largely neutral response to extension services in improving their honey production, it is recommended that extension officers take time to evaluate their impact on beekeepers and see how to improve their services.

5.6.3 Policymakers

This study recommends that policymakers develop a national beekeeping database to track hive numbers, production trends, and pest outbreaks. This information can then be used to map pollinator habitats and identify high-potential zones for apiaries. It is also recommended that policy makers investigate investigating the effects of pesticide usage on bees, this would then inform any future policy on regulating pesticides to promote more bee-friendly alternatives in agricultural zones. Policies can also be established to promote the integration of nectar rich trees into farming systems, this is in line with the findings of most apiaries being near agricultural farms.

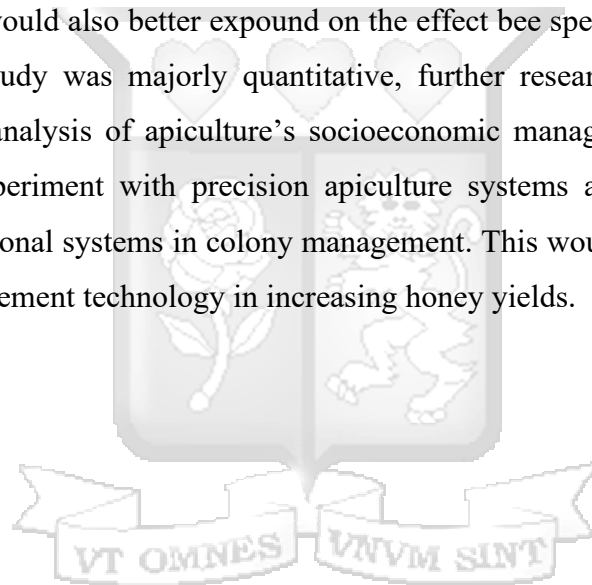
5.7 Limitations of the Study

The research collected data on honey production for two seasons over one year from members of a beekeeping association in Kenya. The results of the study are therefore limited to this association and cannot be generalized to the rest of the country. The self-reporting method, which is used to gather information on beekeeper's apiary management practices and honey production, was used in this study. However, it has drawbacks, such as relying on respondents' recollection and desire

for social appeal. The survey method being a questionnaire did not allow further probing to better understand how the apiculture's management practices could influence honey yields. To overcome this, perhaps future studies could combine data from cooperatives, beekeeping businesses and focus group discussions with beekeepers to capture more information. The cross-sectional design of the study meant that data was collected at specific point in time limiting the study's ability to establish causal relationships.

5.8 Suggestions for Further Research

Further studies can investigate the honey production based on bee species and climatic zones in to order to get a better understanding of what colony management practices are suitable for each species and location. It would also better expound on the effect bee species have on honey yields in Kenya. While this study was majorly quantitative, further research can apply qualitative techniques for a better analysis of apiculture's socioeconomic management practices. Finally, further research can experiment with precision apiculture systems and compare their honey production with conventional systems in colony management. This would better examine the use of modern colony management technology in increasing honey yields.



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APPENDICES

APPENDIX I FACILITATION LETTER

Ole Sangalo Rd, Madaraka Estate
P. O Box 59857 - 00200, Nairobi, Kenya
Cell: +254 703 034 414/8/7
X/Twitter/TikTok: @SBSKenya
Facebook/LinkedIn: Strathmore University Business School
Email: sbsinfo@strathmore.edu or visit www.sbs.strathmore.edu



24th February 2025

To Whom It May Concern,

RE: FACILITATION OF RESEARCH – MARANYA LESTER ONTEGI

This is to introduce Maranya Lester Ontegi who is a Master of Management in Agribusiness Student at Strathmore University Business School, admission number MMA/076182. As part of our MMA Program, Lester is expected to do applied research and undertake a project. This is in partial fulfilment of the requirements of the MMA course. To this effect, Lester would like to request appropriate data from your organization.

Lester is undertaking a research paper on “The Effect of Apiary Management on Honey Yields in Kenya: The Moderating Effect of Bee Species.” The information obtained shall be treated confidentially and shall be used for academic purposes only.

Our MMA seeks to establish links with industry, and one of these ways is by directing our research to areas that would be of direct use to industry. We would be glad to share our findings with you after the research, and we trust that you will find them of great interest and of practical value to your organization.

We appreciate your support and shall be willing to provide any further information if required.

Yours sincerely,

A handwritten signature in black ink, appearing to read "Njoki Kiagiri".

Njoki Kiagiri
Manager – Graduate Programs.
Strathmore University Business School.

Association of African Business Schools



Strathmore Business School is a Proud member of



AACSB

APPENDIX II ETHICS APPROVAL



21st February 2025

Mr Maranya Lester,
lester.maranya@strathmore.edu

Dear Mr Maranya,

RE: The Effect of Apiary Management on Honey Yields in Kenya: The Moderating Effect of Bee Species

This is to inform you that SU-ISERC has reviewed and approved your above SU-masters proposal. Your application reference number is SU-ISERC2631/25. The approval period is from 21st February 2025 to 20th February 2026.

This approval is subject to compliance with the following requirements:

- i. Only approved documents including (informed consents, study instruments, MTA) will be used.
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
- iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
- iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
- v. Clearance for the export of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.




Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) <https://research-portal.nacosti.go.ke/> and obtain other clearances needed.

Yours sincerely,

A handwritten signature in black ink, appearing to read "Ambrose Rachier".

Mr Ambrose Rachier,
Chairperson; SU-ISERC

APPENDIX III RESEARCH LICENCE

 REPUBLIC OF KENYA	 NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
Ref No: 647099	Date of Issue: 14/March/2025
RESEARCH LICENCE	
	
This is to Certify that Mr. Lester Ontegi Maranya of Strathmore University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: THE EFFECT OF APIARY MANAGEMENT ON HONEY YIELDS IN KENYA: THE MODERATING EFFECT OF BEE SPECIES for the period ending : 14/March/2026.	
License No: NACOSTI/P/25/416513	
647099	
Applicant Identification Number	Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
Verification QR Code	
	
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See overleaf for conditions	

Link to electronic questionnaire: [Apiary Management Survey Link](#)

Introduction

Dear *Participant*, This questionnaire is designed to study ‘Effects of Apiary Management Practices on Honey Yields in Kenya: The Moderating Effect of Bee Species’. Your responses will help us better understand which beekeeping management practices can increase bee products’ yields. Your contact was drawn from the membership of the Apiculture Platform of Kenya. The questions in this survey will take less than 10 minutes to respond to. The research team has sole access to the data and will be treated with upmost privacy. Should you have any queries regarding this study you can reach me on lester.maranya@strathmore.edu

Section A: General Information

The questions in this section collect general information about your beekeeping operation.

Please tick ✓ the appropriate box(es) to the following questions

1. How old are you?

- 18 – 24 25 – 34 35 – 44 45 – 54 55 – 64 Above 65 years

2. What is your gender?

- Male Female Prefer not to say

3. What is your level of education?

- No formal Schooling
 Primary School
 Secondary School
 Vocational School
 Undergraduate
 Masters
 PhD

Section B: Apiculture’s Socioeconomic Management

The questions in this section seek to gather information on social and economic activities around your beekeeping operation.

Kindly indicate on a scale of 1 (never) to 5 (always) your level of social participation.

No.	Membership	Never (1)	Rarely (2)	Sometimes (3)	Frequently (4)	Always (5)
6.	Beekeeping Cooperative					
7.	Farmer’s Group					
8.	NGO Program					
9.	Savings Group					

10. Which category makes up the biggest proportion of your annual income?

- Beekeeping Activities Other Farming Activities Non-Farming Activities

11. How many bee hives do you manage?

Type of Beehive	Number of Beehives
Traditional Log Hives	
Langstroth	
Kenya Top Bar	
Other (Please specify):	
Total Number of Managed Bee Hives	

12. Have you accessed financing to grow your beekeeping operation through any of the following ways: *(You may tick ✓ more than one)*

- Bank Loan
- Cooperative Loan
- Farmer’s Group
- NGO Program
- Mobile Money Lenders (Hustler Fund, Tala, Branch etc.)
- Savings
- Family and Friends

This section consists of statements on socioeconomic apiary management practices

Kindly indicate your level of agreement with the following accounts using the scale:

1=Strongly disagree; 2= Disagree; 3=Neutral; 4=Agree; 5=Strongly Agree

	Statement	1	2	3	4	5
13.	Beekeeping training has given me the necessary skills to manage my apiary.					
14.	Engaging with other beekeepers has greatly increased my beekeeping skills.					
15.	Access to finance has prevented me from growing my beekeeping operation.					
16.	Lack of beekeeping experience is the cause for my poor harvests.					
17.	I share or borrow my beekeeping equipment with other beekeepers.					
18.	My family members participate in my beekeeping operation.					
19.	Internet and social media have helped me improve my skills.					
20.	Field visits and extension services have helped me better manage my apiary.					

Section C: Apiculture’s Environmental Management

The questions in this section seek to gain an understanding of the environment where your apiary is located and the environmental activities undertaken to enhance the welfare of your bees.

21. What best describes the environment where your bees are located?

- Forest Farmland Savannah Grassland Arid/Semi-Arid Coastal Other

22. How close are your bee hives to the nearest forest?

- Less than 1 Km 1 - 2 Km Above 3 Km

23. How close are your bee hives to the nearest farm?

- Less than 1 Km 1 - 2 Km Above 3 Km

24. How close is your apiary to the nearest water source (rivers, streams, etc.)?

- Less than 1 Km 1 - 2 Km Above 3 Km

For the following statements, kindly indicate your level of agreement using the scale:

1=Strongly disagree; 2= Disagree; 3=Neutral; 4=Agree; 5=Strongly Agree

	Statement	1	2	3	4	5
25.	Pesticides from nearby farms are a big problem for my bees					
26.	My bees always have enough forage from the surrounding environment.					
27.	The planting of trees and flowers around my apiary has helped increase the amount of bee products I harvest.					
28.	Climate change has affected the productivity of my bees.					
29.	Extra water for bees is provided so that they don’t have to go looking far.					
30.	The environment around my apiary has very many types of plants, flowers, and trees.					
31.	The environment around my apiary mostly has one major type of plant, flower or tree.					

Section D: Apiculture’s Colony Management

The questions in this section seek to gain an understanding of the activities beekeepers engage in to take care of the health and productivity of their bees.

32. What type of feed do you provide?

- Pollen Sugar/Syrup Fruits Other None

33. Which pest is most troublesome to your apiary?

- Wax Moth Honey Badger Mites/Spiders/Ants Other

For the following statements, kindly indicate the frequency of occurrence using the scale:

1=Never; 2= Rarely ; 3=Sometimes; 4=Most of the time 5=All the time

	Statement	1	2	3	4	5
34.	Bees are provided with extra feed to boost their forage stores.					
35.	Queen bee manipulation is a practice I undertake that is important in increasing my honey yields.					
36.	The area around my apiary and bee hives is cleaned.					
37.	I monitor the progress of my honeybees to check on their health and productivity					
38.	Internal beehive inspection is done during routine management.					
39.	I check on each queen bee’s health and egg laying productivity.					
40.	Measures are taken to protect my bees from pests and diseases.					
41.	I keep records on harvests and major occurrences around my apiary					

For the following statements, please select the answer that matches your view most closely using the scale:

1=Strongly disagree; 2= Disagree; 3=Neutral; 4=Agree; 5=Strongly Agree

	Statement	1	2	3	4	5
42.	Pests and diseases have significantly affected the amount of honey harvested.					
43.	I have all the equipment I need to take care of my bees and harvest honey.					
44.	The supplementary feed I give my bees changed the taste of honey harvested.					
45.	I would be interested in putting sensors on my hives to remotely monitor the progress of my bees.					
46.	The swarming of bees has greatly affected my apiary resulting in reduced honey harvest.					

Section E: Honey Yields

The questions in this section seek to gain an understanding of the honey you harvest.

47. How often do you harvest honey?

Every 3 months

Every 4 months

Every 6 months

Once a year

48. Kindly indicate the kilograms of honey produced:

Type of Beehive	Season 1 January - June 2024	Season 2 October - December 2024	Total (Kg)
Traditional Log Hives			
Langstroth			
Kenya Top Bar			
Total (Kg)			

For the following statements, please select the answer that matches your view most closely using the scale:

1=Strongly disagree; 2= Disagree; 3=Neutral; 4=Agree; 5=Strongly Agree

	Statement	1	2	3	4	5
49.	I am happy with the amount of honey harvested.					
50.	The amount of honey harvested has been increasing over the last 5 years.					
51.	My customers complain about the crystallization of honey.					
52.	I have taken steps to increase my honey yields this year.					
53.	I have a ready market for the honey harvested.					

Section E: Bee Species

The questions in this section seek information on the various bee species that may be found in your apiary.

54. Which of the following honeybee species have you spotted in your apiary? (You may tick ✓ the one appearing in most beehives)



Apis mellifera scutellata

Primarily found in savannah grassland areas. Has a yellowish tint.



Apis mellifera monticola

Black in color, it is mostly found in highlands and high altitude areas.



Apis mellifera litorea

Smallest sub-species, mostly in coastal and low altitude areas

Thank you for taking the time to complete this questionnaire, should you have any queries do not hesitate to contact me on lester.maranya@strathmore.edu

APPENDIX V MULTICOLLINEARITY TEST

Correlations

		Age	Gender	Education	Experience	Income Category	Group Participation	Total Number of Hives	Apiculture's Socioeconomic Management Practices	Apiculture's Colony Management Practices	Apiculture's Environmental Management Practices
Age	Pearson Correlation	1	.129	-.020	.703**	-.428**	.302**	.225	.142	.353**	.150
	Sig. (2-tailed)		.232	.850	.000	.000	.004	.035	.188	.001	.164
	N	88	88	88	88	88	88	88	88	88	88
Gender	Pearson Correlation	.129	1	.007	.260*	-.035	-.166	.145	-.046	.153	.104
	Sig. (2-tailed)	.232		.949	.014	.744	.122	.178	.670	.156	.334
	N	88	88	88	88	88	88	88	88	88	88
Education	Pearson Correlation	-.020	.007	1	-.067	.076	.073	.087	-.147	.233	.209
	Sig. (2-tailed)	.850	.949		.535	.484	.498	.418	.173	.029	.051
	N	88	88	88	88	88	88	88	88	88	88
Experience	Pearson Correlation	.703**	.260*	-.067	1	-.583**	.317**	.378**	.267	.510**	.248**
	Sig. (2-tailed)	.000	.014	.535		.000	.003	.000	.012	.000	.020
	N	88	88	88	88	88	88	88	88	88	88
Income Category	Pearson Correlation	-.428**	-.035	.076	-.583**	1	-.282**	-.376**	-.325**	-.496**	-.140
	Sig. (2-tailed)	.000	.744	.484	.000		.008	.000	.002	.000	.192
	N	88	88	88	88	88	88	88	88	88	88
Group Participation	Pearson Correlation	.302**	-.166	.073	.317**	-.282**	1	.025	.647**	.222	.003
	Sig. (2-tailed)	.004	.122	.498	.003	.008		.820	.000	.038	.980
	N	88	88	88	88	88	88	88	88	88	88
Total Number of Hives	Pearson Correlation	.225	.145	.087	.378**	-.376**	.025	1	.022	.329**	-.018
	Sig. (2-tailed)	.035	.178	.418	.000	.000	.820		.837	.002	.871
	N	88	88	88	88	88	88	88	88	88	88
Apiculture's Socioeconomic Management Practices	Pearson Correlation	.142	-.046	-.147	.267	-.325**	.647**	.022	1	.272	.027
	Sig. (2-tailed)	.188	.670	.173	.012	.002	.000	.837		.010	.804
	N	88	88	88	88	88	88	88	88	88	88
Apiculture's Colony Management Practices	Pearson Correlation	.353**	.153	.233	.510**	-.496**	.222	.329**	.272	1	.425**
	Sig. (2-tailed)	.001	.156	.029	.000	.000	.038	.002	.010		.000
	N	88	88	88	88	88	88	88	88	88	88
Apiculture's Environmental Management Practices	Pearson Correlation	.150	.104	.209	.248**	-.140	.003	-.018	.027	.425**	1
	Sig. (2-tailed)	.164	.334	.051	.020	.192	.980	.871	.804	.000	
	N	88	88	88	88	88	88	88	88	88	88

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

APPENDIX VI HISTOGRAM

