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Sustainable Beekeeping in Western Zambia: Approaches, challenges and implication in local farmer community

BACHELOR'S THESIS

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Declaration

I hereby affirm that the thesis titled "*Sustainable Beekeeping in Western Zambia: Approaches, challenges, and implication in local farmer community*" was composed by me independently. All content within this thesis is original. Where external sources have been utilised, they have been accurately cited and acknowledged following the citation guidelines established by the Faculty of Tropical AgriSciences.

In Prague

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Eliška Honzáková

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Abstract

This thesis focused on sustainable beekeeping in Western Zambia, especially in regions traditionally involved in honey hunting, which now adopt beekeeping to diversify production and improve livelihood incomes. The study assessed the implications for local farming communities, considering environmental concerns and bees' critical role in pollination and biodiversity. Utilising interviews and case studies, it highlighted the socio-economic and ecological benefits of beekeeping and emphasised its role in broadening agricultural diversity and generating employment opportunities.

The research highlighted significant livelihood opportunities and environmental conservation opportunities through beekeeping but identified vital obstacles, such as inadequate training and poor data collection related to beehive care, severely limiting its potential. The study recommended overcoming these challenges through integrated agricultural practices and increased community engagement to support the beekeeping industry.

The study described the impact of beekeeping on rural livelihoods using Kenyan top-bar hive, biodiversity conservation, and promoting sustainable agricultural practices by examining the sustainability triad of economic, environmental, and social factors. It identified critical sustainability contributors and challenges, including environmental threats, market access issues, and knowledge gaps.

The study concluded that sustainable beekeeping could significantly enhance rural livelihoods by providing alternative income sources, improving crop production through adequate pollination, and supporting environmental conservation. However, realising these benefits requires targeted interventions to enhance beekeepers' training, financial access, and market opportunities and reduce environmental impacts.

This thesis contributes to the broader conversation about sustainable rural development in Zambia by providing actionable insights into beekeeping as an environmentally friendly agricultural practice and recommending to stakeholders how to increase pollen and nectar resources oriented to agriculture systems to improve sustainable beekeeping's scalability and impact in Western Zambia.

Keywords: agroforestry, apiculture, economic aspects, honey harvesting, Kenyan top-bar hive, resource enhancement for bees, rural livelihoods

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List of Abbreviations and Symbols

BC	Before Christ
ENSO	El Niño/Southern Oscillation
ITCZ	Inter-Tropical Convergence Zone
KTBH	Kenyan-Top Bar Hive
MENDELU	Mendel University in Brno
NGOs	Non-governmental Organization

1 Introduction

Apiculture, also known as beekeeping, involves cultivating bees to harvest honey, wax, and additional bee-derived goods for local consumption and commercial markets (Cadwallader 2011; Masuku 2013). This practice leverages regional expertise and resources to produce various goods for sale. Managing bee colonies is also critical for pollination, essential for a substantial portion of the world's food production, thereby playing a pivotal role in sustaining agricultural output, enhancing nutritional value, and supporting traditional medicinal practices (Hilmi et al. 2012; Klein et al. 2006).

In Zambia, beekeeping significantly contributes to biodiversity conservation and economic development, providing essential pollination services and economic opportunities, particularly in rural areas. Despite its importance, the practice faces challenges such as limited access to modern technologies, inadequate market structures, and environmental degradation. This study aims to explore sustainable beekeeping methodologies suited to Zambia's unique conditions, name challenges and opportunities, and propose strategies to enhance beekeeping sustainability (Gratzer et al. 2021; Illgner et al. 1998). By improving beekeeping practices, this research looks to bolster rural development, alleviate poverty, and support environmental conservation efforts, aligning with national and global sustainability goals.

The project occurs in Western Zambia, where the Czech Republic Development Cooperation financed an Integrated Farming III project from Mendel University in Brno (MENDELU). The main goal of this project is to support farmers' production, increase their income, help them develop skills, build a resilient landscape, and conduct agroforestry activities to enhance bee resources. The target is on a small group of farmers; 30 of them and 91 given hives. Most farmers are part of previous projects of Integrated Farming III, agroforestry and livestock farming (IWPM2 2023).

This thesis analyses global and Zambian beekeeping techniques, their impacts, and industry limitations. The methods section details data collection and analysis techniques. Results show how environmental conditions and management practices affect beekeeping. The discussion synthesises these insights to recommend improvements and concludes with strategies for promoting sustainable beekeeping in Zambia to support local communities. This work enhances understanding and support of sustainable beekeeping, highlighting its local and global benefits.

2 Literature Review

2.1 Beekeeping Practises and History

2.1.1 Global

Apiculture, one of humanity's earliest forms of agriculture, originated in ancient times, with the earliest evidence in rock art dating back to around 13,000 BC in Egypt. By 597 B.C., people had begun domesticating honeybees for honey production. Among the approximately 30,000 identified pollinators, honeybees stand out for their ability to convert nectar into honey with meaningful harvestable storage. This practice has been most prevalent in Europe, Asia, and Africa, where the introduction of European bee varieties over the last four centuries has significantly advanced beekeeping techniques.

The 19th century saw the development of a type of beehive that allowed for movable frames, a significant breakthrough that gave beekeepers greater control over their hives. This period also witnessed the invention of the prefabricated wax foundation, further streamlining hive management. Developing a centrifugal force machine for honey extraction and advancing beekeeping equipment and clothing have also revolutionised how beekeepers harvest honey and manage their colonies (Daberkow et al. 2009; Gupta et al. 2014).

2.1.2 Zambia

Apiculture boasts a rich African heritage, tracing back five millennia (Gupta et al. 2014), with ancient cave illustrations depicting the early interaction between humans and honeybees across the continent (Illgner et al. 1998; Pager 1973). The first written records from the mid-19th century by explorer David Livingstone detail the log hives of the Southern Lunda peoples along the upper Zambezi, evidencing the long-standing tradition of bee cultivation (Coppinger et al. 2019). For generations, communities have crafted cylindrical hives featuring entrance holes and removable sections for collecting honeycombs, alongside the age-old technique of honey-hunting by the light of torches (Gupta et al. 2014).

Beekeeping is a deeply rooted cultural tradition passed down from generation to generation, frequently creating a cornerstone of communal life. Unlike the transient nature of honey hunting, traditional beekeeping nurtures the colonies, allowing for sustainable honey extraction from the same bee colony over time. This practice is notably prevalent in countries such as Zimbabwe, Zambia, Tanzania, and Mozambique, where hives crafted from tree bark are placed high up in trees to safeguard against predators (Figure 1) (Clauss 1992; Ntenga & Mugongo 1991).

Figure 1 Traditional beehive. Source: (UN 2023)

Beekeeping is now recognised for its ecological and economic benefits. It is ideal for rural people without requiring land and feasible even in semi-arid locations, despite past tendencies toward illegal beekeeping for domestic consumption. Acknowledged for its minimal ecological footprint and economic viability, beekeeping emerges as a fitting occupation for rural populations in areas unsuitable for conventional agriculture. It requires no land ownership and leverages naturally available resources, offering a sustainable means of livelihood without extensive bee feeding or management (Illgner et al. 1998; Mulombwa 1998).

Zambia's Northwestern Province has abundant miombo woodlands and a storied history of beeswax trade. Beekeeping underscores this ancient practice's economic and cultural significance (Gupta et al. 2014). Initiating in the late 19th century, the trade in beeswax has matured into a global enterprise, with organically certified honey and beeswax products now reaching international markets from these rural homesteads (Coppinger et al. 2019). The tradition of beekeeping, including honey hunting, not only fulfils critical dietary needs and serves as a trade commodity but also offers resilience to communities facing limited economic opportunities (Gupta et al. 2014). Primarily, Zambia hosts the East African lowland honeybee (*Apis mellifera scutellata*) and the West African honeybee (*Apis mellifera adansonii*). Zambian beekeepers typically utilise whichever subspecies are locally available rather than selecting specific ones (Gratzer et al. 2021; Illgner et al. 1998).

2.2 Impacts of Beekeeping

Natural events and human actions, including deforestation, significantly stress ecosystems, especially in forest-rich countries like Zambia. The expansion of urban areas intensified agriculture based on agrochemicals, and harvesting wood and timber amplifies the challenges of global climate change and the deterioration of local ecosystems. Due to prevalent poverty rates, population growth, and non-sustainable agricultural methods, Zambia's intricate balance between humans and nature needs to improve (Mulenga & Hamauswa 2017).

In this context, beekeeping stands out as a sustainable endeavour capable of reducing environmental harm and enhancing economic and social health. Unlike traditional agriculture, which demands significant land use, beekeeping minimally impacts land, utilising natural resources such as honeybees and flowering plants. It also capitalises on diverse forms of capital, including human expertise, skills, and knowledge; physical assets such as infrastructure and transportation; social resources encompassing community support, networks, and access to information; and financial resources, including funding and financial assistance opportunities (Etxegarai-Legarreta & Sanchez-Famoso 2022).

Furthermore, beekeeping's influence reaches the nutritional, health, and social spheres. Honey and its derivatives offer nutritional benefits and versatility, from dietary supplements to pharmaceutical components, highlighting beekeeping's significant health and social implications. As modern medicine faces increasing scrutiny, these bee products present alternative and supplementary health solutions, emphasising the urgency of developing beekeeping as a sustainable way of life that addresses diverse human needs (Mulenga & Hamauswa 2017).

2.2.1 Ecological and Environmental Aspects

2.2.1.1 Pollination

Honeybees globally play an essential role in pollinating crops and maintaining biodiversity in cultivated and non-cultivated areas, significantly contributing to ecological balance and biological diversity (Klein et al. 2006). Their pollinating activity is crucial for wildlife sustenance and plays a key role in mitigating soil erosion, underscoring their indispensable role in ecosystem health and diversity. A colony with 25,000 foraging bees can pollinate 250 million flowers, illustrating these insects' profound impact on floral reproduction and the sustenance of ecological systems (Hilmi et al. 2012).

However, the stability of ecosystem activities faces jeopardy when significant alterations occur in the populations of key species, such as honeybees and other pollinators (Pimentel & Burgess 2013). The importance of honeybees is further underscored by factors such as the misuse of plant-protection products, environmental pollution, challenges in accessing food sources due to agricultural monoculture, the use of production technologies, and the scarcity of non-agricultural land areas (Papa et al. 2022). Honeybees generate public goods that are non-excludable and non-rivalrous in consumption, demonstrating their value beyond direct agricultural benefits. This phenomenon creates free riders who benefit from these public goods' existence without directly participating in their creation or contributing financially to their maintenance (Vrabcová & Hájek 2020).

2.2.1.2 Biodiversity and Sustainable Agriculture

Bees play a pivotal role in pollinating a wide array of plant and tree species, thereby significantly boosting the growth of biodiversity and ecosystems. By aiding in the pollination of crucial crops, bees not only enhance crop yields but also provide critical nectar sources for themselves, establishing a vital link between agricultural productivity and environmental health (Hilmi et al. 2012; Illgner et al. 1998; Murcia-Morales et al. 2021).

As indicators of climate trends and ecosystem disturbances, honeybees offer invaluable insights into agrochemical reservoirs (Murcia-Morales et al. 2021). Their unique sensitivity to chemicals and phytosanitary products and capacity to gather samples from diverse environmental mediums position them as crucial bioindicators (Papa et al. 2022). Their roles in tracking demographic shifts, observing behavioural changes, and detecting bioaccumulation, along with their capacity to collect microplastic pollution and biomonitoring air for heavy metal content, further substantiate this evidence. (Edo et al. 2021; Etxegarai-Legarreta & Sanchez-Famoso 2022). The presence of toxic residues in bee products and their susceptibility to pesticides underscores their importance in environmental monitoring (Hilmi et al. 2012).

Beekeeping integrates seamlessly with small-scale farming systems, requiring neither land ownership nor considerations of soil fertility, thus eliminating competition for essential resources for livestock and crops. This practice underscores sustainability, notably in regions such as southern Africa, where the agricultural potential faces constraints from limited arable land or erratic rainfall patterns, demonstrating the adaptability and resilience inherent in beekeeping activities (Hilmi et al. 2012; Ntenga & Mugongo 1991).

Furthermore, beekeeping practises advocate for the conservation of local habitats, with beekeepers actively preserving nectar and pollen-rich vegetation, fostering a form of agriculture that protects indigenous vegetation (Illgner et al. 1998). By removing pesticides to safeguard honeybees, beekeepers highlight the environmental advantages of their trade (Etxegarai-Legarreta & Sanchez-Famoso 2022). Promoting training and education underscores the importance of sustainability and environmental protection within beekeeping, demanding specific expertise for the effective dissemination of knowledge (Ali 2015). Beyond bolstering food security, beekeeping requires minimal inputs other than labour, with inputs for beekeeping being locally procured without affecting other agricultural activities, thereby contributing significantly to livelihoods without the burden of extensive farm inputs (Hilmi et al. 2012).

2.2.2 Economic Aspects

2.2.2.1 Income Generation

Beekeeping improves the lives of beekeepers by ensuring they have access to vital tools, equipment, and critical infrastructure such as roads and markets (Allen-Wardell 1982). Earnings from beekeeping activities allow beekeepers to cover expenses for necessities like food, their children's education, social services, and housing, thereby contributing to an increase in their savings due to the boost in income (Mulenga & Hamauswa 2017). Specifically, beekeeping boosts cash flows in dry seasons when farm income diminishes, allowing for harvesting hive products multiple times a year during periods of high consumption, such as school fee seasons. Thanks to their prolonged shelf life, sellers can treat beeswax and propolis as savings, selling them off as necessary (Enzama 2008; Kidd 2001).

The practice creates economic linkages, connecting honey-processing industries and suppliers of modern beehives. High-value commodities like honey and beeswax enhance agriculture, offering easy transport and storage and a significant income source for subsistence farmers (Illgner et al. 1998; Mulenga & Hamauswa 2017). Beekeeping yields diverse products—honey, pollen, royal jelly, wax, propolis, and apitoxin—valuable in local markets and easily traded. These products, requiring minimal inputs, are profitable and transportable to distant markets, including exports (Aryal et al. 2020; Etxegarai-Legarreta & Sanchez-Famoso 2022).

Additionally, minimal processing turns bee products into value-added goods, such as candles and soap, increasing farm families' income. Bee pollination services for commercial crops can also generate revenue, enhancing crop yields and quality. Beekeeping provides economic stability, producing dependable, high-value products essential for rural farmers during economic downturns. Products like beeswax, which have an indefinite storage life, embody this stability (Hilmi et al. 2012; Illgner et al. 1998; Mickels-Kokwe 2006).

Beekeeping, when practised on a small scale, demands minimal labour, allowing beekeepers to continue traditional agricultural activities. It complements crop production and can boost yields and cash income through pollination (Ntenga & Mugongo 1991). Beekeeping stands out as a sustainable, low-cost initiative with minimal environmental impact, crucial for rural development by promoting food security, creating jobs, and conserving the environment (Illgner et al. 1998).

Bee products fulfil specific roles within the hive and offer substantial economic benefits when utilised by humans (Etxegarai-Legarreta & Sanchez-Famoso 2022). Beehives can also act as natural barriers against wildlife, protecting crops (Aryal et al. 2020). Faced with issues such as environmental decline and periods of drought, beekeeping presents itself as a creative strategy, offering a stable source of revenue even under challenging circumstances (Illgner et al. 1998). This practice allows farm families diverse and consistent yearly earnings, underscoring the vital economic role beekeeping plays in supporting rural areas (Ntenga & Mugongo 1991).

2.2.2.2 Employment Opportunities

Starting a beekeeping business in rural areas requires a thorough grasp of the local market dynamics and the capabilities of local small-scale farmers.

A comprehensive feasibility study on beekeeping as a potential business venture is advisable to prevent starting with an unsustainable number of hives or expanding beyond what the market can bear. Small-scale farmers are encouraged to assess market demand thoroughly, pinpoint where and how they can sell their bee products, and determine the necessary scale of production, equipment requirements, financing needs, and the overall economic viability of the enterprise. Market research is essential for pinpointing the demand for bee-related products and grasping the competitive landscape and market limitations.

To optimise production, small-scale farmers must evaluate factors such as nectar and pollen flow, hive location, water sources, the number of bee colonies and hives, average yield per hive, potential risks to production levels, labour needs, and post-harvest processing locations. The evaluation involves estimating equipment costs, exploring credit options within the local area, and calculating the beekeeping business's overall costs versus potential profits. Decisions regarding the initiation or expansion of beekeeping operations should consider profit potential and the broader implications for the farmer's family, local cultural norms, and social practices. Advisors are critical in guiding feasibility studies, yet the decision rests with the farmer and their family (Hilmi et al. 2012).

The beekeeping journey enriches farmers with new knowledge and skills pertinent to beekeeping practises through structured training programmes or accumulating experience (Carroll & Kinsella 2013). These newfound capabilities bolster beekeepers' proficiency. Furthermore, beekeeping fosters community networking opportunities through group formations that facilitate more accessible access to extension services, promoting rural diversification, offering an alternative source of income and employment in regions with limited arable land and high demographic pressure and assisting households in navigating economic shocks, thereby mitigating vulnerability (Benin et al. 2007; Illgner et al. 1998).

2.2.2.3 Diversification of Agriculture

Beekeeping is crucial in fostering rural diversification, offering an essential alternative income and employment source in regions where limited arable land and increasing population density render traditional landholdings less profitable (Illgner et al. 1998). In areas characterised by poor soil quality, beekeeping becomes a critical method for diversifying livelihoods, complementing their pastoral farming practices. This activity is vital for enhancing agricultural productivity and enriching farmers' incomes without demanding additional resources from agrarian pursuits. Beekeeping is especially beneficial for small-scale agricultural systems, as it requires neither land, soil fertility, nor feed, utilising untapped resources like nectar and pollen. Its ability to pollinate crops further contributes to increased agricultural yields.

Apart from labour during harvesting and processing stages, the minimal inputs required for beekeeping position it as an accessible and sustainable enterprise. It necessitates processing on the farm itself, creating opportunities for small-scale farmers to learn new skills and expand their capabilities. Such activities encompass basic processing tasks such as cutting honeycombs, extracting honey, filtering, and more advanced value-added processes like producing honey-infused sweets and soap. Through these on-farm processing activities, beekeeping boosts incomes and improves food security and availability, making bee products continuously available to farming families and local communities throughout the year (Hilmi et al. 2012).

2.2.3 Social Aspects

2.2.3.1 Community Development

The alarming decline in bee populations, a shift towards embracing neo-rural lifestyles, and reverence for rural values drive the surge in urban beekeeping across global cities. This expanding movement bolsters urban green spaces, slow food, and culinary arts, leveraging produce from individual vegetable gardens (Theodorou et al. 2020). A pivotal benefit of urban beekeeping lies in its capacity to enhance the pollination of urban flora, creating a pesticide-free environment ripe for fostering social consciousness (Coffman 2011).

Historically rooted in rural settings, beekeeping transcends mere agricultural practice, acting as a conduit for transmitting and enhancing community-based skills, knowledge, and traditions (Hilmi et al. 2012). By commercialising beekeeping, communities have seen an uplift in the competencies and capabilities of small-scale farmers, thereby nurturing and preserving beekeeping traditions without straying from established local practices and tools. This adaptability ensures a smoother and more fruitful adoption process.

Beekeeping artisanry also catalyses job creation, particularly in producing equipment such as hives, smokers, and protective gear (Illgner et al. 1998). It enables participants to generate supplementary income by crafting hives for beginners. Beyond its economic impact, beekeeping is instrumental in rural prosperity, augmenting crop yields through pollination, securing food and nutritional needs, provisioning traditional medicinal resources, and elevating overall community well-being (Hilmi et al. 2012). Bee products are cherished in cultural celebrations, thus knitting closer community bonds and perpetuating traditions.

Furthermore, beekeeping is a platform for community collaboration and cohesion, notably during the honey harvesting season when farmer associations commonly emerge. This collaborative essence is also evident in educational outreach, where beekeepers engage students through direct demonstrations, underscoring beekeeping's communal and educational value. Through such endeavours, beekeeping emerges as a pivotal force in nurturing economic growth and fortifying community solidarity in rural and urban landscapes (Aryal et al. 2020; Hilmi et al. 2012).

2.2.3.2 Empowerment

Beekeeping frequently develops into a family enterprise, featuring differentiated roles where men typically focus on harvesting, and women concentrate on extracting and processing honey (Hilmi et al. 2012). This arrangement allows women to engage in beekeeping as a traditional activity and positions it as a sustainable livelihood. The minimal labour and time requirements for managing bees and the flexibility to place hives within or near the household render beekeeping a remarkably adaptable and convenient practice (Illgner et al. 1998). It enables women to participate in an economic activity that fosters financial independence and resilience, particularly in challenging times. Moreover, beekeepers can readily market bee products to neighbours or local markets when necessary, offering a reliable cash source. This practice not only facilitates gender empowerment by enhancing women's societal and community standing but also addresses the broader challenges of unemployment in the context of increasing population and land scarcity (Coffman 2011).

While urban beekeeping presents its own set of challenges related to regulations, safety, and animal management, its sociocultural advantages, such as fostering community associations, providing biomimetic insights and enabling agritourism, are substantial (Kolayli & Keskin 2020). Beekeeping emerges as a critical instrument for community advancement and women's empowerment, displaying its relevance across rural and urban landscapes (Hilmi et al. 2012; Illgner et al. 1998).

2.2.3.3 Cultural Significances

Beekeeping transcends its role as a hobby, presenting significant advantages for societal well-being, satisfaction, and personal fulfilment. This activity has gained recognition as a cultural norm in various regions, notably within southern African communities, where a broad knowledge of honeybees and the practice of honey collection prevails (Illgner et al. 1998; Papa et al. 2022). Cultures across the globe cherish bee products, celebrating their value in rituals and celebrations like weddings and births.

The practice of beekeeping connects to diverse sociocultural functions, such as the promotion of participatory science, the innovation of beekeeping coworking spaces, the sponsorship of beehives, and the advocacy for pollination as a universal right. These advancements bolster the sustainability of beekeeping operations and play a pivotal role in environmental education, enhancing the synergy between beekeeping and sectors such as agriculture, livestock management, and nutritional sciences (Etxegarai-Legarreta & Sanchez-Famoso 2022).

Bees themselves are instrumental in the sustenance and health of agricultural communities. Their need for uncontaminated water sources and ability to forage across diverse landscapes render them indispensable allies, particularly in conflicting regions. Their pivotal role in pollinating a variety of flora contributes to the vitality of farm ecosystems. Through these interactions, beekeeping acts as a conduit for strengthening community bonds and preserving cultural heritage, thereby asserting its critical role in fostering community development and ensuring the continuity of traditional practices (Hilmi et al. 2012).

2.2.4 Health Aspects

2.2.4.1 Nutritional Benefits

Beekeeping increases food accessibility by enabling direct income generation, which families can use to buy nutritious foods. This practice helps decrease the occurrence of deficiencies in protein, iodine, vitamins, and iron (Wilson 2006). It also serves as a substantial source of nutrition due to its contribution to food availability.

Central to this are bee products, particularly honey, which find multiple uses in homes, notably as a natural sweetener (Gemeda 2014).

Honey characterises itself by its unique composition of antioxidants, essential minerals, various vitamins and proteins, and significant energy-value elements not found in synthetic sweeteners (Gemeda 2014; Illgner et al. 1998). Though not a primary food source, people often use honey as a dietary supplement, acknowledging its cultural significance. For instance, in Africa, communities commonly use honey to brew traditional beer for cultural and religious purposes (Krell 1996).

As a high-carbohydrate food source, honey introduces minerals, vitamins, and other nutrients into human diets, enriching nutritional variety (Gemeda 2014). It also enhances physical performance, resistance to fatigue, and mental efficiency while improving food assimilation (Hilmi et al. 2012; Krell 1996). Beyond honey, beekeeping yields products like pollen, which, sourced from various plants, contributes significantly to human nutrition with its thirty per cent protein content alongside vitamins, minerals, lipids, and trace elements (Hilmi et al. 2012).

Scientific evidence increasingly recognises honey more as a nutritional food than a medicine, underscoring its health benefits. These benefits are primarily nutritional, reflecting honey's role in a balanced diet. Bee products, including honey and pollen, exhibit unique characteristics based on their botanical and geographical origins and beekeeping practises (Hilmi et al. 2012; Sforcin 2016). They show a variety of health-enhancing and therapeutic attributes, including anti-inflammatory, antioxidative, antiseptic, and restorative benefits, among others that contribute positively to well-being (Oršolić et al. 2004).

2.2.4.2 Medicinal Use

A considerable body of history acknowledges the medicinal properties of bees and their products, including honey, pollen, propolis, wax, royal jelly, and venom. Many regard these products as having curative properties, although some scepticism exists due to the lack of thorough scientific examination. Traditionally, medicinal practises uniquely recognise honey's healing attributes linked to its origin from specific medicinal plants. Despite these beliefs, orthodox scientific evidence does not consistently support such claims (Hilmi et al. 2012).

Honey's antibacterial properties are well-documented, making it a popular remedy for colds and throat irritations (Krell 1996). It inhibits the growth of *Streptococcus pyogenes*, a common bacterium causing sore throats (Bradbear 2009). Beyond its antibacterial uses, honey promotes tissue regeneration and reduces scarring, even in its unprocessed form. It also enhances food assimilation, mitigating intestinal issues such as constipation, duodenal ulcers, and liver disturbances, thereby improving food utilisation. The demonstration of tropical honey applications expedites wound healing in animals, establishing it as a 'lifesaver' for persons with serious health problems (Krell 1996).

Propolis, known for its medicinal value, is widely used in herbal medicine across sub-Saharan Africa (Hilmi et al. 2012). Scientific studies confirm its bactericidal, fungicidal, and antiviral effects. Similarly, beeswax is recognised for its antibiotic properties, relieving arthritis and nasal inflammations (Krell 1996). While acclaimed for its positive effects on human health, royal jelly faces scrutiny over the lack of scientific evidence to substantiate these claims (Bradbear 2009). It, alongside propolis, is consumed for its medicinal benefits, with royal jelly also credited with enhancing physical resistance and intellectual performance (Hilmi et al. 2012).

Bee venom finds application in treating rheumatoid arthritis and muscle injuries despite ongoing debates regarding the scientific validation of these benefits (Bradbear 2009). Likewise, pollen serves in traditional medicine for issues like prostate problems, illustrating the diverse medicinal applications of bee products. Bees and their product use extend to pharmacological and biochemical research, leveraging the unique chemical compounds developed through their co-evolution with plants, prey, and predators.

Additionally, honeybee products emerge as valued commercial entities, particularly in regions such as northwestern Zambia, highlighting the economic significance of bees in medicine and commerce. This comprehensive overview underlines the intricate relationship between bees and human health, advocating for further scientific exploration to fully understand and validate the medicinal potential of bee products (Hilmi et al. 2012; Illgner et al. 1998).

2.3 Major Constraints Associated with Beekeeping

2.3.1 Environmental Impacts on Beekeeping

2.3.1.1 Climate Change and Weather Patterns

In most of Africa, the annual cycle of honeybee colonies is primarily limited by rainfall rather than temperature, prompting bees to forage throughout the year to sustain the colony. Even though temperature fluctuations do not deter honeybee activity, the lack of rainfall significantly hampers vegetation's ability to perform, particularly during flowering periods. This situation results in unavoidable conflicts between honeybee colonies due to the compounded effects of limited resources. As the dry season progresses, a noticeable decrease in available pollen and nectar exacerbates the situation, leading to a decline in worker brood-rearing and the cessation of drone production. Consequently, there is a marked decrease in food income and brood production, accompanied by a reduction in the colony's adult workforce due to natural attrition. This recurring annual challenge in the region often escalates into robbing behaviour among colonies as they vie for dwindling resources (Hepburn & Radloff 2011).

Annually, the dry season's culmination heralds bushfire occurrences, significantly impacting beekeeping through environmental degradation (Hepburn & Radloff 2011). These fires, often accidentally ignited during honey collection due to the smoking of hives, exacerbate the aggressive nature of tropical honeybees. Consequently, beekeepers must implement safety measures, including using protective gear and strategically placing bee colonies to mitigate risks to humans and animals (Illgner et al. 1998). Moreover, the frequency and timing of these fires critically influence the ecosystem. Late, recurrent fires hinder the regrowth of species sensitive to fire, altering the ecological balance and leading to a predominance of chip vegetation. Such environmental alterations transform the habitat and decimate diverse faunal populations, causing irreversible damage to the resource base on which beekeeping relies (Mulombwa 1998).

2.3.1.2 Habitat Loss

In Zambia, deforestation, happening at an annual rate of one and a half per cent because of agricultural expansion, fires, wood-fuel harvesting, and charcoal production for urban use, significantly endangers beekeeping. Half of the districts with the potential for beekeeping face severe pressures from agriculture and wood fuel extraction. It is crucial to carefully assess bee forage availability and implement protective policies before investing in beekeeping (Hilmi et al. 2012). Selectively cutting certain tree species and turning forests into agricultural lands leads to species extinction and increases susceptibility to late-season fires by promoting grass growth (Mulombwa 1998).

2.3.2 Biological and Ecological Challenges

2.3.2.1 Bee Colony Aggressive and Defensive Behaviour

Despite decades of research, a comprehensive understanding of honeybee colony defence and aggressiveness still needs to be discovered. The challenge lies in the nuanced distinction between aggressiveness and defensiveness —the former describes internal interactions within the colony, while the latter responds to external threats. In Africa, this distinction blurs, with historical apicultural literature offering little clarity. Analysing colony behaviour rather than focusing on individual bees presents additional difficulties (Hepburn & Radloff 2011).

Through their comparative experiences, seasonal agriculturalists have qualitatively categorised African honeybee races by their relative aggressiveness/defensiveness. These traits, being quantitatively inherited, display considerable variability in expression, influenced by time of day, weather, and seasonal changes. Aggressiveness fluctuates, peaking during intensive foraging and showing a midday decrease (Adjaloo & Yeboah-Gyan 2006). The degree of aggressiveness correlates with the colony's population at home, notably during low foraging periods (Woyke 1964).

Behavioural observations reveal that docile colonies allow hive inspection with minimal protection, while aggressive colonies increase hostility during the examination and require longer settling post-inspection. The level of aggression also synchronises with nectar availability and is not directly proportional to the number of bees within a colony. Aggression surges during the principal nectar flow in dry and rainy seasons, contrasting with reduced aggression during nectar dearth, regardless of the mean monthly temperature differences (Hepburn & Radloff 2011).

2.3.2.2 Issues with Swarming, Absconding, and Migration

Swarming in honeybee colonies, particularly prevalent from spring to early summer, marks a colony's natural reproduction process. It begins with worker bees reducing flight and engorging on honey, culminating in heightened activity, signalling the swarm's departure (Ferrari et al. 2008). This phenomenon, deeply rooted in the colony's response to climatic conditions and forage availability, aligns with rainfall patterns that drive flowering and brood production. Local environmental cues, such as droughts and sudden rainfall, influence the timing and frequency of swarming. The process involves preparations like queen cell construction and drone production, reflecting the colony's readiness to swarm. Supersedure, or replacing an underperforming queen, further illustrates the colony's adaptive mechanisms, ensuring its longevity. This complex interplay between environmental factors and colony dynamics underscores beekeepers' economic and managerial challenges, emphasising the significance of understanding swarming behaviours for sustainable beekeeping practices (Clauss 1992; Hepburn & Radloff 2011).

Absconding in African honeybee colonies occurs when entire colonies desert their nests due to disturbances, including predation by ants, wax moths, small hive beetles, bee wolves, or human-induced damage from traditional honey harvesting (Crane 1990). Environmental factors like nest inundation, overheating, or fires also trigger absconding. This behaviour is most noticeable when diminishing field resources, which results in decreased brood production and colony size, rendering colonies more vulnerable to pests and predators. Prepared absconding, a deliberate colony response to unfavourable conditions, involves reducing egg-laying, awaiting brood emergence, and consuming stores before leaving. Observations indicate that colonies opting for prepared absconding are typically smaller, with limited honey, brood, and foraging activity before departure, reflecting a strategic adaptation to environmental challenges (Hepburn & Radloff 2011).

Migration in African honeybees is a seasonally predictable adaptation to climate and floral patterns, not requiring the presence of queen cells or drones in migrating colonies. It is a strategic move for better foraging opportunities and conditions suitable for reproductive swarming. In Kenya, colonies migrate to forests rich in Dombeya blossoms due to resource scarcity and return to the savanna later. Similarly, in Zambia, colonies respond to *Brachystegia* sp. flowering with a cycle of brood rearing, swarming, and migration, indicating a close link between migration, resource access, and reproductive strategies (Crane 1990; Hepburn & Radloff 2011).

2.3.2.3 Predators, Pests, and Diseases

In Africa, honeybee colonies face significant predation threats that impact their populations and behaviour. As honey hunters and traditional beekeepers, humans are the most significant predators, often leading to the near-complete destruction of nests during harvest. Honey badgers (*Mellivora capensis*), particularly adept at accessing hives through climbing or digging, alongside their resistance to bee stings, pose a substantial natural threat—other mammals, such as rodents and the chacma baboon (*Papio ursinus*), opportunistically prey on honeybees or their nests (Skinner 2007).

Birds also contribute to the predation of honeybees, with families such as bee-eaters (family Meropidae), drongos (Dicruridae), swifts (Apodidae), and honeyguides (Indicatoridae) being notable avian predators. While reptiles and amphibians, including lizards, frogs, and toads, are reported to prey on honeybees, the lack of specific identifications makes understanding their impact challenging. Beetles and, more prominently, ants and wasps are considerable insect predators. Carnivorous ants can devastate apiaries by consuming brood and stores rapidly, forcing honeybee colonies to abscond in defence. This predation landscape underlines honeybees' complex threats from various African predators, necessitating adaptive survival and colony maintenance strategies (Hepburn & Radloff 2011; Robinson 1982).

In African honeybee populations, parasites such as the widespread bee lice, *Braula* sp., and numerous mite species, including *Varroa* sp., pose significant challenges (Skaife 1922). Mites, with almost 100 species identified, still need to be studied in Africa, yet their introduction has led to colony declines, notably *Varroa* sp. (De Jong et al. 1982; Morse 1991).

Pests, particularly Lepidoptera, such as the greater wax moth (*Galleria mellonella*) and lesser wax moth (*Achroia grisella*), inflict considerable damage on honeybee nests and stored frames worldwide (Williams et al. 1990). While robust colonies can often manage wax moth larvae, weaker colonies may abscond due to unchecked larvae destruction, leaving silk and frass debris trails through combs (Fletcher 1978).

2.3.3 Human-Induced Challenges

2.3.3.1 Agricultural Practices

Despite scarce documentation on how pollution from mining and industry affects biodiversity, the evidence of environmental damage is unmistakable. Industrial activities have led to air and soil pollution, significantly killing off plant life. This pollution spans from chemical leaks at waste disposal locations to widespread agrochemical use and deteriorating water quality (Muimba-Kankolongo et al. 2015). These environmental issues threaten ecosystems and could adversely impact bee populations and the broader ecological networks reliant on them (Mulombwa 1998).

2.3.3.2 Resource Competition

Robbing among bee colonies, particularly pronounced during the dry season's dearth periods, significantly impacts colony viability and reproduction. Smaller colonies, with their reduced stores, are more vulnerable to robbing, leading to the depletion of resources and the death of workers. Furthermore, the tumult of robbing-fighting poses a critical risk to the colony's continuity as queens can be encased by bees (balled) and potentially killed. Such a colony faces inevitable demise without a worker brood to sustain its future. This sequence of events, recurring annually in many African regions, underscores the harsh realities bee populations face, highlighting the dire consequences of environmental stressors and resource scarcity on these pivotal pollinators (Hepburn & Radloff 2011).

2.3.4 Socio-Economic and Operational Barriers

2.3.4.1 Processing and Market Access

Beekeepers and honey hunters in remote and underserved regions face significant barriers in processing and accessing markets for their products. Challenges include the need for suitable honey storage, transport, and sale containers, compounded by limited retail packaging options. The need for more infrastructure, such as roads, transportation options, and inadequate communication facilities further exacerbates these difficulties. Beekeepers need more bargaining power, organisational support, and access to quality training and technical advice. Poor access, low product prices, and weak social linkages with other producers and potential buyers constrain the market for honey.

Additionally, the sector needs more targeted extension materials, marketing information, and skilled trainers. Weak organisational representation and better linkages between producers and buyers help the industry's growth. Coordination between beekeeping and other relevant sectors like horticulture, forestry, health, and the environment is minimal. The lack of effective product promotion, beekeeping policies in developing countries, and no global consensus on honey standards limit market access. Beekeepers working alone frequently receive insufficient compensation because of these obstacles and the logistical problems of transporting honey to marketable areas. Consequently, they are susceptible to low-price offers from traders looking to exploit these vulnerabilities (Bradbear 2009).

2.3.4.2 Knowledge and Education Gaps

A significant challenge in beekeeping is the illiteracy of numerous farmers and beekeepers, which complicates record-keeping for each honeybee colony. It is crucial as it allows beekeepers to track the honey amount and the colony's condition throughout the year, facilitating optimal harvest timing decisions. Furthermore, illiteracy hinders the efficient dissemination of information to beekeepers, impacting their ability to manage colonies effectively (Illgner et al. 1998).

2.3.4.3 Research and Development

The lack of extensive research on African bees represents a significant issue. While considerable research has focused on honeybee races in the world's temperate regions, exploring more than tropical African races is needed. The behaviours of temperate bee races often differ markedly from those in tropical environments, rendering beekeeping techniques homed in temperate climates unsuitable for tropical settings. For instance, temperate bee colonies can endure cold periods by clustering together and amassing substantial food stores during abundant times. In contrast, tropical bee colonies exhibit nomadic behaviours to adapt to their environments (Hilmi et al. 2012; Illgner et al. 1998).

2.3.5 Management and Conservation Strategies

2.3.5.1 Enhancing Beekeeping Sustainability and Beekeeper Competence

Promoting sustainable beekeeping requires addressing several challenges, including environmental degradation. Frequent bushfires pose a significant threat. Beekeeping support services for small-scale farmers must be accessible, sustainable, and located near production areas, addressing immediate needs while anticipating future requirements and evolving resources. Crucial to promoting beekeeping and enhancing current practices are technical training, the provision of modern beekeeping equipment like removable frame hives, and practical information dissemination. However, reaching rural and remote areas with this knowledge poses a challenge, necessitating modern communication technologies alongside traditional media (Illgner et al. 1998).

Moreover, incorporating business skills training into technical training programmes, including marketing and business management, enriches beekeepers' understanding of managing a beekeeping business. This direct approach fosters learning through action, observation, analysis, and decision-making.

Empowering women in beekeeping is paramount, given the barriers they face in actively participating in commercialising their produce. When tailored to be socially and culturally acceptable, development programs can elevate women's roles in beekeeping, enhance their production knowledge, and ensure the industry hears their voices.

Finally, establishing trust and strong linkages between small-scale farmers and traders is vital for the sector's development. Promoting commodity associations and enhancing transparency in the bee product supply chain can facilitate more robust relationships between all stakeholders, thereby supporting the sustainable growth of beekeeping. This comprehensive approach aims to improve beekeeping sustainability and competence, contributing significantly to the sector's development (Hilmi et al. 2012).

2.4 Value of the Apicultural Industry in Zambia

Due to its advantageous environmental conditions, Zambia's apiculture sector shows a promising avenue for economic development and poverty alleviation (Mickels-Kokwe 2006). Regions characterised by dry climates, dense bushland, indigenous forests, and expansive Brachystegia woodlands at low altitudes present ideal bee habitats, ensuring a rich nectar source during distinct flowering seasons. Such ecological attributes underscore the country's capacity for significant honey production (Ali 2015; Hilmi et al. 2012).

Zambia has emerged as a significant contributor to the African and global honey markets, with historical data highlighting its capacity to generate over US$12 million annually through honey exports. Achieving this potential necessitates a stronger emphasis on research and applying advanced technologies in beekeeping. This sector plays a crucial role in rural development, providing an avenue for economic improvement with low startup costs (Ali 2015). Transitioning to commercial-scale operations through adopting modern beekeeping techniques and strategies for adding value, such as obtaining different certifications and meeting international honey standards, is crucial for maximising the industry's economic benefits (Mickels-Kokwe 2006).

Initiatives to enhance the honey industry's value include improving honey quality and establishing Zambian honey standards that align with global benchmarks, which are supported by the Zambia Honey Council, underscoring the strategic move towards boosting the economic prospects of beekeeping and ensuring sustainability and competitiveness in international markets. This strategic approach emphasises the importance of integrating innovative practices with traditional beekeeping, marking a significant step towards realising Zambia's full potential in the honey export market (Mutumweno 2012).

Zambia's biodiversity, especially its indigenous African honeybee (*Apis mellifera* ssp.) populations in the Miombo belt, is crucial in sustaining the commercial beekeeping industry, contributing to global honey production and pollination services (Mickels-Kokwe 2006). The North-Western Province stands out as a significant beekeeping area, with honey and beeswax exports to Europe bolstering Zambia's foreign exchange earnings and providing a substantial income source for local beekeepers (Coppinger et al. 2019).

The apiculture industry in Zambia holds considerable promise for enhancing socio-economic development in rural communities. It aligns with strategic goals focusing on research, commercialisation, and compliance with quality standards (Kaal et al. 1992). This strategic orientation capitalises on Zambia's favourable environmental conditions and industry advancements towards value addition and standardisation, promising improved livelihoods for beekeeping employees (Mickels-Kokwe 2006).

2.5 Existing Methods of Beekeeping

2.5.1 Traditional Beekeeping

Over the decades, communities have relied on honeybees for sustenance, transitioning from bee hunting to beekeeping for honeybee colony maintenance. Such evolution in bee management, especially in the tropics, has unfolded through several stages—initially, communities engaged in opportunistic honey hunting from wild nests (Gupta et al. 2014). Gradually, the practice morphed into an organised honey collection from nests recognised as belonging to individuals or communities. The progression continued with beekeeping's inception, characterised by utilising simulated natural nest sites. Subsequently, apiary beekeeping began, signifying a shift towards relocating natural nest sites to apiaries and employing fixed-comb hives (Crane 1999). The culmination of this development saw the adoption of purpose-designed hives, ranging from basic to more advanced configurations, including horizontal hives with removable parts for ease of maintenance and honey storage and single-chamber top-bar hives for movable-comb operations (Hilmi et al. 2012).

Beekeeping encompasses capturing and domesticating wild colonies into manufactured boxes, such as wooden boxes or clay and mud cylinders, traditionally known as beehives. Within these structures, honeybees proceed to construct and tend their natural combs. The two main types of hives used in this method are the traditional fixed frame and the improved movable frame, with variations such as log, pot, and basket hives included in the former (Engel et al. 2009). These traditional methods, defined by practices and techniques passed down through generations, often via oral instruction, form the backbone of beekeeping in many underdeveloped regions. Despite their diminished prevalence in industrialised nations, where health inspection regulations may even outlaw them, communities in developing countries still consider fixed comb hives integral to their livelihoods. They favour these hives for cost-effectiveness, as people can construct them from readily available materials (Hilmi et al. 2012).

This traditional beekeeping has evolved to protect the bee colonies and ensure periodic harvests of honey and wax without jeopardising the colonies' survival and critical pollination services. In contrast, honey hunting, a practice aimed at diversifying food sources and generating income through the sale of honey, poses significant risks to bee populations, potentially leading to colony destruction and wildfires, thereby endangering the hunters' livelihoods and resulting in lower-quality honey and wax (Hilmi et al. 2012; Mickels-Kokwe 2006).

Figure 2 Beehive made from bark (Nature's Nectar Zambia 2019)

The narrative extends to Zambia, where honey collection has historical roots, with evidence of beekeeping and honey hunting dating back to the mid-19th century. Beekeeping has notably flourished in the North-Western Province, a major producer of honey and beeswax, leveraging traditional materials like logs, calabashes, and pots for hive construction (Figure 2). The prominence of bark hives, favoured for their technological superiority and profitability, emerged under colonial encouragement (Mickels-Kokwe 2006).

However, the commercialisation of beekeeping and the consequent rise in beekeeper numbers alongside a growing population have exerted significant pressure on forest resources (Clauss 1992; Mickels-Kokwe 2006).

Bark harvesting for hive construction has sparked criticism because of its potential adverse effects on the ecosystem, the potential for biodiversity loss, pressure on nectar-bearing species, and alterations in woodland composition. The sustainability of traditional beekeeping practices in regions like the North-Western Province of Zambia is thus under scrutiny, challenged by human population growth, limited alternative income sources, and the adverse effects of deforestation and agricultural expansion (Mickels-Kokwe 2006).

2.5.2 Intermediate Technology Beekeeping

Intermediate technology beekeeping originates in ancient practices, notably in Ancient Egypt around 5000 BC, where beekeepers first used purpose-made hives. These early hives, constructed from earth materials or woven plant stems, featured removable ends for managing bees, a technique that spread across the Mediterranean (Gupta et al. 2014). In Northern Europe, traditional beekeeping employed hollow logs to simulate natural nests, enhancing protection against predators and stabilising temperatures. This method evolved into fixed-comb hives, which saw innovations such as introducing a removable top and adding honey chamber extensions in tropical regions (Mickels-Kokwe 2006).

The development of beekeeping further advanced with the introduction of movable-comb hives, such as single-chamber top-bar hives, improving ease of management, inspection, and harvesting (Figure 3). In contrast, movable frame hives like the Langstroth and Kenya top bar became preferred for their practical advantages, significantly contributing to beekeeping's popularity as a sustainable livelihood strategy (Ellis & Bahiigwa 2003).

Figure 3 Hive made from regionally sourced material

Amidst technological advancements, the natural beekeeping movement emerged, advocating for more straightforward practices that align closely with bee's natural behaviours. Proponents favour the top-bar hive for its simplicity and non-invasive design, positioning it as a modern alternative to conventional hives. This movement challenges mainstream beekeeping practices, promoting a return to methods prioritising bee colonies' health and instincts (Hilmi et al. 2012).

2.5.3 Modern (Moveable-frame) Beekeeping

Modern beekeeping has evolved significantly with the introduction of movable-frame hives, facilitating efficient honey production and bee colony management. The Langstroth hive, prevalent in the United States, marked the first successful design with movable frames. However, traditional straw skeps and unframed box hives have fallen out of favour due to legal restrictions for disease inspection, though they remain in hobbyist use for swarm collection (Hilmi et al. 2012).

Adopting top-bar hives, such as the Kenyan and Tanzanian Top Bar Hives, is rising among amateur beekeepers for their simplicity and reduced physical strain during bee interactions (Figure 4). These hives, widespread in Africa and Asia, do not allow for comb reuse after honey extraction, unlike frame hives.

Movable frame hives are designed for maximum honey yield by recycling beeswax combs, requiring precise construction and regular replacement of components like frames and foundations. Centrifugal extractors are essential for optimising honey harvests, with production levels dependent on forage availability and colony health (Gupta et al. 2014).

Figure 4 Two Kenyan top bar hives hung on a low branch

The beekeeping industry, boosted by these innovations, has expanded employment opportunities and contributed to local and global markets. The shift towards movable-frame hives, including the Langstroth and various top-bar designs, aligns with efforts to eradicate poverty and promote environmental conservation through minimised tree cutting and the support of agroforestry, underscoring the move from traditional to more sustainable and efficient beekeeping practices (Hilmi et al. 2012; Mulenga & Hamauswa 2017).

2.6 Development, Extension Services and Adoption Dynamics of Beekeeping

In Zambia, beekeeping is a critical sector with significant potential for national growth, especially in the North-Western Province, which produces most of the country's honey and beeswax. Exporters send most beeswax abroad despite robust domestic demand, generating essential foreign cash. Increased honey and beeswax production, particularly in resource-rich areas, boosts the economy and supports impoverished rural communities by improving food security. The sector's potential for environmental conservation is noteworthy, albeit complex, due to beekeepers' limited control over other forest users, scant institutional support, and governmental enforcement challenges. Organic or Fairtrade certification has emerged as a private sector initiative to boost export earnings by tapping into international market premiums, although it currently receives minimal government recognition and support (Mickels-Kokwe 2006).

Historically, the Zambian government's engagement in beekeeping dates to commercial activities initiated in the 1890s. Initial efforts concentrated on bark hive-making and beeswax production under the Department of Agriculture. These efforts evolved with establishing a beekeeping division in 1959, transitioning the focus from agriculture to forestry. Despite significant investment and extension services to enhance beekeeping practices, the liberalisation of the economy marked a shift away from government involvement.

Legislation and policy have historically framed beekeeping as a rural income enhancement and forest conservation tool. Notably, policies have aimed at modernising beekeeping practices, improving production, and encouraging the formation of beekeeper cooperatives. The Zambian Forest policy and the Forest Act delineate bee products as minor forest produce, setting the stage for a structured approach to beekeeping. Comparative analysis with neighbouring countries like Zimbabwe and Tanzania reveals a more robust legislative framework elsewhere, emphasising bee disease control, conservation, and beekeeping management (Clauss 1992; Ntenga & Mugongo 1991; Mickels-Kokwe 2006).

A wide range of players, including government organisations, non-governmental organisations (NGOs), and the business sector, influence the beekeeping environment in Zambia, highlighting the importance of policies that recognise the contributions of these diverse actors. The supply chain, from production to retail, involves many participants, each playing a critical role in the industry's sustainability (Mickels-Kokwe 2006; Mulombwa 1998).

Domestic production of honey and beeswax has faced challenges, including fluctuating yields attributed to environmental factors like the flowering patterns of the mutondo tree (*Julbernardia paniculata*). Despite these challenges, the honey market remains vibrant, with local consumption and exports contributing to the economic fabric of rural communities. The industry's reliance on natural forests for beekeeping underscores the importance of sustainable practices and the conservation of these habitats (Mickels-Kokwe 2006).

3 Aims of Thesis

This thesis aimed to analyse and provide recommendations for enhancing the sustainability and effectiveness of beekeeping practices in Western Zambia.

1) **The main objective**
   - The main objective of this study is to assess the current beekeeping practices in Western Zambia to understand their sustainability and efficiency.
2) **Specific objectives**
   - To identify significant challenges for local farmers, including environmental and socio-economic barriers.
   - To investigate the potential of sustainable beekeeping practices and their adoption by farmers and propose actionable and sustainable methods to enhance apiculture and community well-being.
   - To examine the integration of apiculture with other agricultural practices for mutual benefits.
3) **Research questions**
   - What are the current beekeeping practices among local farmers in Western Zambia, and how sustainable are they?
   - What methods are used by farmers, and how effective are they in terms of honey production and hive health?
   - What are the main challenges farmers face in Western Zambia, and what strategies can be employed to overcome them?
   - What sustainable beekeeping practices can be recommended to improve both the beekeeping industry and the livelihoods of local farmers in Western Zambia?
4) **Hypotheses**
   - Insufficient access to appropriate training and resources for beekeeping constitutes a considerable obstacle to the efficiency of beekeeping objectives in Western Zambia.
   - Local beekeepers in Western Zambia employ a mix of traditional and modern beekeeping practices with varying degrees of sustainability.
   - Integrating beekeeping with other forms of agriculture leads to increased overall productivity and environmental sustainability on farms in Western Zambia.
   - Major challenges hindering the adoption of sustainable beekeeping practices in Western Zambia include knowledge gaps and environmental constraints.

- Implementing targeted interventions and education programs on sustainable beekeeping practices can significantly improve the sustainability of beekeeping in Western Zambia and the livelihoods of local farmers.

4 Methods

4.1 Theoretical Part

This research investigated the subject through a comprehensive review of secondary data, focusing on tropical beekeeping, primarily in Africa and Sub-Saharan Africa, and its management. I searched for relevant information using literature, electronic articles, and professional manuals. The exploration included the limitations associated with beekeeping, the development of farmers new to this practice, and the diverse benefits beekeeping offers small-scale farmers.

I drew secondary data from scientific databases, including Google Scholar, ResearchGate, ScienceDirect, Scopus, and JSTOR, to conduct this research. The search strategy used keywords such as apiculture, traditional beekeeping, Zambia, Africa, Kenyan Top Bar Hive, economic development, bee products, social development, challenges in beekeeping, beekeeping history, maternity behaviour, and others.

Therefore, I evaluated the gathered data using content analysis, synthesis, and comparison techniques. This methodological approach allowed for a thorough analysis of the available literature.

4.2 Practical Part

4.2.1 Study Area

The methodology section details three study areas—Nalolo, Senanga, and Lituya—in Western Zambia (Figure 5) (IWPM2, 2023). These areas are situated within the Barotse Floodplain, a significant wetland in Zambia's Western Province, part of the Barotse sub-catchment of the Upper Zambezi River Basin (Figure 6). A sub-tropical climate characterises this region, delineated into three main seasons: a hot, dry season from mid-August to mid-November; a wet, rainy season from mid-November to April; and a dry, cold season from May to mid-August. The climate and weather patterns are crucial to the study as they significantly influence local agricultural practices, particularly beekeeping, which is central to this research.

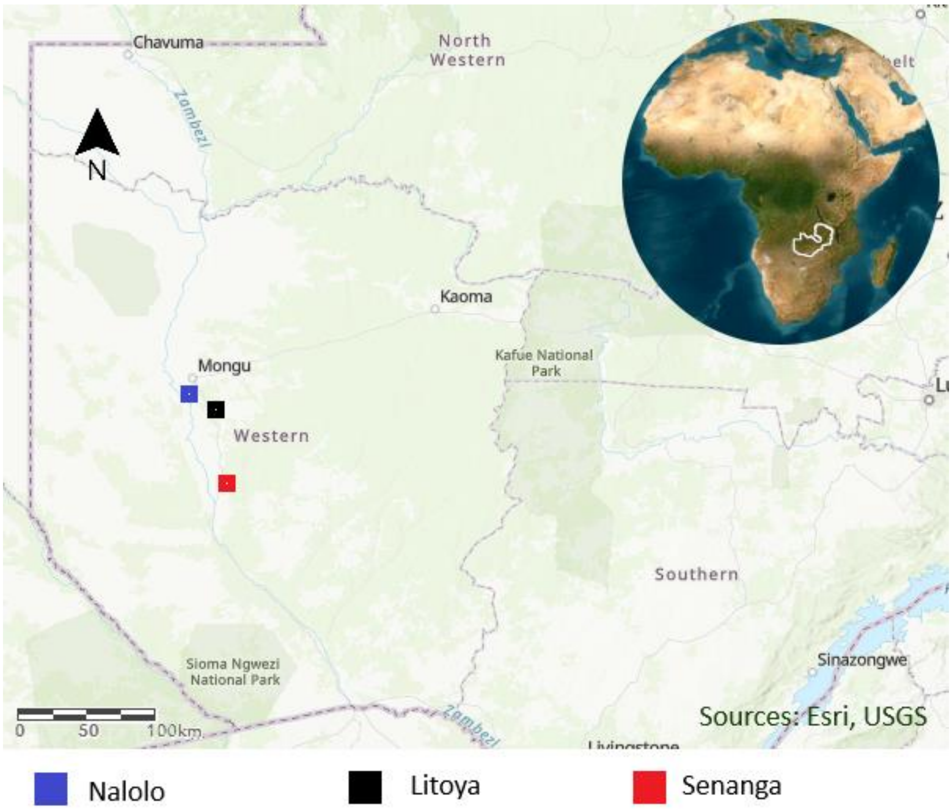

Figure 5 Map of researched places (Esri, USGS 2023)

The Inter-Tropical Convergence Zone (ITCZ) and the El Niño/Southern Oscillation (ENSO) are major climatic factors affecting rainfall variability, vital for understanding agricultural productivity and sustainability in these areas. The ITCZ annually oscillates between the northern and southern tropics, affecting rainfall from October to April, while ENSO contributes to inter-annual rainfall variability. El Niño typically results in reduced rainfall in the country's southern half during the wet months, whereas La Niña tends to increase rainfall in these areas. These patterns are referenced from climate data provided by the World Bank (2022) and detailed geographic information from Banda et al. (2023), offering a comprehensive understanding of the environmental factors that affect the study regions (Figure 5).

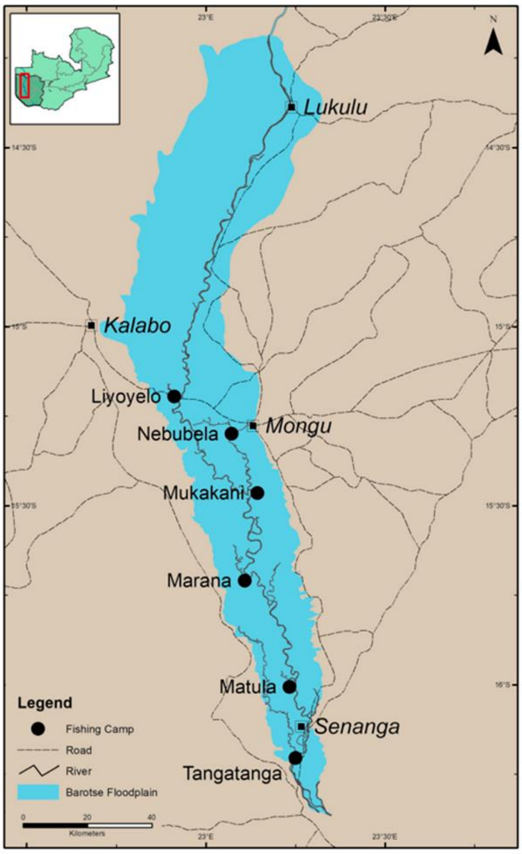

Figure 6 Map of the Barotse Floodplain with district towns (Kaminski et al. 2020)

4.2.1 Data Collection

The study took place from mid-November to the end of November 2023, in other words, the end of the dry season and the beginning of the wet season. Despite the beginning of the wet season, we encountered no complications with rain during data collection.

A mixed-methods approach comprising qualitative and quantitative techniques was applied to the study. Qualitatively, the study involved five individual structured interviews, three with a local MENDELU project manager about a description of farmers and places, the challenges with beekeeping, and the criteria for choosing farmers and two interviews with selected farmers, using a field participative approach and with ex-pats engaged in beekeeping. These interviews aimed to gather insights on beekeeping experiences, challenges, and hive conditions. The second qualitative method was a debate with the farmers, with whom we could not do individual interviews. On the quantitative side, the study collected data on hive occupancy from each participating farmer. This data provided a numerical basis for evaluating the effectiveness of beekeeping practices. This methodology combined empirical data with personal insights, offered a comprehensive understanding of beekeeping practices and challenges, and informed practical solutions. A voice recorder was used to gather the primary data during the individual interviews and debates.

We initially planned to conduct a hive inspection. However, upon arrival and after observing the hives, we decided against performing the inspection. After failed tries of inspection of empty hives and only a small number of hives occupied, we decided that due to the small number of hives occupied and the limited time available (IWPM1 2023).

With the assistance of Ing. Radim Kotrba, Ph.D., and a local MENDELU project manager, we compiled the number of locations and anticipated participants. We developed questions for individual structured interviews for these locations, which included two parts and debate prompts. Based on the field officers' experiences, they selected farmers for these interviews and an interview with the project manager. We held debates three times at meetings with farmers from the study location. After the debates, we tried to promote sustainable beekeeping methods, having discussions with farmers to answer questions about topics they were unsure about from previous training sessions by MENDELU (Figure 7).

Figure 7 Debate with farmers

4.2.1.1 Individual Structured Interview

The first section of the individual structured interview aimed to collect general information about the location, challenges farmers face, beekeeping methods, satisfaction with the hive type, desires for changes, previous beekeeping experiences, integration of beekeeping with other agricultural practices, and environmental factors. The second section used a table to record the total number of hives each farmer received, the reception dates, how many were occupied by bees, and instances where hives were temporarily occupied due to absconding (IWPM1 2023).

The objective was to evaluate current beekeeping practices in western Zambia to understand their sustainability and effectiveness and to identify and address challenges. The individual structured interview with the project manager aimed to gather information about the project, the challenges those working with farmers face, and future expectations. I engaged with three farmer groups of 9, 10, and 11 members in the debate.

4.2.1.2 Debate

The debates primarily involved farmers who did not participate in the individual interviews. However, farmers who had been interviewed were also present to contribute additional insights that others might have overlooked. This data collection mirrored the second part of the individual interviews, focusing on the total number of hives, their reception dates, the number occupied by bees, and any temporarily occupied hives. The second part of the discussion addressed challenges, comments, and uncertainties in beekeeping, aligning with topics from the first part of the individual interviews.

The debate aimed to uncover additional challenges a farmer might have overlooked during an individual interview, compare their challenges, and provide responses. My limited connection with MENDELU proved beneficial, as it encouraged farmers to openly discuss the challenges they face with the project.

Due to language barriers, field officers translated the interviews and discussions for the farmers. In compliance with GDPR and restricted access to participant names, the results remain anonymous, not specifying the respondents' gender or age. We evaluated the data using Excel tables and prepared graphs for individual locations to illustrate the relative use of various management methods in breeding across institutions (IWPM1 2023).

4.3 Data Analysis

During the study, I conducted interviews and debates crucial for gathering quantitative and qualitative data. I recorded these sessions using a voice recorder to ensure accuracy in data capture. Subsequently, I meticulously transcribed the recordings to convert the oral data into a written format. This transcription process was essential for accurately capturing the details of each conversation.

For the quantitative analysis, the data obtained from interviews included specific metrics such as the number of hives each farmer owned, the number of these hives that were full, the number that were empty, and the duration for which the hives had been in use. I input these data into Microsoft Excel and organised them into tables, facilitating a structured analysis. This step was vital for preparing the data for statistical analysis and visual representation in the results section.

For the qualitative aspects, the interviews and debates provided rich, descriptive data that were not quantified in percentages but were indicative of common trends and opinions among the participants. For instance, if a participant mentioned a problem with ants and others agreed (DWFIL 2023), I noted this consensus as a significant qualitative finding rather than a quantifying agreement. This approach allowed me to capture the breadth of experiences and opinions on various issues affecting the participants, such as pest problems or other beekeeping challenges.

Integrating both quantitative and qualitative data analysis methods provided a comprehensive understanding of the beekeeping practices in the study area, highlighting both statistical trends and individual experiences and insights from the participants. This dual approach enriched the findings, offering numerical data and contextual interpretations essential for comprehensively addressing the research questions.

5 Results

5.1 Structured Individual Interviews and Debates

5.1.1 Environmental Factors

During our research, we observed several environmental challenges that negatively impacted beekeeping. Many hives, unfortunately, became residences for ants rather than bees, threatening the hives. The absence of pollen for several months affected the bees' ability to populate new hives. To address the scarcity of local flora (DWFIL 2023), MENDELU provided farmers with seedlings and young trees from their agroforestry project, offering a broader range of plant species. This initiative aimed to enhance the environmental sustainability of beekeeping by improving habitat diversity, thereby supporting both bee populations and local biodiversity (DWFIL 2023).

Figure 8 Wood dried on the hive and created gaps

5.1.2 Management Practices and Hive Maintenance

The interviews and debates highlighted significant deficiencies in management practices and hive maintenance. Farmers occasionally killed queen bees accidentally during routine procedures or harvesting (IWPM1 2023). The use of grease to combat ant infestations adversely affected the bees due to its harmful components (DWFIS 2023). Improperly placed hives on trees frequently led to stability issues, requiring hives to be hung correctly rather than leaning against trees (DWFIN 2023). The wood used on hives was not dried, and it cracked as it dried and created holes in the hives (Figure 8). This misalignment compromised the structural integrity of the hives. Additionally, delays in wax provision and not helping farmers apply wax adequately after receiving clean and unprepared hives hindered the bees' ability to establish themselves within the new environments (Figure 9) (DWFIL 2023).

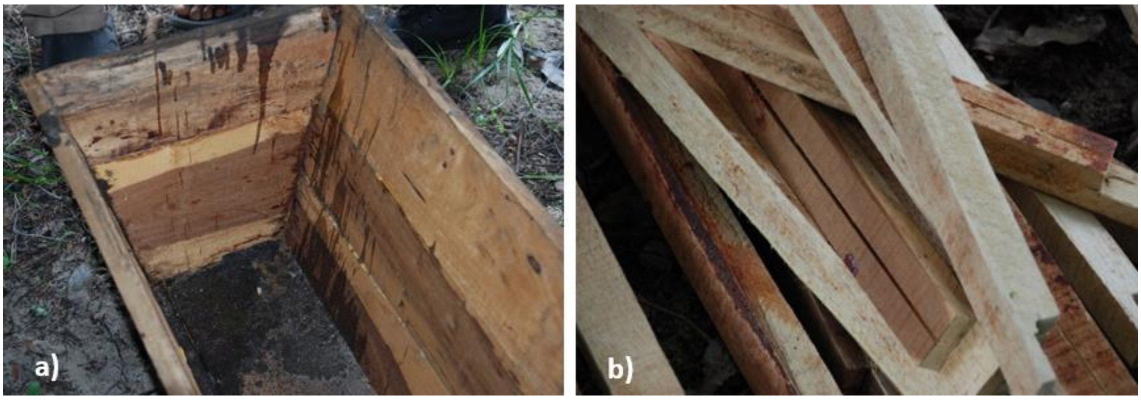

Figure 9 Application of wax by farmers: (a) wax poured on hive floor; (b) no wax applied on bars in the same hive

5.1.3 Bee Behaviour

Observations recorded during the study period identified absconding behaviours among the bees, signifying instability within the hives. This instability was exacerbated by leaks from the tops of hives, holes in the floor of the hive, and problems arising from improper hanging and insufficient windbreaks, all of which contributed to the stress experienced by the bee colonies. Seasonally, bees were expected to return around December to January, displaying a recurring pattern in their activity. However, farmers demonstrated a need for more awareness regarding the maintenance of absconded hives, leaving them untouched (Figure 10). This neglect led to mould on the loft combs and allowed ants and wax moths to infest the abandoned structures (Figure 11). Enhanced training on hive management after absconding incidents is crucial to prevent such detrimental outcomes and maintain bee colonies' health and productivity (DWFIS 2023).

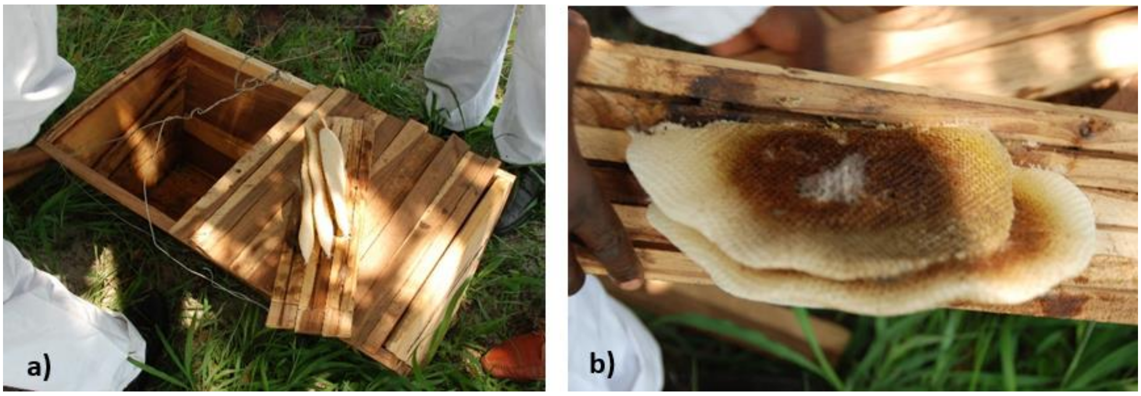

Figure 10 Absconded hive with combs left inside (a) and mould on them (b)

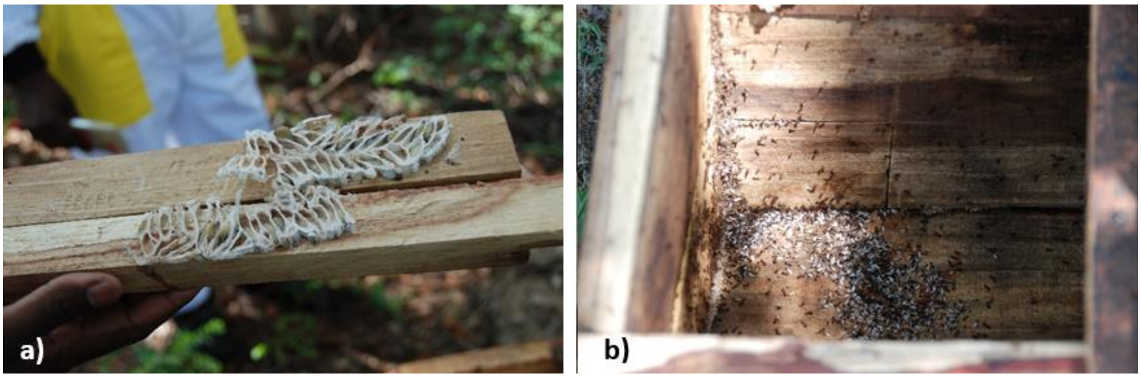

Figure 11 A wax moth in the abducted beehive (a); ant colony in the abducted beehive (b)

5.1.4 Assessment of Beekeeping Methodologies

All participating farmers utilised the Kenyan Top Bar Hive (KTBH) provided by MENDELU (IWPM3 2023). Along with the hives, they received essential beekeeping tools such as a smoker, hive tool, protective clothing with a veil, and a brush for maintenance. They were equipped with a knife and a bucket for harvesting (Figure 12) (IWPM2 2023). However, harvesting often involved manually cutting most of the combs from the bars and squeezing them in a bucket. Due to the cutting of combs, even with brood, practices like that harm the bees and degrade not only the quality of the honey but also the colony itself (IWPM1 2023). Additionally, many hives were positioned in open areas lacking adequate protection from wind and sun, adversely affecting temperature regulation and compromising the hives' security (DWFIN 2023). To mitigate these issues, it is crucial to introduce improved harvesting techniques that minimise harm to bees, enhance honey quality and reevaluate hive placement strategies to ensure better environmental control and safety.

Figure 12 Small bucket filled with harvested combs with honey

5.1.5 Infrastructural and Community Challenges

This study revealed several infrastructural and community challenges that significantly impact beekeeping practices. One of the primary infrastructural issues identified was ant and termite infestations within the hives, which posed substantial problems for beekeepers (DWFIS 2023). Additionally, the findings highlighted the prevalence of solitary work among farmers, which led to infrequent hive checks, sometimes occurring only once every two months. This lack of regular maintenance is primarily due to the farmers' independent working style, with little collaboration beyond immediate family members (DWFIL 2023).

The data further indicated a need for communal engagement in beekeeping activities, suggesting that strengthening community ties could enhance collective support and efficiency. Participants also expressed the need for improved knowledge concerning the optimal timing for hive inspections, indicating a significant gap in primary beekeeping education (IWPM1 2023).

Moreover, external disturbances were frequently reported, such as noise from children playing near the hives or animals tied under the trees to graze (mainly goats). These disruptions stress the bee colonies and complicate the beekeepers' efforts to maintain a calm and stable environment for their hives (Figure 13). Together, these challenges underscore the critical need for enhanced training and community cooperation to overcome the obstacles beekeepers face in this region (DWFIN 2023).

Figure 13 Hive hung in the tree canopy, away from ground-level stressors, on a farm where a beekeeper successfully has seven occupied beehives - the challenge is, on the other hand, regular inspection of the colony.

Participants needed better knowledge about the optimal timing for hive inspections and reported disturbances from external noise, such as children playing near the hives. Additionally, the scarcity of local flora providing necessary pollen or nectar and detrimental practices like burning near the hives negatively impacted the bees' environment. The remoteness of water sources further complicated beekeeping activities (IWPM1 2023).

Lastly, the equipment provided by MENDELU needed to be improved, and farmers voiced a need for more tools and to enhance their beekeeping capabilities. These findings suggest that addressing community cooperation and infrastructural improvements is essential for advancing sustainable beekeeping in the region (DWFIL 2023).

5.1.6 Language Barriers and Education

Language barriers and literacy issues presented significant challenges in the training of farmers. Most farmers spoke only Lozi, their local dialect, and did not understand English. Historically, most experts who conducted training sessions communicated exclusively in English, necessitating the presence of a field officer to translate. Moreover, the farmers were provided with a beekeeping manual written primarily in English, which included only a few illustrative pictures to depict various beekeeping activities. This approach proved inadequate, as evidenced by the farmers' inability to answer basic questions about beekeeping, such as identifying what honey on a comb looks like, even after several training sessions with MENDELU (IWPM1 2023).

The debates and interviews revealed that the farmers lacked critical knowledge about beekeeping. The manual, primarily written as an academic introduction to the subject, focused on bee biology and harvesting techniques rather than serving as a practical educational tool tailored to the farmers' needs. It is imperative to develop training materials and manuals in Lozi, enriched with extensive visual aids to enhance understanding and retention. This adjustment would bridge the communication gap and significantly improve the effectiveness of the beekeeping training programs (DWFIS 2023).

5.2 Hive Occupancy

The hive occupancy data collected from Nalolo, Litoya, and Senanga provide an informative perspective on the success of beekeeping practices in these regions.

In Nalolo, the data indicate a total of 33 beehives were managed by farmers, of which only 14 were occupied by bees at the time of data collection, leaving 19 hives empty. The timing of hive distribution is a significant factor, as all hives received in July 2023 were unoccupied. In contrast, one farmer who received hives in 2021 and July 2023 managed to occupy all seven hives. One of the possibilities for his successful occupancy of hives was that he lived farther from the village and had almost no stressors or disturbances near the beehives (Table 1) (DWFIN 2023).

Table 1 Hive occupancy in Nalolo (DWFIN 2023)

Farmer	Time of receiving hives	Number of hives	Number of occupied hives	Number of empty hives
1.	July 2023	3	0	3
2.	July 2023	3	0	3
3.	July 2023	3	0	3
4.	July 2023	2	2	0
5.	July 2023	3	0	3
6.	July 2023	3	0	3
7.	July 2023	1	0	1
8.	July 2023	2	2	0
9.	July 2023	2	2	0
10.	2021	4	1	3
11.	2021 + July 2023	4+3	7	0
Total number of beehives			33	
Total number of occupied hives			14	
The number of empty hives			19	

Litoya, located near Nalolo, reported a contrasting beekeeping situation with 28 hives, of which only three were occupied. Despite sharing similar environmental properties with Nalolo, Litoya benefited from fewer disturbances due to fewer children and better protection for hives concealed in tree crowns. Additionally, the proximity of water sources and extensive agricultural lands did not translate into higher hive occupancy due to the proximity of the hives to fields where pesticides and chemical fertilisers were used. The lack of a consistent planting schedule for flowers also disrupted potential foraging patterns for bees. After a debate with farmers, one innovative idea emerged to adjust agricultural practices to promote more sustainable and bee-friendly methods, aiming to increase the usage of abandoned hives (Table 2) (DWFIL 2023).

Table 2 Hive occupancy in Litoya (DWFIL 2023)

Farmer	Time of receiving hives	Number of hives	Number of occupied hives	Number of empty hives
1.	July 2023	3	0	3
2.	July 2023	3	0	3
3.	July 2023	3	0	3
4.	2021	1	0	1
5.	July 2023	3	1	2
6.	2021	4	0	4
7.	2021	1	0	1
8.	2021 + July 2023	1+3	2	2
9.	2021 + July 2023	1+1	0	2
10.	2021 + 2022 + 2023	1+3+1	0	4
Total number of beehives				28
Total number of occupied hives				3
The number of empty hives				25

Senanga, unlike the previous two areas studied, was situated adjacent to the Zambezi River. This location gave the farmers an advantage, as they benefited from their experience and prolonged collaboration with earlier MENDELU agricultural projects, leading to more efficient farming practices. In Senanga, 29 beehives were distributed among the participant farmers; seven of these hives were occupied, while 22 remained empty. The timing of hive receipt significantly influenced occupancy rates. Hives distributed in earlier years, such as 2021, exhibited slightly better occupancy rates than those distributed in July 2023, as indicated in Table 3. A contributing factor to this higher occupancy might have been the wider variety of plants and trees near the Zambezi River and integration with other agricultural practices that some farmers have been practising since 2021, potentially providing better foraging opportunities for bees. However, despite the advantageous environment, the number of occupied hives remained low, suggesting that other factors also played a role in hive occupancy (DWFIS 2023).

Table 3 Hive occupancy in Senanga (DWFIS 2023)

Farmer	Time of receiving hives	Number of hives	Number of occupied hives	Number of empty hives
1.	2021	3	1	2
2.	2021	4	0	4
3.	October 2023	3	2	1
4.	October 2023	3	1	2
5.	2021	4	2	2
6.	2021	4	1	3
7.	July 2023	3	0	3
8.	July 2023	3	0	3
9.	July 2023	2	0	2
Total number of beehives			29	
Total number of occupied hives			7	
The number of empty hives			22	

6 Discussion

The findings of this study substantiated the first hypothesis, indicating that insufficient access to appropriate training and resources significantly hinders the effectiveness of beekeeping initiatives in Western Zambia. This confirmation highlights the urgent need for enhanced educational programs and better resource allocation to improve the success of local beekeeping efforts.

Although farmers received practical training from MENDELU, subsequent evaluations revealed that they needed a clearer understanding of beekeeping essentials, such as identifying honey on a comb and distinguishing between honey and brood (DWFIS 2023). One potential cause of this confusion could be the language barrier, as instruction was primarily verbal, without visual aids like pictures to clarify critical concepts (IWPM1 2023). Additionally, some farmers may have needed more genuine interest in beekeeping if the bees would manage themselves and merely require farmers to harvest the honey. Hilmi et al. (2012) explored similar challenges, noting the importance of fundamental training for small-scale farmers in beekeeping.

The necessity of comprehensive training is well-established; however, more than brief instructional sessions, as observed in our study, are required (DWFIS 2023). Farmers would benefit significantly from observing older, occupied hives firsthand to see practical examples of the concepts discussed rather than relying solely on pictures or verbal descriptions (IWPM3 2023). This direct approach would enhance their understanding and engagement in beekeeping practices.

In this study, we sought to answer the first research question: What are the current beekeeping practices among local farmers in Western Zambia, and how sustainable are these practices regarding environmental impact and economic viability? Concurrently, the research was guided by the second hypothesis that local beekeepers in Western Zambia demonstrate varying sustainability by combining traditional and modern beekeeping techniques. It was predicted that while traditional practices may be more environmentally sustainable, they could be less economically viable than modern techniques.

While traditional beekeeping is ecologically more sustainable, it has challenges. For instance, traditional agriculture, which underpins this type of beekeeping, demands significant land use and often involves cutting down trees (Etxegarai-Legarreta & Sanchez-Famoso 2022). On the other hand, traditional beekeeping demands minimal labour, allowing beekeepers to continue with their traditional agricultural activities with less time and resource investment (Ntenga & Mugongo 1991).

However, the beekeepers in our study did not engage in this traditional mix because they all received Kenyan Top Bar Hives (KTBH), which are part of a more modern approach (IWPM3 2023). Economically, traditional beekeeping is also less viable because it typically destroys most of the bee structure within the hive during honey harvest. In contrast, using frames, modern methods preserve the bee's living structures and allow for ongoing honey production (Adjare 1990).

Despite these modern advantages, the study found that this approach could have been more economically beneficial because the beekeepers are still learning what to harvest. This results in outcomes like traditional methods, where the entire colony is sometimes destroyed during harvest (IWPM1 2023). Thus, neither method proved economically advantageous in my study, highlighting the need for further training and adaptation to more sustainable beekeeping practices.

We explored the effectiveness of various beekeeping methods utilised by farmers in Western Zambia, focusing on their impact on honey production and hive health. This examination is anchored by the second research question: "What methods are used by farmers, and how effective are they in honey production and hive health?" Furthermore, the third hypothesis, "Integrating beekeeping with other forms of agriculture leads to increased overall productivity and environmental sustainability on farms in Western Zambia", guided the analysis.

Our findings indicate that farmers employ modern approaches. Due to the small number of occupied hives and young colonies inside, the farmers did not get a chance to harvest honey and create new methods to increase the yield (DWFIL 2023). To start a strategy for higher yields, the farmers must repair and prepare the hives adequately and hang them in better locations.

The hypothesis was substantiated through observations that integrated beekeeping with crop cultivation and livestock farming leads to synergistic effects, enhancing biodiversity and ecological balance (DWFIS 2023). This integration supports increased plant pollination, crucial for crop yield, and provides bees with a richer, more stable nectar source (Hilmi et al. 2012; Illgner et al. 1998; Murcia-Morales et al. 2021).

Consequently, these practices improve honey production and promote sustainability by fostering a more resilient agricultural ecosystem. Thus, the discussion emphasises that in Senanga, integrating beekeeping with other agrarian practices aligns with sustainable farming principles while increasing productivity and hive health, confirming the proposed hypothesis and providing a comprehensive answer to the research question (DWFIS 2023).

The third research question was: What are the main challenges farmers face in Western Zambia, and what strategies can be employed to overcome them? The fourth hypothesis posited that significant challenges hindering the adoption of sustainable beekeeping practices in Western Zambia include knowledge gaps and environmental constraints.

Firstly, environmental constraints, such as degrading natural habitats, significantly affect bee health and productivity (Mulombwa 1998). Combating these environmental challenges includes promoting agroforestry practices that integrate crop production with cultivating melliferous plants (Hilmi et al. 2012; IWPM3 2023).

Secondly, absconding is found in this study. As a result of the debate, bees stayed in beehives for a few weeks or days and then absconded. This was due to the wrong placement of hives, holes in hives, or lack of pollen in their area (Crane 1990; DWFIL 2023).

The findings from this study substantiate the hypothesis by revealing significant knowledge gaps among farmers that undermine practical beekeeping and result in low honey yields. Ali (2015) underscores the importance of education and training in promoting sustainability and environmental preservation in beekeeping. Additionally, Carroll and Kinsella (2013) emphasise that through formal training programs or accumulated experience, beekeepers acquire new skills relevant to their practices.

This statement of Illgner et al. (1998) perfectly describes the problem of our studied area. The illiteracy of many farmers and beekeepers complicates the record-keeping for honeybee colonies. Effective record-keeping is vital for monitoring honey production and the overall condition of the colony, enabling optimal timing for honey harvesting. Furthermore, illiteracy impedes the efficient dissemination of crucial beekeeping information, adversely affecting colony management (IWPM1 2023). These educational interventions are thus vital for bridging the knowledge gaps and enhancing the efficacy of beekeeping initiatives.

The last research question of this study focused on identifying sustainable beekeeping practices that could enhance both the beekeeping industry and the livelihoods of local farmers in Western Zambia. In parallel, the hypothesis posited that implementing targeted interventions and education programs on sustainable beekeeping practices would significantly improve the sustainability of the industry and the economic well-being of these farmers.

These interventions include diversifying flora to ensure year-round food sources for bees, developing community-based beekeeping cooperatives for resource sharing, and introducing improved hive management techniques (Klein et al. 2006; Hilmi et al. 2012; Papa et al. 2022). As previously mentioned, the data underscores the critical need for tailored educational programs that address both practical beekeeping skills and broader agricultural knowledge to maximise the benefits of beekeeping in the region (DWFIS 2023).

By integrating these sustainable practices, as demonstrated through the study's results, local farmers can achieve greater productivity and stability in their beekeeping endeavours, thereby improving their livelihoods. This alignment between the study's findings and the hypothesis validates the proposed interventions and highlights the effectiveness of such educational and practical adjustments in advancing sustainable beekeeping in Western Zambia.

7 Conclusion

Although comprehensive studies on beekeeping in Western Zambia have been limited, existing research has primarily focused on the northwestern, central (Clauss 1992), and eastern (Coppinger et al. 2019) regions of Zambia (Mickels-Kokwe 2006; Muimba-Kankolongo et al. 2015). However, this study reveals significant potential for beekeeping in Western Zambia, particularly near the Barotse floodplain, provided it is practised with appropriate methods and tools (IWPM3 2023). For instance, one farmer correctly placed and prepared his hives, achieved full occupancy in all seven beehives and successfully harvested honey (IWFF2 2023). This success underscores the importance of correct hive placement and maintenance, including ensuring that hives do not touch parts of the tree that could give ants access and regularly sowing plants to provide bees with consistent pollen and nectar sources and create a beekeeping calendar (IWPM1 2023). The project or the local governmental body should provide professional extension services to tailor individual and local beekeeping specifics into appropriate managemental practice (IWPM3 2023).

Moreover, this study highlighted the critical need for improved management practices, enhanced community support structures, and greater awareness of the environmental factors affecting bee health. These improvements are essential for advancing sustainable beekeeping practices to increase hive productivity and promote bee welfare (IWPM2 2023).

Despite the promising findings, this research was conducted under several constraints. The time allocated needed to be increased, as more than two weeks spent collecting data was necessary to understand the nuances of local beekeeping practices fully. Furthermore, the training provided to farmers after the debates was too brief, leading to occasional misunderstandings. For example, farmers struggled to differentiate between worker bees, drones, and the queen, and they could not distinguish between capped honey and brood on the same comb (DWFIL 2023).

Acknowledging that this study was limited to addressing only the initial question regarding beekeeping potential is essential. Future research should explore the remaining questions about enhancing beekeeping practices and technology use. This study suggests that the commercialisation of beekeeping should begin with productivity improvements, achievable through adopting appropriate technologies.

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Appendices

Appendix 1: List of interviews and debates

Codes are used for citation purposes

Code	Place	Day	Additional information regarding the interviews and debates
IWPM1	Mongu – project base	15.11.2023	Individual structured interview with a MENDELU project manager about the project
IWPM2	Mongu – project base	16.11.2023	Individual structured interview with a MENDELU project manager about farmers
IWPM3	Mongu - project base	17.11.2023	Individual structured interview with a MENDELU project manager about work in the field
IWFF1	Nalolo	17.11.2023	Individual structured interview with a farmer with previous beekeeping experience
IWFF2	Nalolo	17.11.2023	Individual structured interview with a farmer with seven beehives occupied
DWFIN	Nalolo	20.11.2023	Discussion with farmers in Nalolo
DWFIL	Litoya	21.11.2023	Discussion with farmers in Litoya
DWFIS	Senanga	22.11.2023	Discussion with farmers in Senanga

Appendix 2: The narrative from individual structured interviews and debates

15.11.2023	Code: IWPM1
Mongu – project base	
Project manager	

EH: How does the training address individual challenges, mainly when farmers need clarification about determining the right time for harvest?

PM: There are individual challenges. If three farmers mentioned that they do not understand how to do the harvest or identify it, the hand is ready; we need to harvest. Also, there is a language barrier. Most of the farmers do not understand English, spoken or written, so wherever we go with an expert, we need a translator.

EH: What specific issues have farmers identified that they need help with, especially regarding harvest timing and readiness?

PM: Some farmers still need help learning the appropriate times for gathering and preparation. Ensuring they openly communicate their needs, like specific challenges, will enable the identification of requirements, such as six out of ten farmers needing one type of assistance and two needing another. This approach will facilitate the preparation and provision of a necessary help.

EH: How do beekeepers manage the placement of beehives to ensure safety and productivity, and what are the recommended strategies for harvesting to mitigate risks and losses?

PM: We can have an example from Senanga; beekeepers supported about 44 beehives, with one individual harvesting up to 20 to 25 kilograms of honey. Unfortunately, due to the beehives' remote placement for safety, incidents occurred where people carried away the beehives, harvested the honey, and left the structures destroyed, leaving the farmer to discover only the remains. Planning for the next harvest, the farmer considered strategies for future success.

To balance community safety and address safety concerns, the advice is to position beehives at least 100 to 200 meters away from households, with an optimal recommendation of 500 meters. Managing this distance presents challenges within the community, but efforts focus on achieving a 200-meter distance. Additionally, the expert advised farmers to harvest honey at night or early in the morning when bees are less active, minimising the risk of disturbance and ensuring safer harvesting conditions.

EH: What challenges do farmers face? Do the farmers need to learn the basics of beekeeping or the use of tools?

PM: A few farmers understand beekeeping, yet most are new. Approximately 15 farmers require more profound assistance and help. Consequently, the team informed the field officers about the necessity of visiting already occupied bee hives, which are facing challenges with bee hives such as bee swarming. Empty beehives and swarming represent the most significant challenges encountered in suitable locations.

EH: What are the possible impacts on the beehive environment?

PM: The challenge mentioned involves bees abandoning the beehives after harvesting. During the last field visit, a farmer was observed improperly cutting through a comb while harvesting, accidentally severing a bee in half, including its abdomen. With the highest chance, it was the queen bee. The killing of the queen bee released a scent or smell, alarming other bees, which might have been perceived as a threat, leading to their higher activity. Pests are another factor.

EH: Besides pests, do farmers face any other challenges?

PM: Pests present a significant challenge and are ubiquitous. Unlike typical pests, these predators, especially ants and insects, pose a considerable threat. Recommendations on overcoming these challenges, including the abandoning of beehives by bees and issues with predators, are forthcoming.

However, fire revealed that farmers carelessly burn shrubs, the environment, and the grass. This carelessness decreased honey production and the bee population, as the fire harmed some bee colonies. Such incidents have diminished, although a few farmers continue to burn. The practice is partially under control, but fewer farmers engage in it.

EH: How does the approach to honey collection, involving farmers cutting every bar without regard for the presence of honey or nectar, need improvement?

PM: Some farmers need help to separate honey and boil the comb, while only a few can properly separate it. It poses a challenge for many farmers. We recommend leaving at least two combs with capped honey during harvest. However, the issue arises when farmers remove all honeycombs, leading to bees leaving due to the emptiness. Additionally, removing all combs can result in worker bees dying, affecting the hive's productivity. Consequently, the removal and disposal of these combs waste potential bee labour. Our expert employed a harvesting method that, unfortunately, led to the accidental cutting of combs in half. However, sometimes, the farmers cut not only honeycombs but also combs with brood, which leads to the weakening of the bee colony.

EH: How does the data collection process evolve?

PM: An observation concerning the data takes place in the morning. Collecting all data, such as the kilograms of harvest, is still underway. Focusing on specific groups necessitates an intensification of data collection methods. Direct engagement with these groups will enable recording the farmers' challenges. Familiarity with the farmers often leads them to conceal some obstacles. Nevertheless, introducing a new person prompts them to reveal all challenges. This disclosure, occurring during field visits, assists in uncovering even the concealed challenges. There are several bee colonies in hives, yet not all bees have settled, with only a small percentage showing occupancy. Thursday's field visit target includes 20 occupied beehives in two places.

EH: How big is the beehive?

PM: Eighty centimetres, and here it is 80 centimetres. Twenty-five centimetres, 25 millimetres. On top of that, we have 21 bars; some have 20, and some 19. The maximum is 20.

EH: Moreover, what is the thickness of the bars? Like 3 cm or more?

PM: The other day, the measurement was not maintained; therefore, the joiner made the top bars for different intermittent needs.

EH: Are there any challenges from the office side? What are the challenges that may be slowing down this project?

PM: A challenge exists in finalising the bee calendar, particularly detailing bee activities for January and corresponding farmer actions during the rainy season.

The goal involves comprehending the local environment, field characteristics, tree types, and flowering patterns to compile essential beekeeping information for the calendar. We do not have the process itself. We know the time of the day when the bees are actively collecting pollen and nectar; however, we need to know what happens throughout the months. What is the best time for the farmers to harvest? What would be the signs for them to do without opening their bees? Because our bees, the mother bees, are aggressive. The bees, therefore, attack the people.

Secondly, farmers recently questioned the variance in honey colours, ranging from white to dark brown and light brown, expressing confusion and preferences, notably for white honey. The explanation highlighted that flower types dictate the honey colour and pollen characteristics. With this understanding, farmers now grasp that the available flora limits their control over honey colour. However, by selecting viable trees, they can influence their beehive environment.

EH: Are there any actions that should change?

PM: However, we must train the farmers and ensure accurate checking. That provides the answer.

16.11.2023	Code: IWPM2
Mongu – project base	
Project manager	

EH: What kind of project is this?
PM: The Integrated Farming Project III project started in 2022 and ended in 2024, next year. It is a continuation of the Integrated Farming Project II, which began in 2019 and lasted until 2021 and is financially supported by the Czech Republic Development Cooperation.
EH: What is the main goal?
PM: The main goal of this project is to support farmers' production, increase their income, and help them develop skills. Additionally, it builds a resilient landscape and conducts agroforestry activities, creating three value chains: animal production, fish production, and agroforestry products.
EH: What group is the target?

PM: We target small and medium farmers, but our scope includes processing groups, cooperatives, and holistic groups.
EH: What is meant by holistic groups?
PM: Holistic refers to building a resilient landscape and managing natural resources to ensure environmental safety. This includes agroforestry activities and holistic land and livestock management, where farmers group for planting, grazing, and crop shifting to utilise livestock effectively.
EH: Besides direct support in beekeeping, what other forms of assistance are provided to farmers to enhance their overall business and income from beekeeping?
PM: Besides beekeeping, we are building free value chains to ensure that farmers can produce honey and sell it at a reasonable price, thereby increasing their income. We impart business skills to help them find a good market for their processed products, adding value to their offerings.
EH: What is the rationale behind emphasising product processing before sale?
PM: Processing products before sale adds value, leading to better earnings than selling unprocessed products. Agroforestry, integrating crop cultivation with forest products, is part of this strategy.
EH: What are the primary benefits of engaging in agroforestry?
PM: When harvesting vegetables, participants dry them, gather fruits and mushrooms, and extract oil as part of the forest products.
EH: What additional initiatives are being undertaken with farmers to improve productivity and income?
PM: In this project, we conduct several activities to increase production and income. The activities we want to do are fish farming, where we need to work on the fishponds, and when we have fishponds, farmers will be able to sell the fish.
PM: The other aspect is to work on the livestock, which we circulate to the farmers; they have vaccinations to prevent the animals from getting diseases. We teach them to manage accessible, safe veterinary practices.
The other aspect is agroforestry, where we plant 10,000 trees to help the landscape. Trees will add manure, which may be used for medicinal purposes, to attract bees. We have a target for these tree farmers to be able to plant trees.
EH: What objectives does the tree-planting initiative aim to achieve among agroforestry farmers?

PM: We have a target for these tree farmers to be able to plant trees. We divide it into four districts. We work in Mongu, Senanga, Nalolo, and Limulunga. We have a total of nine communities where we are working. However, the direct number that we are working with is one hundred. So, we have 25 farmers in each district.

The other significant activity we are conducting is beekeeping. We are doing the beekeeping activities based on essential knowledge. Farmers should be able to understand the level of the market they have.

EH: Can the knowledge base of beekeeping among the farmers be described?

PM: They possess the skills to manage beekeeping effectively. Questions arise, such as, "What actions are necessary in certain situations?" and "What materials are essential for a beekeeper?" Our training ensures they grasp the fundamentals of beekeeping, including handling bee attacks with appropriate protective measures, managing bee colonies, and executing harvests.

Topics extend to the environmental and ecological aspects of beekeeping. We provide them with the necessary equipment and materials to support their learning.

EH: What equipment and materials does the organisation provide to support farmers in beekeeping?

PM: We provide smokers with protective clothes, beehive tools, gloves, knives, buckets, brushes, and beehives. We supply beehives as a material. Additionally, we supply them with buckets, beehive tools, and hive knives for use during the harvest. We offer materials related to soft wires for hanging, packaging for storage, and scaling so they can measure the harvest weight in kilograms. We also provide recording materials, such as hardcover books.

EH: How many farmers are actively participating in the beekeeping program?

PM: This year, the program targets 30 farmers, building on the 15 farmers from last year. Currently, the beekeeping initiative involves 45 farmers. Including some old farmers from integrated farming, the total potentially reaches 50. We additionally worked with our honey processing groups, establishing four groups to process honey.

EH: What is the target number of beekeepers?

PM: 60 beekeepers. Once we reach 60 beekeepers, we can spread the knowledge to others.

EH: In which districts have honey production commenced, and how does this influence the focus of fieldwork?

PM: Honey production is underway in two districts: Nalolo and Senanga. Thus, fieldwork concentrates on these districts, where the project's primary activities are focused.

EH: What is the overarching goal for beekeeping farmers regarding honey production and market access?

PM: Our primary goal here or plan is to make sure they bulk the honey and put them where these four groups are. Therefore, we can look for bulk buyers or aggregators who can buy the bulk of honey together. We do not want them buying bulks individually, but at least as a whole. That is the reason we have the groups. The groups can collect all the money and the bulk and then involve a buyer from a reputable company or a business to buy the honey. We have two active groups, one in Senanga and one in Litoya. Hopefully, the other two groups will be involved next year.

EH: How are farmers trained in beekeeping, and what strategies are employed to enhance honey production?

PM: Local experts deliver training, with additional insights from Holistic Solution in the Czech Republic on value chain analysis, aiming to navigate market stages efficiently and establish productive categories for farmers.

EH: What market access strategies have been developed for the farmers?

PM: The plan is to ensure the farmers get a process with two categories. To guide the farmers through the stages and show them how they can best do the production and reach the market. There is one option where we can link them to bulk buyers or companies that can purchase raw honey as it is, allowing them to enter markets such as ShopRite. However, for them to enter that market, they need to be registered, they need to be certified, and they need to have their products labelled and appropriately packaged.

Two categories exist for farmers' action: selling to bulk buyers and packaging. The goal is to link farmers to these two types of markets by the project's end. Achieving this link signifies reaching the goal.

EH: What market access strategies have been developed for the farmers?

PM: This project provides monitoring and technical support to the farmers to see if they are doing the correct things if the beehives are producing honey, and if there are challenges where we can help, especially at the technical level. We have trained local experts and consultants who can provide technical support, focusing on beehive productivity and addressing challenges.

EH: Can you elaborate on the collaboration between the project and governmental stakeholders?

PM: The collaboration spans multiple ministries, including Agriculture, Green Economy and Environment, Small and Medium Enterprise Development, and Community Development and Social Welfare, fostering an integrated project implementation and focus approach.

EH: What initiatives are included under the extension within this project, and what are the goals related to landscape resilience?

PM: Under this project, we are also doing the extension of agroforestry projects and the processing and the building resilience, landscape resilience, which is the one I mentioned before, where we are training stakeholders in natural resource management, how to do natural resource management, and how to do mapping using the geographical information system.

EH: How does data collection contribute to project evaluation and outcomes?

PM: The data we are collecting is to check if the project is having some results with the farmer we are supporting. Just have that evaluation to know if you are doing something or not doing anything. It helps us; it guides us.

EH: Can you describe the structure and focus of holistic land and livestock management groups?

PM: We have 10 of them scattered in the four districts. These groups concentrate on landscape management and environmental protection through controlled grazing, reduction of unnecessary burning, and cutting of trees, integrating agroforestry principles. We also share experiences with them, and they learn from one another. Holistic land and livestock management is more on the landscape, more on the environment, to safeguard the environment.

EH: How do the land and livestock management groups contribute to environmental protection and agroforestry?

PM: Community tree nurseries contribute to environmental enhancement and landscape resilience, providing seedlings for strategic planting to attract bees and restore dry streams, aligning with broader project objectives.

EH: How does strategic tree planting benefit beekeeping efforts and overall project goals?

PM: Farmers plant in abandoned crop fields or bare land so that something can be there to contribute to the environment. Strategic planting aims to reduce bee foraging distances, increase honey production efficiency, and contribute to the project's environmental restoration goals and enhanced agricultural productivity.

EH: What are the expected outcomes of reducing the foraging distance for bees and the project's impact on natural water bodies?

PM: Strategic planting aims to reduce bee foraging distances, increase honey production efficiency, and contribute to the project's environmental restoration goals and enhanced agricultural productivity.

17.11.2023	Code: IWPM3
Mongu – project base	
Project manager	

EH: What criteria did you use to select farmers for the beekeeping project, and how did you assess their engagement and environmental suitability?

PM: The selection process for farmers participating in our beekeeping project relied on specific criteria we established to ensure the environment's suitability and the farmers' active involvement. We sought farmers who demonstrated a high level of engagement with the project, evidenced by their attendance at training sessions, meeting participation, and related activities. To assess this, we scored farmers on a scale from 0 to 10, with higher scores indicating more significant activity and commitment to beekeeping and its integration with other farm practices.

EH: How do you evaluate the environmental conditions for beekeeping at a farmer's location, including water source proximity and flowering plants?

PM: We also evaluated the potential for successful beekeeping based on the environmental conditions of each farmer's location. Key factors included the proximity of water sources and the availability of flowering plants and trees that provide essential resources for bees. We measured the distance to the nearest water source in meters. We assessed the abundance of suitable flowering trees and agroforestry practices, favouring farmers willing to plant trees that support bee health and attract bees with their flowers.

EH: What factors did you consider in determining a farmer's suitability for beekeeping, including their willingness to participate and integrate beekeeping with other farm activities?

PM: Furthermore, we considered the farmers' willingness to embrace beekeeping and their ability to integrate it into their existing farming operations. This included an assessment of their attitudes towards trees and bees, recognising the symbiotic relationship between these elements. We inquired about each farmer's past beekeeping experience, training from other organisations, and willingness to engage in beekeeping. Through these questions, we aimed to gauge their interest in honey production and their reasons for wanting to participate in the project.

EH: How do you support farmers starting and sustaining their beekeeping activities, and what does the training program entail?

PM: In the beekeeping project, we provided the farmers with buckets to store honey until bulk buyers purchased it. Recognising their initial challenges in sourcing beeswax to start their operations, we supplied each farmer with one kilogram for each baiting session. This beeswax serves as an attractant for bees, facilitating the start of their beekeeping endeavours. Farmers are expected to produce their beeswax for subsequent baiting sessions as they progress, especially if they encounter issues with the initial bees attracted or need to expand. Additionally, we provide a comprehensive training program for beekeepers, which is integral to the project. This training covers various aspects of beekeeping and requires resources such as stationery and work materials, with a specific budget allocation dedicated to these educational efforts.

EH: Could you elaborate on the training and resources provided to farmers to enhance honey production and its impact?

PM: We have trained farmers in honey production, processing, storage, marketing, sales, and packaging and have awarded them microgrants to boost honey production. They have received materials and equipment, including honey pressers, storage buckets, packaging packs, scales, and more, following the project's support, consultations, and technical recommendations, making honey production manageable.

EH: What are the key components and topics covered in your beekeeping training manual, and how does it serve as a comprehensive guide for beekeepers?

PM: Our training manual covers a wide array of topics essential for beekeeping, starting with the ecological importance of bees to our environment. We emphasise the multifaceted role of bees, including their contribution to pollination and ecosystem balance, which underscores their value beyond honey production. The manual details the nutritional and medicinal benefits of honey, propolis, and bee venom. It highlights their market value and the potential for bee products like beeswax to be transformed into saleable items. We delve into the biology of honeybees, explaining the roles of workers, drones, and the queen, which is crucial for understanding bee colony dynamics.

Health and safety practices in handling African bees are thoroughly addressed, equipping farmers with knowledge on managing the different bee types and using the Kenyan Top Bar beehive. The process of baiting and swarming, vital for colony establishment, is identified as a top priority. Our manual guides farmers through the stages of harvesting, with a focus on improving and meeting the requirements for top-bar beekeeping. However, we acknowledge the need to expand our coverage to include grading and processing honey in future sessions.

The manual provides practical advice on using honey pressers, which we have purchased for groups to facilitate honey extraction. Marketing and sales strategies are also covered to empower farmers to market their bee products successfully. However, we recognise a gap in our manual regarding the beekeeping calendar, a crucial tool for timing beekeeping activities throughout the year. We plan to request additional information to complete our manual, ensuring it is a comprehensive resource for beekeepers.

Additionally, the manual touches on the importance of proper baiting techniques and packaging, which are essential skills for beekeepers to master. Through this comprehensive approach, our training manual serves not only as a guide to beekeeping but also as a resource for understanding the broader impact of beekeeping on income, nutrition, and environmental sustainability.

EH: What is the distribution range of beehives among the farmers, and how do you categorise farmers based on the number of beehives they own?

PM: If we categorise farmers by the number of beehives they own, I can provide a range. A farmer's maximum number of beehives is seven, with quantities ranging from one to seven. Many farmers, particularly those from the old project, own just one beehive, while others have a spread of three, four, five, or seven beehives. However, only a few farmers own a maximum of seven beehives, with the majority owning between three and four.

EH: How does your budget allocation plan support farmers expand their beekeeping operations?

PM: We aim to allocate the budget to beekeeping activities, providing farmers with essential materials to increase beehive numbers. This includes supplying simple equipment such as protective clothing, knives, and additional small items to enhance their beekeeping operations. We also plan to support farmers with honey pressers, machines designed to extract honey, which we will distribute to processing groups. Furthermore, we intend to purchase packaging materials for these groups, enabling them to process and package honey for sale in various markets, including bulk purchases.

EH: How does the budget allocation for beekeeping materials contribute to the project's success, and how have farmers' perceptions of beekeeping changed over time?

PM: A significant portion of our budget focuses on beekeeping materials, acknowledging their importance in successfully implementing our project. Initially, many potential beekeepers expressed fear of bee stings and the associated risks, discouraging them from pursuing beekeeping. However, with the inclusion of 15 new farmers in 2022, interest in beekeeping surged. By 2023, even more farmers expressed a willingness to participate. Despite this enthusiasm, we must remind interested parties that our project has a target limit; we aim to incorporate 30 farmers to ensure manageable and practical support.

EH: What are the goals and challenges of scaling the number of beekeepers in your project, and how do you plan to address discrepancies in reporting to donors and stakeholders?

PM: Our project aims to expand from supporting 50 to 30 farmers and include 60 beekeepers in our integrated farming project. However, in our reporting and planning, we face a unique challenge. Next year, when we include previous participants, our total will reach 65, exceeding our initial target. This discrepancy arises because we aim to support a specific group of five beekeepers without counting them towards our overall goal of 60, as they participate in different capacities. This strategy seeks clarity for donors and stakeholders, ensuring our project targets remain transparent and achievable.

EH: What preferences do farmers have regarding the production of honey, wax, or both, and how does this influence buyer engagement and product focus?

PM: We aim to understand whether farmers prefer to produce honey, wax, or both. This knowledge is crucial, especially when engaging buyers. We recognise that some farmers can produce wax, which directs buyers towards specific preferences. For instance, one farmer may focus exclusively on wax production, another on honey and wax, and a third solely on honey. Understanding these preferences allows us to tailor our approach to buyers, highlighting the varied product offerings.

EH: A comparison indicates Senanga has superior performance despite the potential in both areas. Moreover, is there any identifiable reason for this difference?

PM: The Zambezi River contributes to Senanga's better performance than others. The Zambezi River, hosting three species more attractive to bees, is a significant advantage for Senanga. One key factor observed is the interest of farmers in Senanga, marking my first encounter with beekeeping there. The beekeeping tradition from their fathers and modern improvements may have facilitated their more significant advancement in beekeeping compared to Nauru.

EH: Does the collection of data still need to occur?

PM: Progress in terms of one product reveals that comparing Senanga and Nalolo shows Senanga leading. Senanga produces reasonable amounts of honey in contrast to Nalolo.

17.11.2023	Code: IWFF1
Nalolo	
Farmer with previous beekeeping experience	

EH: Why did you start beekeeping?

Farmer: For the health benefits found in honey and money.

EH: Have you been beekeeping ever before this project? Or were you a honey hunter, or had nothing to do with bees?

Farmer: I was beekeeping from 1986 until 2006 in a bark hive but started with the Kenyan top bar hive only in 2021.

EH: How many beehives do you have, and when did you get them?

Farmer: I have four since 2021.

EH: How many of them are occupied?

Farmer: Only one. However, two weeks ago, I had two occupied hives, but the bees left.

EH: Do you know how to catch a swarm and extend the number of beehives?

Farmer: I know how to do it but never succeeded.

EH: What tools do you have?

Farmer: I have a hive tool, smoker, bucket, protective clothing, gloves and a small brush.

EH: Have you planted specific plants or crops around your apiary to support bee activity?

Farmer: The project of MENDELU planted crops, flowers, and trees near beehives, but they are too young to have enough pollen for all the bees in this community.

EH: How often do you check on your bees?

Farmer: Once a month.

EH: What does the process of honey harvest look like? From beehive to jar?

Farmer: We cut combs from the bar, put them in a bucket, smash them, and then heat them so the combs and beeswax float on top and separate them from the honey.

EH: What do you collect while harvesting honey?

Farmer: I cut all the combs with honey, capped, uncapped, and sometimes with brood.

EH: What challenges do you face?

Farmer: Lack of trees and plants with nectar and pollen for farmers, not enough trees to hang beehives on, ants and primarily absconding bees.

EH: Any challenges, additions, or comments to this project? What to change?

Farmer: Not enough equipment. It is hard to check on bees when you are doing it all by yourself.

17.11.2023	Code: IWFF2
Nalolo	
Farmer with seven beehives occupied	

EH: Why did you start beekeeping?

Farmer: For selling honey and other by-products.

EH: Have you been beekeeping ever before this project? Or were you a honey hunter, or had nothing to do with bees?

Farmer: No, until I learned about the beekeeping project from MENDELU in 2021

EH: How many beehives do you have, and when did you get them?

Farmer: I got 3 in 2019 and 4 in July 2023.

EH: How many of them are occupied?

Farmer: All seven of them.

EH: Do you know how to catch a swarm and extend the number of beehives?

Farmer: I know how to do it, but succeeding is hard.

EH: What tools do you have?

Farmer: I have buckets, only one protective cloak, gloves, a smoker and a hive tool

EH: Have you planted specific plants or crops around your apiary to support bee activity?

Farmer: No, I have a lot of trees and plants around me, so bees have enough of a source.

EH: How often do you check on your bees?

Farmer: Once or twice a week.

EH: What does the process of honey harvest look like? From beehive to jar?

Farmer: I check the hives in April and November and take a bucket. If honey is capped in combs, I take it, smash it in a bucket, then let it sit and separate from the combs.

EH: What do you collect while harvesting honey?

Farmer: I cut all the combs with capped honey, sometimes uncapped and leave some uncapped ones.

EH: What challenges do you face?

Farmer: The trees have too high branches, and it is not easy to climb and reach them that often.

EH: Any challenges, additions, or comments to this project? What to change?

Farmer: I need more protective clothing. I gave mine to my daughter, put on my trousers and a jacket, and dealt with the stings.

20.11.2023	Code: DWFIN
Nalolo	
Discussion with farmers in Nalolo	

EH: Why did you start beekeeping?

Farmers: To have honey as a source of income and food and sell wax.

EH: Have you been beekeeping ever before this project? Or were you a honey hunter, or had nothing to do with bees?

EH: How many beehives do you have, and when did you get them? How many of them are occupied?

Farmer 1: I received three hives in July 2023, and none are occupied.

Farmer 2: I have had three hives since July 2023, and none are occupied.

Farmer 3: Same here. I received three hives in July 2023, and none are occupied.

Farmer 4: I received two hives in July 2023; two are occupied.

Farmer 5: I received three hives in July 2023, and none are occupied.

Farmer 6: I received three hives in July 2023, and they are not occupied.

Farmer 7: I received one hive in July 2023, which is not occupied.

Farmer 8: I received two hives in July 2023, which are occupied.

Farmer 9: I received two hives in July 2023, which are occupied.

Farmer 10: I received four hives in 2021, and only one is occupied.

Farmer 11: I received four hives in 2021 and 3 in July 2023, all occupied.

EH: Do you know how to catch a swarm and extend the number of beehives?

Farmers: We know how, but most of the time, it is unsuccessful.

EH: What tools do you have?

Farmers: Protective clothing, gloves, smokers, hive tools, buckets and small brush.

EH: Have you planted specific plants or crops around your apiary to support bee activity?

Farmers: Not us, but the Field officers provided seedlings during the previous part of the MENDELU agroforestry project.

EH: How often do you check on your bees?

Farmers: It depends on how we are, but it is mostly twice a month up to once every two months.

EH: What does the process of honey harvest look like? From beehive to jar?

Farmers: We cut the combs from bars and leave some. We take capped and uncapped honey as well. When there is honey and brood, we take it as well. We smash it in the bucket and heat the honey, dividing it from the wax.

EH: What do you collect while harvesting honey?

Farmers: We collect most of the combs, leaving them the empty ones and the ones in the front of the hive.

EH: What challenges do you face?

Farmers: Absconding of bees and ants, almost no plants with pollen or nectar, wrong placement of beehives on trees and wrong time of receiving hives because the bees are no longer active in July. The noise from kids playing around and throwing stones at hives might be a problem. There are no water sources, and the water is too far away.

EH: Any challenges, additions, or comments to this project? What to change?

Farmers: There is scarce protective clothing, and it is hard to check the hives myself.

21.11.2023	Code: DWFIL
Litoya	
Discussion with farmers in Litoya	

EH: Why did you start beekeeping?

Farmers: To have honey as a source of income and food and sell wax.

EH: Have you been beekeeping ever before this project? Or were you a honey hunter, or had nothing to do with bees?

Farmers: None of us had any previous experience keeping bees.

EH: How many beehives do you have, and when did you get them? How many of them are occupied?

Farmer 1: I received three hives in July 2023, and none are occupied.

Farmer 2: I received three hives in July 2023, and none are occupied.

Farmer 3: I received three hives in July 2023, and none are occupied.

Farmer 4: I received one hive in 2021, which is not occupied.

Farmer 5: I received three hives in July 2023, and one is occupied.

Farmer 6: I received four hives in 2021, and none are occupied.

Farmer 7: I received one hive in 2021, which is not occupied.

Farmer 8: I received one hive in 2021, three in July 2023, and two occupied.

Farmer 9: I received one hive in 2021 and one in July 2023, and none are occupied.

Farmer 10: I received one hive in 2021, three hives in 2022 and one in July 2023, and none are occupied.

EH: Do you know how to catch a swarm and extend the number of beehives?

Farmers: Most of us know only the theory of catching swarms, but none of us tried to because we are unsure about the steps.

EH: What tools do you have?

Farmers: Protective clothing, gloves, smokers, hive tools, buckets and small brush.

EH: Have you planted specific plants or crops around your apiary to support bee activity?

Farmers: Not really, due to the water near us. The bees have many plants around them that are blooming and providing pollen.

EH: How often do you check on your bees?

Farmers: Once a month or once in two months, we go inside, but sometimes, we go around them to see if any bees are flying in and out.

EH: What does the process of honey harvest look like? From beehive to jar?

Farmers: Most of us did not have a chance to harvest honey, but we were taught the process of it. Cut the combs, smash hit, let it sit and separate honey from wax.

EH: What do you collect while harvesting honey?

Farmers: During harvest, we are supposed to take the combs with something in them. If you try to cut it, it should not be white inside, but we should see honey. We are not sure about the differences in capped things on combs.

EH: What challenges do you face?

Farmers: We received hives, and after two weeks or so, we received wax to prepare the hives for bees, but it was too late. Also, the hives have holes in them, mainly in the roof. Swarming and absconding occur often; the bees are in the hive for three weeks and then leave. Ants are also a problem, but we received grease from putting on hooks on which hives hung, and after application on occupied hives, the bees left the hive, mainly due to the grease. Cobwebs are also in hives, and bees do not want to settle in. We do not have enough pollen to have a set sowing plan, but we do not think the bees will pollinate our crops as a primary source for them. Also, how do I recognise the worker bee, drone or queen?

EH: Any challenges, additions, or comments to this project? What to change?

Farmers: We think the hives were given at the wrong time during the year. It was too late, and we had to wait months to have bees around again. Also, we do not have enough protective clothing and additional tools if something breaks; without them, we do not want to risk going into beehives.

22.11.2023	Code: DWFIS
Senanga	
Discussion with farmers in Senanga	

EH: Why did you start beekeeping?

Farmers: To have bees pollinate our crops and have them as a side income and for health benefits.

EH: Have you been beekeeping ever before this project? Or were you a honey hunter, or had nothing to do with bees?

Farmers: None of us had any previous experience keeping bees.

EH: How many beehives do you have, and when did you get them? How many of them are occupied?

Farmer 1: I received three hives in 2021, and one is occupied.

Farmer 2: I received four hives in 2021, and none are occupied.

Farmer 3: I received three hives in October 2023, and two are occupied.

Farmer 4: I received three hives in October 2023, and one is occupied.

Farmer 5: I received four hives in 2021, and two are occupied.

Farmer 6: I received four hives in 2021, and one is occupied.

Farmer 7: I received three hives in July 2023, and one is occupied.

Farmer 8: I received three hives in July 2023, and none are occupied.

Farmer 9: I received two hives in July 2023, and none are occupied.

EH: Do you know how to catch a swarm and extend the number of beehives?

Farmers: We know how but did not see many swarms to catch them.

EH: What tools do you have?

Farmers: We have brushes, hive tools, smokers, buckets, gloves and protective clothing.

EH: Have you planted specific plants or crops around your apiary to support bee activity?

Farmers: Yes, we did, but a long time before receiving hives. The planting was part of the agroforestry project.

EH: How often do you check on your bees?

Farmers: We try to check them at least twice or once a month.

EH: What does the process of honey harvest look like? From beehive to jar?

Farmers: We collect the combs with capped and uncapped honey, sometimes with a small quantity of brood if it is with honey on the same combs. Then we put it in a bucket, smash it, let it sit, pick out the combs, warm up the combs, and the rest of the honey left inside them separates from it.

EH: What do you collect while harvesting honey?

Farmers: As said, comb with honey and sometimes with brood, leaving empty combs inside.

EH: What challenges do you face?

Farmers: Many bees abscond the hives. It might be due to holes in the hives and, while raining, leaking inside them. In many hives, there are ants; even after we applied the grease, they still got in, and bees left. Not only ants but also termites, spiders and larvae are found in empty beehives, and we leave them in because we do not know how to get rid of them.

EH: Any challenges, additions, or comments to this project? What to change?

Farmers: We think the hives were given when bees were not looking for homes. Also, we need more help with the bees and more practical training than theoretical training, for example, what to do with an absconded beehive.