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Mirroring the Ecological Impact of Apiculture as an Indigenous Activity in Mayo Darle, Cameroon.

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Abstract
Although beekeeping significantly affects the environment, this agricultural sector faces numerous obstacles. This study examines the ecological impacts of local beekeeping methods in Mayo Darle, Cameroon. Employing the explanatory sequential design, 175 participants were chosen through stratified random sampling and were given structured questionnaires, interviews, and observations for gathering data. Data analysis was conducted using the Chi-Square distribution test and frequency tables. Tree planting activities (63.8%, $X^2 = 187.434$, $p = 0.000$), the creation of home gardens (66%, $X^2 = 215.959$, $p = 0.000$), flower pollination (45.6%, $X^2 = 84.291$, $p = 0.000$), and the occurrences of bush fires (noted by 87.1% prior and 12.4% currently with beekeeping, $X^2 = 171.516$, $p = 0.000$) were all reported to have shown a positive and significant increase. On the downside, it was observed that access to land had significantly diminished (reported at 98.4% before and now 0% with beekeeping, $X^2 = 286.803$, $p = 0.000$), and the occurrence of medicinal plants had notably reduced (from 93.6% previously to about 14% with beekeeping, $X^2 = 182.778$, $p = 0.000$). Promoting environmental sustainability via sustainable beekeeping can aid in safeguarding the ecosystem and yield beneficial ecological outcomes, mitigating the adverse impacts of climate change.

Keywords: Adamawa Region, Beekeeping, Cameroon, Ecological Effects, Mayo Darle.

INTRODUCTION

Beekeeping, also known as apiculture (Prodanović *et al.,* 2024), is an important activity that supports environmental sustainability (Harianja *et al.,* 2023). Pollination (Kaya *et al.,* 2023), honey creation, propolis, beeswax, and royal jelly (Prodanović *et al.,* 2024), conservation of biodiversity (Ntalwila *et al.,* 2017), pollination of wildflowers (Devkota, 2020), and income generation (Kinati, 2022; Prodanović *et al.,* 2024) are merely some of the methods through which honeybees enhance societal welfare. Therefore, preserving apiculture could be crucial for achieving ecological or environmental sustainability (Izquierdo-Gascón & Rubio-Gil, 2023) and its advantages for human welfare (Hariram *et al.,* 2023). An approximate 1.6 million tons (Kamala & Devanand, 2021) of honey is generated each year by over 80 million beehives (Kaya *et al.,* 2023), based on the United Nations' Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Hailu *et al.,* 2024).

Beekeeping enhances agricultural output (Devkota, 2020) by facilitating floral cross-pollination and supporting biodiversity (Kassa Degu & Regasa Megerssa, 2020; Khan & Khan, 2018) and ecosystems through pollination efforts. Estimates suggest that animal pollinators contribute approximately 35% (Porto *et al.,* 2021) to total agricultural production, sustaining the diversity of wild plants (Khalifa *et al.,* 2021). Engaging in tasks such as planting flowers that produce nectar and pollen (Nicholls & Hempel de Ibarra, 2017), attracting bees to natural environments and constructing beehives (Mutinhima *et al.,* 2024), among others, would all aid in enhancing apiculture and support the bees in remaining within their native habitats (Haldhar

et al., 2021). The understanding of beekeeping has increased (Tulu *et al.,* 2020), along with recognition of the importance of bee products and their possible health advantages (Pimentel *et al.,* 2022). From an ecological perspective, beekeeping fosters biodiversity (Fabricius *et al.,* 2024; Roy *et al.,* 2024), improves soil quality (Feketéné Ferenczi *et al.,* 2023), and aids in plant variety and food production via pollination (Prodanović *et al.,* 2024). It additionally provides natural pest management (Sharma & Birman, 2024) by diminishing the population of destructive insects (Raj, 202), preventing deforestation (Vossler, 2024), aiding forest stewardship (Harianja *et al.,* 2023), and enhancing the upkeep of robust ecosystems through the pollination of numerous plant species.

With no competition for space, apiculture is an eco-friendly method that may be included in already-existing agricultural businesses such as horticulture, agronomy, cattle and dairy, aquaculture, cuniculture, and piggery (Mudzengi *et al.,* 2020). At livestock-wildlife interfaces, beehive fences have been proven to be an effective multifaceted conflict-mitigation strategy for safeguarding crops from elephant assaults (King *et al.,* 2017). Apiculture yields rapid returns and uses low-cost, locally accessible resources (Mudzengi *et al.,* 2020). By producing by-products such as wax, bee venom, royal jelly, and propolis, apiculture offers direct advantages beyond honey (Gernt *et al.,* 2024). According to Rodriguez *et al.* (2012), honey derived from eucalyptus, bellflower, and orange blossoms, for example, has antibacterial action against *Salmonella Typhimurium* ATCC 14028, *Bacillus cereus* ATCC 10876, *Listeria monocytogenes* Scott A, and *Staphylococcus aureus* ATCC 6538. *Erica* spp., *Protea* spp., *Aloe* spp., and trees like *Vachellia karroo* and *Ziziphus mucronata,* as well as Miombo woods, are other significant native plant species for foraging that in turn rely on bees for pollination (SANBI, 2014). Since apiculture is less detrimental to the environment, it is most appropriate as an indigenous activity.

Despite the apparent impact of apiculture as an indigenous activity in Mayo Darle Subdivision, this area continues to encounter numerous challenges in beekeeping, including habitat destruction (Soytemiz, 2024), heightened competition among species (Blüthgen *et al.,* 2023), alterations in the availability and variety of forage (Hassana *et al.,* 2023), along cumulative pressures from parasites, pesticides, and insufficient flowering plants (Wakgari & Yigezu, 2021), despite the significant ecological advantages of beekeeping for the environment, human well-being, and plant vitality. Additional challenges confronting beekeepers in the Mayo Darle Subdivision encompass theft and bushfires ignited by herders seeking grazing land for their animals, both of which affect the region's capacity to sustainably produce honey and its derivatives with negative environmental consequences.

Several researchers have concentrated on the technical aspects of beekeeping (Hassana *et al.,* 2023), as well as beekeeping characteristics in the Cameroon Adamawa grasslands (Meutchieye, 2018), neglecting the ecological impact of beekeeping in the Adamawa region of Cameroon, especially in Mayo Darle. Therefore, by contributing to the body of empirical research in the field, this study seeks to fill this research gap. The study suggests that gaining a more profound grasp of household viewpoints and actual field conditions may yield insights that can be recorded and employed to direct policymakers in achieving Sustainable Development Goal 12, which highlights environmental sustainability. In the Adamawa area of the Mayo Darle Subdivision in Cameroon, this study aimed to examine the ecological impact of apiculture as an indigenous activity.

RESEARCH METHODS

Mayo Darle Subdivision is in the Mayo Banyo Division of the Adamawa Region, Cameroon (figure 1). As stated by (Tantoh *et al.,* 2024), Mayo Darle is situated approximately at 6°28'0" North latitude and 11°33'0" East longitude. This area encompasses a total surface of

1920 km^2 (Tantoh *et al.,* 2024) with a population close to 41,720, (Mayo Darle Council Development Plan, 2012), including 8,974 residing in urban regions and 32,746 in rural locales, at a growth rate of 3.2% (Mayo Darle Council Development Plan, 2012). It borders Nyawa village to the north, Mayo-Njinga village to the south, Bambol to the east, and the Mambilas Mountains to the west (Essapo & Ekedi, 2020). As noted by Essapo & Ekedi (2020), the area experiences a standard Sudano-Guinean climate, featuring two separate seasons: the rainy season, averaging seven months in duration, and the dry season, which spans five months. The area experiences an average annual rainfall of 1400 mm, with temperatures varying from 16°C in December and January to 32°C at the end of February (Tantoh *et al.,* 2024). Numerous honey-producing plants, such as acacia trees that supply the nectar and pollen essential for bees, flourish in this Sudano-Guinea setting (Nguemo *et al.,* 2016). The Mayo Darle Subdivision comprises 56 communities (Tantoh *et al.,* 2024). The vegetation of Mayo Darle consists of plant communities that support robust bee populations and possess floral characteristics that are unquantifiable (Requier, 2019). Savannahs provide a combination of open areas and wooded spaces, making them perfect for bees. The diversity of plant species ensures that bees receive a balanced diet, which improves their overall health (Papa *et al.,* 2022). The Mayo Darle Subdivision is ideal for this research on the ecological impacts of beekeeping in the area due to its rich biodiversity characteristics.

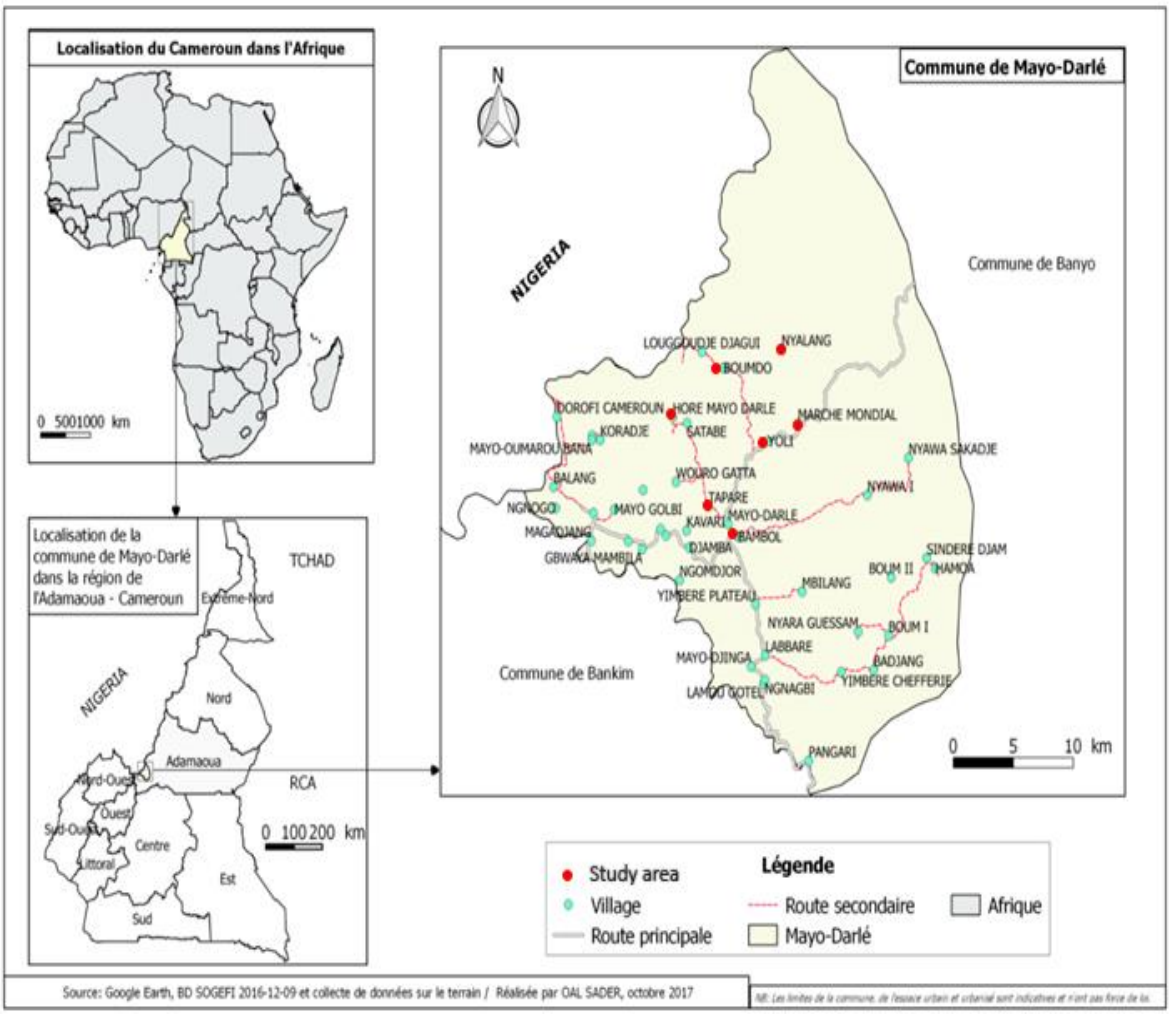

Figure 1: Mayo Darle Sub-Division, Mayo Banyo Division, Adamawa Region, Cameroon
Source: Modified from Mayo Darle Council Development Plan (2018)

Study Design, Population and Sampling

Employing an explanatory sequential design, the ecological impact of traditional beekeeping practices in Mayo Darle, Cameroon, was investigated through quantitative and qualitative methods. From March to April 2024, a survey was conducted among beekeepers in Mayo Darle.

Study Population

The study population consisted of the male and female residents of Mayo Darle who raised bees. As per Tantoh *et al.* (2024), approximately 6800 beekeepers reside in Mayo Darle, the location from which the study's sample size was drawn. Individuals in the community who did not maintain bees were excluded from the study sample.

Sampling Techniques

The researchers selected a representative sample of 175 participants through randomization to ensure the findings were acceptable and valid, at least for the study region, since the total number of beekeeping households was not known. The Mayo Darle Subdivision was deliberately selected for its diverse array of plant species and trees, creating an ideal environment for beekeeping. Furthermore, seven (7) beekeeping Villages; Bambol, Boumdo, Hore Mayo Darle, Nyalang, Yoli, Mondial, and Tapare were intentionally selected. The research utilized stratified random sampling. Before categorizing the villages in the Mayo Darle Subdivision, the researchers initially created a list of the principal roads and housing areas for each community. The local authorities aided in developing sample frames on the ground quarterly. Once every beekeeper in each stratum was identified, the researchers randomly selected twenty-five (25) male and female beekeepers until the needed sample size was achieved. For the qualitative data, a purposive sampling method was used to select fifteen Key Informants (KI). This group consists of ten men and five women, representing all seven villages and includes one delegate from MINEPIA, one gender focal point from MINFOF, one MINADER representative from Mayo Darle, two council officers, two ACEFA representatives, two buyers of bee products, two marketers of bee products, two traditional leaders, and two youth representatives.

Instruments

A systematic questionnaire, interviews with important informants and observations were utilized to gather primary data from participants in each of the seven beekeeping communities within the Mayo Darle Subdivision. The primary data was collected utilizing pre-tested research tools in February 2024.

Validity And Reliability

To guarantee the instrument's validity and reliability, a small percentage of the research participants from each of the seven chosen villages was interviewed by distributing 30 questionnaires to the participants to evaluate the actual conditions in the region, along with conducting regular field visits.

Ethical Considerations

To ensure confidentiality, consent from the respondent was obtained before starting each interview. The researchers dedicated 2 months to fieldwork and gathered data from 175 beekeepers. In total, 25 beekeepers were chosen from each of the 7 villages included in the research.

Data Analysis

The ecological impact data of beekeeping in the Mayo Darle Subdivision was examined using a Chi-Square (X^2) distribution test to assess the variance between means and the severity scores capped at 10, as illustrated in Table 2, correlating the results with qualitative data and presented. The insights gathered from key informant interviews were employed to strengthen the quantitative data. Information from key informant interviews was transcribed exactly as spoken right after the interview. This provided the researchers with the chance to recall everything

discussed in the interview. The recognized categories were distinctly specified and implemented with codes allocated to them. The coded responses from the interviewees were analyzed; contrasts and commonalities were highlighted; the findings were interpreted and presented.

RESULT AND DISCUSSION

Demographic Characteristics of Respondents

Figure 2 indicates that approximately 94% of the beekeepers surveyed were male, in contrast to roughly 6% who were female. This was clarified by the understanding that beekeeping is a demanding job, especially for women, that requires establishing hives in elevated areas. Additionally, the area's Muslim-oriented lifestyle ensures that men perform much of the labour, while women participate in less physically demanding activities. Unlike single individuals, couples need to earn extra income to meet additional societal requirements. Kalsane *et al.* (2023) performed research on the technical features and socio-economic significance of beekeeping in the Far North Region of Cameroon. It was observed that beekeeping in the region is a secondary pursuit (89%), predominantly carried out by men (98%) and farmers (63.46%) (Kalsane *et al.,* 2023). Meutchieye *et al.* (2018) conducted an empirical investigation on beekeeping characteristics in the Adamawa grasslands of Cameroon, revealing that all respondents, 100%, were male beekeepers. In Kenya, it was found that women were more inclined than men to engage in beekeeping (Mburu *et al.,* 2017).

Moreover, during the interview, 24% of the farmers were unmarried, while 76% of them were married (Figure 2). To meet extra social obligations, couples need to earn more than individuals. These findings align with the work of Austin *et al.* (2020), who investigated the obstacles preventing women from participating in beekeeping in Papua New Guinea. Austin *et al.* (2020) state that although some women (n = 10) tend to be independent, they depend on external help to oversee their activities. Many women (n = 90) were identified as beekeepers in partnership with their husbands (Austin *et al.,* 2020). These results also resemble those of Meutchieye *et al.* (2018), who discovered that most beekeepers were aged 30-50, over 80% were married, and all identified as Muslim in Mayo Banyo.

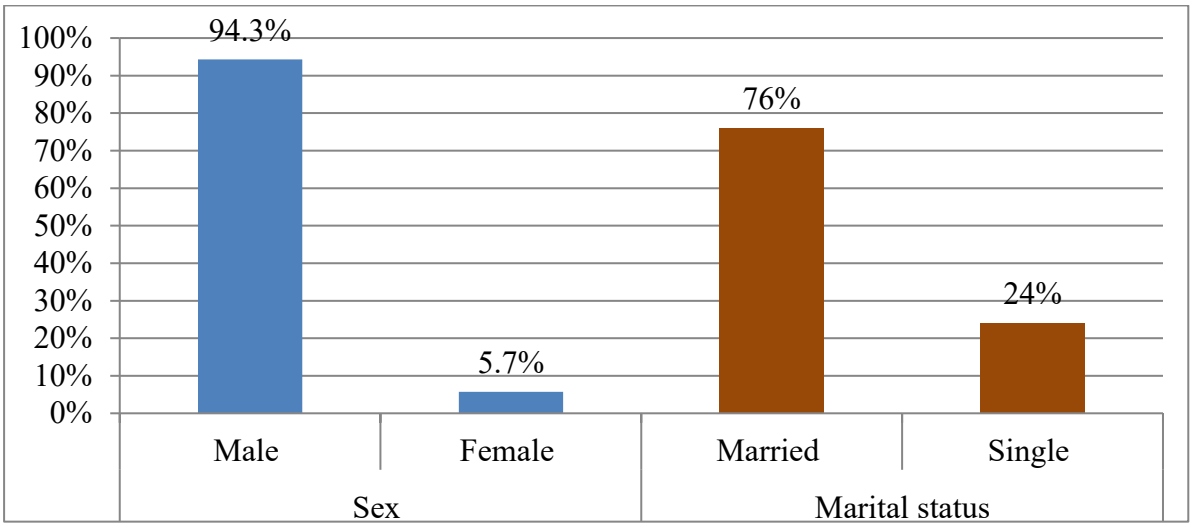

Figure 2: Distribution of Farmers by Sex and Marital Status
Source: Field Data (2024)

Moreover, the findings presented in Table 1 reveal that more than 71% of beekeepers in Mayo Darle lacked formal education. This signifies a significant level of illiteracy among local beekeepers, adversely affecting honey production since they are unprepared to embrace innovative beekeeping practices due to their educational deficits. These results oppose

Meutchieye *et al.* (2018), who discovered that fewer than 87% of participants have experienced formal education. Moreover, merely 8% of them indicated possessing a university degree, while approximately 22% had finished only primary school, and just over 5% had achieved GCE Ordinary Levels. Considering the low literacy levels noted in the three northern regions of Cameroon (Bang *et al.,* 2019), this was evident. It is important to mention that Andaregie & Astatkie (2021) found similar results regarding the factors that encourage smallholder rural communities in Northwest Ethiopia to participate in beekeeping. According to various respondents, the primary benefits of advanced beekeeping technology are high yield, easy inspection, and honey quality (Andaregie & Astatkie, 2021); the major drawbacks include high expenses, the requirement for extensive knowledge, and technology accessibility (Andaregie & Astatkie, 2021). It is crucial to encourage beekeepers to participate in training that will improve their knowledge and abilities to increase the amount and quality of honey produced in Mayo Darle. In a study Vapa-Tankosić *et al.* (2020), concerning research and development (R&D) investment and the integration of new technologies in sustainable beekeeping. Higher education attainment and more professional beekeeping experience are associated with a greater readiness to spend time in research and development (Vapa-Tankosić *et al.,* 2020). Higher education positively influences people's openness to partnering with organizations or expert consultants to conduct research (Lo & Tian, 2020) and develop beekeeping methods. To improve beekeeping techniques, beekeepers aged over 41, Serbian women involved in beekeeping, and those who are actively pursuing careers in the field are more inclined to recognize the importance of support from scientific and research institutions (Vapa-Tankosić *et al.,* 2020). Products from honeybees that add value and arise from the use of modern technologies are significantly influenced by higher education. Educational attainment has a positive influence on acceptance of new technologies (Skoumpopoulou *et al.,* 2018). Consequently, to enhance the quality and quantity of their production, beekeepers in Mayo Darle should begin to expand their knowledge of beekeeping.

Of many participants, 82.1% were Muslims, Christians were only 17.3%, and African religious practitioners were 0.6%. This is logical because the area is a Muslim-dominated area.

Table 1: Education and Religious Affiliations

Educational Level of Farmers			
No formal education	FSLC	GCE Ordinary Level	Bachelor's degree and above
71.3%	21.8%	5.2%	7.7%
Religious Affiliations			
Christian	Muslim	African Traditional Religion	Others
17.3%	82.1%	0.6%	0

Source: Field data (2024)

Ecological Impact of Beekeeping in Mayo Darle Subdivision

This research explored the ecological impacts of beekeeping in the Mayo Darle Subdivision as understood by the beekeepers. Employing critical ecological concerns emphasized in literature like crop pollination, availability of medicinal flora, occurrences of bushfires, deforestation, and tree planting and afforestation, data was gathered and examined using the Chi-Square distribution test, with severity scores developed to a maximum of 10 (Table 2). As indicated in Table 2, beekeepers observed a marked rise in crop pollination levels attributed to beekeeping in Mayo Darle (from 39.5% to 78.8%, a rise of 43.3%, $X^2 = 66.527$, $p = 0.000$). Findings from this research show a notable rise in flower pollination attributed to beekeeping in Mayo Dale, as noted by the beekeepers (from 37.1% to 82.7%, an increase of 45.6%, $X^2 = 84.291$, $p = 0.000$). The findings align with Khalifa et al.'s (2021) findings when

exploring the overall features of bee pollination and its financial implications in farming. Their study indicates that animal pollination accounts for 30% (Khalifa *et al.,* 2021) of global food production, with bee-pollinated crops comprising about one-third (Alebachew, 2018) of the total food consumed by humans. Bees are acknowledged as vital pollinators due to their effectiveness and widespread presence (Khalifa *et al.,* 2021).

Bee pollination offers significant benefits to the amount and quality of crops (Tanda, 2022), improving global economic and nutritional results (Khalifa *et al.,* 2021). In addition to describing the various kinds of bees and other pollination-related insects, this research highlights the significance of bee pollination for the economy. Richardson (2023), who studied the role of beekeeping in enhancing environmental public health and food security, supported this conclusion. The findings point to several advantages, including improved pollination, higher crop yields, healthier ecosystems, and increased climate change resilience (Richardson, 2023). Just 1.4% (Richardson, 2023) of beekeepers in the USA participate in commercial beekeeping, even though beekeeping offers significant benefits for food security and the nutritional contributions of bee products (Richardson, 2023). According to Richardson (2023), 89.7% of colonies are dominated by 1.4% of commercial beekeepers, illustrating a significant neglect for apiculture. From April 2022 to April 2023, there was a shocking 48.2% (Richardson, 2023) drop in honeybee colonies due to this negligence.

Breeze *et al.* (2019) focused on connecting the preferences of farmers and beekeepers with ecological knowledge to enhance crop pollination. In opposition to these findings, studies on honeybee decrease, its effects on beekeepers, and agricultural pollination in Western Nepal were carried out by Kortsch *et al.* (2024). The research revealed that beekeepers identified that the primary causes of this reduction are floral shortage and climate change (Kortsch *et al.,* 2024). These reductions present a significant danger to local communities since honey sales account for roughly 16% (Kortsch *et al.,* 2024) of beekeepers' household earnings, and Apis *cerana cerana* is a crucial pollinator for numerous vital crops. Similarly, it seems that beekeeping has resulted in an increase in tree planting efforts (from 9.5% before beekeeping to 73.7% with beekeeping, representing a 63.8% rise in implementation, X2 = 187.434, p = 0.000). This is logical since trees that attract bees are crucial for successful beekeeping. In their research about bee wells, Burke and Corrigan (2024) discovered that pro-environmental measures positively impacted the psychological health of beekeepers and their families. Based on their research, beekeepers in Ireland enhanced bee foraging by creating a native apple orchard on their property and planting 4,500 native hedgerow plants (Burke & Corrigan, 2024) native hedgerow plants. This was like the results of a study on the variety of plant species used as feed sources in honey beekeeping conducted in South Africa and Jambi by Pujiastuti *et al.* (2024).

Additionally, the percentage of these beekeepers who created home gardens grew from 0.8% to 66.8% following their initiation into beekeeping (a 66% increase in implementation, X^2 = 215.959, p = 0.000). With an emphasis on the value of beekeeping in the preservation of Ethiopia's traditional home gardens, Tolera *et al.* (2021) evaluated and contrasted traditional conservation methods with the variety and abundance of plants found in home gardens kept by both beekeepers and non-beekeepers. These research results resemble those of that study. Their research indicated that the mean quantity of flower species found in gardens of beekeepers was 22.8 ± 3.2, while in gardens of non-beekeepers, it was 14.2 ± 2.1 (Tolera *et al.,* 2021). The quantity and quality of honey were linked to various types of bee feed (Simanonok *et al.,* 2020). Seyida Afreen and colleagues (2021) examined home gardens as a budget-friendly approach. The results indicate that home gardening offers social advantages such as enhancing physical health, improving food and nutrition security, increasing social significance, and fostering gender equality (Seyida Afreen *et al.,* 2021). The evaluation states that cultivating food in a home garden is more beneficial than buying food from the market (Seyida Afreen *et al.,* 2021). The cost-benefit evaluation indicates that employing family members as workers is economical (Seyida

Afreen et al., 2021). In probable developing countries, the exchange of both urban and rural household garden products yields greater revenue for family members (Seyida Afreen *et al.,* 2021).

In the Mayo Darle Subdivision, beekeepers thrive by cultivating home gardens to enhance the diversity and abundance of plants that attract bees, maximize apiary yields, and boost household food security and wellness. Based on insights gathered from interviews with key informants, one respondent reinforced the quantitative data by stating that:

> Some of the ecological effects of beekeeping in Mayo Darle have increased crop pollination, and the protection of more bee-loving trees, accompanied by the planting of new ones by beekeepers. Watershed trees have also been planted, which has increased water availability in certain areas. Incidents of bushfires have also been reduced due to fear of burning bee hives and by so doing ensuring environmental sustainability (Delegate of MINEPIA for Mayo Darle Sub-Division, Age 55, 19/04/2024). In summary, an additional participant in the detailed interview noted that:
>
> Beekeeping has enhanced agricultural production in fields, resulting in a noticeable rise in the pollination of plants. In areas where beekeeping occurs, there is a reduction in deforestation. Beekeepers protect their beehives and trees that are vital for bees from bushfires. This also helps wildlife, as we observe numerous birds and reptiles in beekeeping communities (Village Chief of Mondial Village, Age 65, 19/04/2024). To support these facts, another participant expressed the opinion that: This has also resulted in the planting of many trees that provide flowers in the farmlands necessary for the harvesting of nectar by bees for honey production, crops that flowered before and don't bear fruits can now produce fruits. Some vegetation that never produced flowers can now make, and above all, the availability of water is because of the planting of watershed trees by beekeepers (Field Coordinator for ACEFA livelihood program, Age 45, 19/04/2024).

The ecological results of the study also reveal a decline in certain regions, particularly a significant drop in the availability of medicinal plants (from 93.6% before beekeeping to about 14% currently, $X^2 = 182.778$, $p = 0.000$). This is probably due to beekeepers gathering medicinal plants in an unsustainable way. To preserve agrobiodiversity, Ávila-Bello *et al.* (2024) investigated the construction of complex agroecosystems in the Santa Marta Mountains of Veracruz, Mexico, with an emphasis on formal and traditional knowledge. The research indicates that habitat destruction and degradation are primary factors contributing to the decline of medicinal plant availability (Ávila-Bello *et al.,* 2024). In this way, Narciso *et al.* (2024) investigated how natural therapies affected the degree of varroa mite infection and the general well-being of *Apis mellifera* (honeybee) colonies. Research indicates that certain beekeepers combat bacteria, fungi, mites, and honeybee illnesses using medicinal plant species rather than chemical pesticides (Narciso *et al.,* 2024). Ghisbain *et al.* (2024) provided evidence for this in their study of the anticipated decline in European bumblebee populations in the twenty-first century. The research indicates that at-risk plant species struggle as bee populations decrease. Remotti *et al.* (2024) claimed in their study on how Liguria beekeepers in Italy perceive climate change that the overuse of medicinal plants by beekeepers as a key source of healthcare resulted in a decline in plant species within beekeeping communities. These findings align with research that discovered a reduced number of medicinal plants in the area. This was corroborated by one of the KII participants who stated that:

> Frequent collection of medicinal plants is taking place near bee farms. This assists with local health issues. The Mayo Darle market is seeing a rise in the

> availability of herbal products. There are medicinal plants that are utilized locally to safeguard bee hives from pests and illnesses. These plants are quickly vanishing due to beekeepers excessively harvesting them (Herbal practitioner and bee farmer, Tapare Village, 72 years, 21/04/2024). In summary, another participant reinforced this perspective by stating that "*There has been an enhancement in the access to non-timber forest products from regions with bee hives*" (Experienced beekeeper from Boumdo community, 46 years old, 22/04/2024).

Incidents of bushfires have notably declined (previously reported at 87.1% and now at just 12.4% with beekeeping, $X^2 = 171.516$, $p = 0.000$). Mulwanda *et al.* (2024) examined smallholder farmers in Zambia's Murundu ward within the Mufulira mining zone as part of their study on traditional ecological knowledge, attitudes, and practices related to insect pollinator conservation. They found that these farmers use fire breaks as a bushfire prevention tactic (Mulwanda *et al.*, 2024). This result is like theirs. As stated by Pienaah *et al.* (2024), beekeeping represents a sustainable approach to reducing the incidence of bushfires in Ghana. The recent study indicates that many beekeepers in the Mayo Darle Subdivision primarily employ traditional beekeeping methods; however, the benefits of beekeeping encourage preemptive actions to avert bushfires, leading to a reduction in bushfire occurrences in the area. These findings were also emphasized in the KII:

> In the past, women could not go to some of their farmlands in the dry seasons for fear of random bushfires that threatened their lives. Because of beekeeping, inhabitants became conscious of these fires and watched out because beekeepers ask for compensation when bushfires destroy their bee hives and bee-loving trees planted by them. This effort of beekeepers has reduced bushfires in some areas, today, where bee hives are found, we can go to our farms at any time without fear of bushfires (Female beekeeper in Hore Mayo Darle Village, age 53, 24/04/2024).

However, it is crucial to mention that since these beekeepers started their practices, the area of land in the Mayo Darle Subdivision has markedly diminished (declined from 98.4% previously to 0% now with beekeeping, $X^2 = 286.803$, $p = 0.000$). Intense competition for land to set up apiaries, rising population, demands for greater food production, and various other endeavours that would elevate the worth of available land may contribute to this. Consequently, many individuals living in poverty might not have access to these lands, as they are typically owned by those with high incomes (Information can be found in Table 2). To back up this perspective, another important contributor pointed out that:

> Nitrogen-fixing plants can now grow well and produce. This has also improved the quality of the degraded soil and the availability of useful insects in the soil. This has encouraged people to engage in crop cultivation and has also attracted people from other parts of Cameroon to come and carry out crop farming in Mayo Darle. With increased agricultural activities, land has become very expensive (Female Bee Farmer in Bambol village: age 38, 21/04/2014). A comparable reply came from the Agric Technician at Mayo Darle Council (age 47, 22/04/2024), stating: "*Certain trees that support bees function as natural fertilizers, improving soil fertility and thereby boosting agricultural productivity*." These trees are cultivated by beekeepers, and their quantity grows each year.

Table 2: Ecological Impact of Beekeeping in Mayo Darle Subdivision

Table 2: Ecological Effects of Beekeeping Aspect	State	Not Existing	Low	No Change	High	Very High	Severity/10
Pollination of crops $X^2 = 66.527$, p = 0.000	Before	0.8%	58.9%	0.8%	34.7%	4.8%	6.98±1.637
	Now	0%	16.6%	4.6%	53.7%	25.1%	
Pollination of flowers $X^2 = 84.291$, p = 0.000	Before	0%	62.1%	0.8%	33.1%	4%	7.41±1.401
	Now	0%	13.3%	4%	55.7%	27%	
Presence of medicinal plants $X^2 = 182.778$, p = 0.000	Before	0%	5.6%	0.8%	46%	47.6%	4.4±1.481
	Now	0%	84%	1.7%	6.3%	8%	
Bush fires incidence $X^2 = 171.516$, p = 0.000	Before	0%	9.7%	3.2%	75%	12.1%	4.95±1.752
	Now	0%	81.7%	6.9%	9.7%	1.7%	
Deforestation $X^2 = 199.462$, p = 0.000	Before	7.3%	77.4%	0.8%	8.9%	5.6%	7.57±1.389
	Now	0%	4.6%	1.1%	44%	50.3%	
Tree planting/afforestation $X^2 = 187.434$, p = 0.000	Before	16.1%	72.6%	0.8%	9.7%	0.8%	5.93±2.73
	Now	0%	10.3%	16%	37.1%	36.6%	
Forest degradation $X^2 = 181.353$, p = 0.000	Before	9.7%	75%	2.4%	11.3%	1.6%	7.46±1.564
	Now	0%	8.6%	1.7%	54.3%	35.4%	
Creation of home gardens $X^2 = 215.959$, p = 0.000	Before	19.4%	77.4%	2.4%	0.8%	0%	5.59±2.696
	Now	1.7%	9.1%	22.3%	53.7%	13.1%	
Poor weather/climatic conditions $X^2 = 77.586$, p = 0.000	Before	16.9%	26.6%	0.8%	55.6%	0%	6.16±2.247
	Now	0%	40.6%	0%	32.6%	26.9%	

Source: Field Data (2024)

CONCLUSION

This research examined the impact of beekeeping on the environment in the Mayo Darle Subdivision of Cameroon's Adamawa Region. Beekeeping affects a community's ecology in both positive and negative ways. In Mayo Darle Subdivision, apiculture has played an essential part in lowering the occurrence of wildfires, boosting tree planting initiatives, inspiring beekeepers to establish home gardens, and aiding in the pollination of crops and flowers. However, in the Mayo Darle Subdivision, beekeeping has led to a notable decrease in the amount of land available and the presence of therapeutic plants. Thus, it is essential to find a balance between safeguarding biodiversity and beekeeping practices to maintain the ecosystem by growing diverse flowering trees that draw in bees. To enhance environmental sustainability, the research recommends that beekeepers consider the importance of the ecological relationships between beekeeping and the environment. Interestingly, the findings of the study carry multiple implications for various parties involved: Initially, beekeepers would see an improvement in crop production through enhanced apiculture methods as they could experience elevated pollination levels; organizations and government bodies that support apiculture would significantly contribute to addressing climate change by promoting tree planting and minimizing bush fires. Based on the findings of this study, one may think that forthcoming experimental research could establish how promoting beekeeping may lead to tree planting and, consequently, assist in combating desertification in areas impacted by it, such as the Lake Chad basin.

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