

(RESEARCH ARTICLE)



BEEKEEPING IN CASHEW-TREE FIELDS: TECHNICAL CHARACTERISTICS AND BEEKEEPERS' PERCEPTIONS IN M'BENGUÉ SUBPREFECTURE (NORTHERN CÔTE D'IVOIRE)

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ABSTRACT

Cashew tree farms can provide favorable conditions for beekeeping, which in turn offers the opportunity to optimize flower pollination and cashew nut production. Despite its significant potential benefits, the integration of beekeeping with cashew farms is limited in Côte d'Ivoire. The objective of this study was to determine the characteristics of beekeeping associated with cashew farms and beekeepers' perceptions of this integration in the subprefecture of M'Bengué. A survey was conducted among 30 beekeepers whose apiaries are located in cashew farms. Observations were made at the apiaries located in cashew farms. The beekeepers' professional experience ranges from one to six years. A total of 495 hives, including 417 Kenyan hives (84.24%) and 78 Langstroth hives (15.76%), were counted in the cashew orchards. Small apiaries accounted for 83.33%, while medium-sized apiaries constituted 16.67%. The hive occupation rate was 91.37% for Kenyan hives, 100% for Langstroth hives, and 92.73% for all hives. The method used to populate the hives is the capture of wild swarms. Honey is harvested by all beekeepers, while beeswax is harvested by 63.33% of beekeepers. The majority of beekeepers (70%) view the integration of beekeeping with cashew farms as a practice that increases honey production, cashew nut production, and income. For the remaining beekeepers (30%), this integration has no impact on honey production, cashew nut production, or income. The integration of beekeeping with cashew farms is a relatively recent development in the M'Bengué subprefecture. However, the majority of beekeepers view it as a practice that benefits honey production, cashew nut production, and income.

Keywords: Beekeeping, Cashew farms, Beehives, Honey production M'Bengué, Côte d'Ivoire

1 INTRODUCTION

Cashew tree (*Anacardium occidentale* L.) is a shrub belonging to the Anacardiaceae family. The cashew tree is cultivated in tropical regions for its fruit, the cashew nut, which is widely recognized for its economic value. The cashew nut plays a strategic role in Côte d'Ivoire, which has been the world's leading producer and exporter since 2015 [1], [2]. In 2023, Côte d'Ivoire's production was estimated at 1,225,935 metric tons, accounting for approximately 40% of world production [2].

Despite the importance of cashews to the economy of Côte d'Ivoire, cashew farms are very unproductive. In fact, average yields range from 350 kg/ha to 500 kg/ha in Côte d'Ivoire, whereas in countries such as India, Brazil, and Vietnam, they reach 1,000 kg/ha [2]. These low yields in Côte d'Ivoire are often attributed to the use of low-yielding plant material, the aging of cashew trees, a lack of expertise in cultivation practices, and often insufficient pollination [3], [4], [5].

Research conducted in India and Brazil has identified insufficient pollination as one of the main causes of low cashew yields [6], [7]. According to [6], in India, 25% to 72% of cashew tree pistils were not pollinated due to a shortage of pollinating insects. The honeybee (*Apis mellifera*) is the most effective pollinator of the cashew tree in northeastern Brazil [7]. Thus, integrating beekeeping into cashew orchards can help improve their productivity and sustainability.

Beekeeping is the practice of raising bees for the purpose of producing and utilizing hive products such as honey, beeswax, pollen, royal jelly, propolis, and bee venom [8]. Beekeeping is considered an agricultural activity with significant economic and ecological potential for several reasons. First, beekeeping is an economic activity whose success is directly linked to the availability of flowering plants in sufficient quantities for the bees [9]. Furthermore, beekeeping can be easily combined with other agricultural activities, as it requires relatively few financial, material, and human resources [10], [11]. Finally, beekeeping has a positive impact on agricultural yields due to the role that foraging bees play in pollinating crops [12], [13], [14], [15], [16], [17].

Despite its significant potential benefits, the integration of beekeeping with cashew farms is limited in Côte d'Ivoire. The objective of this study was to determine the characteristics of beekeeping integrated with cashew farms and beekeepers' perceptions of this integration in the M'Bengué subprefecture.

2 METHODOLOGY

2.1 Study area

The study was conducted in the M'Bengué Subprefecture, located in northern Côte d'Ivoire (Figure 1). This area has a dry tropical climate characterized by a dry season and a rainy season. The dry season lasts seven months, from November to May. The rainy season lasts five months (from June to October), with the highest rainfall occurring in August [18]. The dry season includes the Harmattan period from December to February. The average annual rainfall is 1,200 mm [19]. The average annual temperature is 27°C [20]. This area is located in the sub-sudanian phytogeographic region of Côte d'Ivoire [21]. Thus, natural vegetation types include wooded savannas, shrubby savannas, dense dry forests, and open forests [22]. Agriculture is the main economic activity for the people of the M'bengué subprefecture. The people grow food crops such as millet (*Pennisetum* sp.), corn (*Zea mays*), rice (*Oriza* sp.), sorghum (*Sorghum* sp.), yams (*Dioscorea* sp.), and industrial crops such as cotton (*Gossypium* sp.) and cashew (*Anacardium occidentale*).

2.2 Data collection

2.2.1 Survey

The survey was conducted from March to April 2025 among 30 beekeepers whose apiaries are located in the cashew farms of the M'Bengué subprefecture. This sample was selected using the snowball sampling method. In fact, the first beekeepers surveyed recommended other beekeepers in their network who met the study's criteria. Thus, the sample was expanded as interviews progressed until it reached its final size. This method was chosen due to the lack of a survey database and the difficulty of directly identifying the stakeholders relevant to the study [23].

The survey was conducted through individual interviews with beekeepers whose apiaries are located in cashew farms, based on a questionnaire. The information sought during these individual interviews included gender, ethnic group, age, literacy level, primary occupation, and professional experience of the beekeepers; the area of the cashew farms housing the apiary, hive colonization techniques; the hive products harvested by the beekeepers, and the beekeepers' perceptions of the relationship between beekeeping and cashew farms.

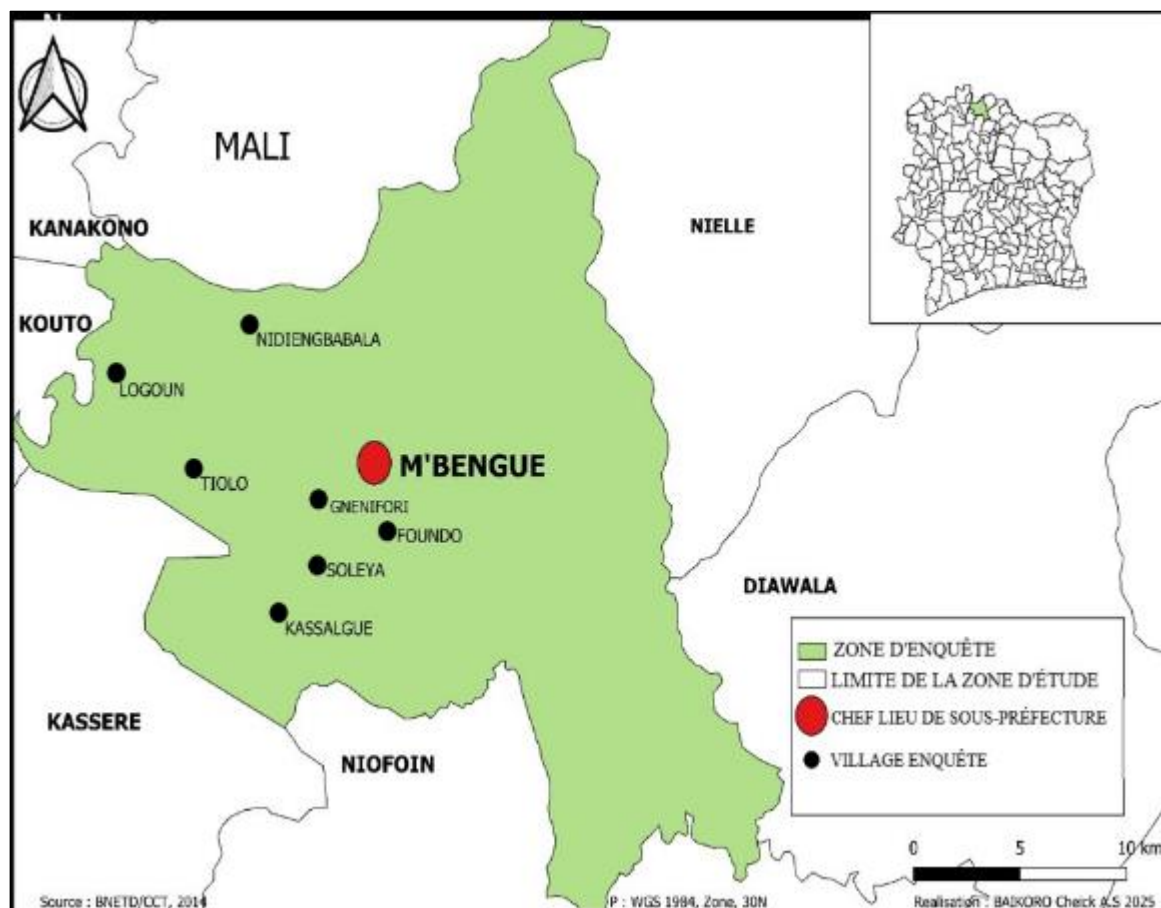


Figure 1: Location of the M'Bengué subprefecture

2.2.2 Visits to and observations of apiaries

After interviewing each beekeeper, a visit to the apiary was conducted to confirm its association with a cashew farm and to make observations. The observations focused on the size of the apiary, meaning the number of hives installed, the types of hives, and the number of hives occupied by bees. The observations were recorded on data sheets.

2.3 Data processing and analysis

The data obtained after compiling the survey forms and data collection sheets were entered into an Excel spreadsheet. Pivot table reports were used to provide information on :

- Sociodemographic profile of beekeepers ;
- Number and types of beehives installed in cashew farms ;
- Techniques for populating hives and their occupation rates ;
- Hive products harvested by beekeepers ;
- Beekeepers' perceptions of the relationship between beekeeping and cashew farms.
- The hive occupation rate was determined using the following formula :

$$\text{Hive occupation rate} = \frac{\text{Number of beehives occupied by bees}}{\text{Number of hives installed}}$$

Correlation tests and simple linear regressions were used to describe the relationship between beekeepers' professional experience and the amount of honey produced. The relationship between these variables was assessed using Pearson's correlation coefficient (r) and the coefficient of determination (R^2). The significance test was conducted at a p -value of 0.05. Pearson's correlation coefficient (r) indicates the nature (negative or positive) and strength (null, insignificant, weak, moderate, strong, very strong) of the relationship between two variables. As for the coefficient of determination (R^2), it denotes the percentage of the values of variable Y explained by variable X . These tests were performed using Excel. The normality of the data was always verified beforehand.

3 RESULTS

3.1 Socio-professional profile of beekeepers

3.1.1 Gender, ethnic origin, and age

The survey showed that beekeeping in association with cashew orchards was practiced exclusively by men. All of the beekeepers surveyed were Senufo, the indigenous ethnic group of the M'Bengué Subprefecture. The study revealed that the beekeepers' ages ranged from 23 to 69 years, with an average of 39.97 ± 11.54 years. The distribution of beekeepers by age group is shown in Figure 2. The age group]35 years; 60 years] was the most represented, accounting for 63.33% of the beekeepers surveyed. It was followed by the [18 years; 35 years] age group, which accounted for 33.33% of the beekeepers. The least represented age group was the]60 years; 69 years] group, accounting for 3.33% of the beekeepers.

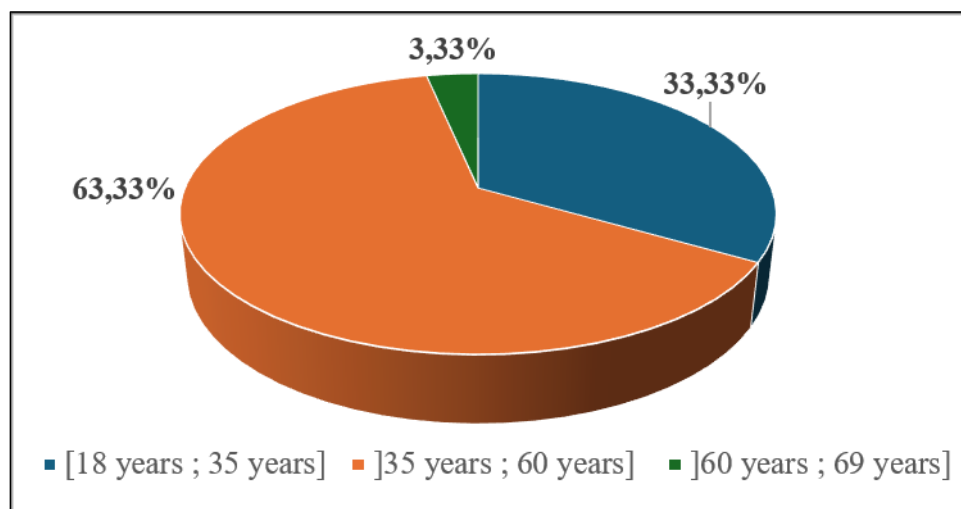


Figure 2: Distribution of beekeepers by age group

3.1.2 Literacy level

The beekeepers surveyed had different levels of literacy (Figure 3). The illiterate group constituted the largest proportion (83.33% of beekeepers). Next were those who had reached secondary school level, accounting for 13.33%. The primary school level was the least represented, with only 3.33% of beekeepers.

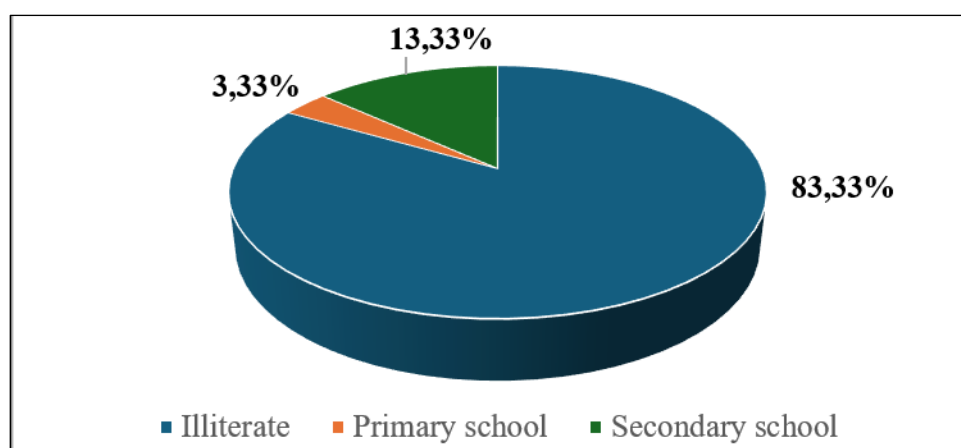


Figure 3: Distribution of beekeepers according to their literacy level

3.1.3 Main activities

Figure 4 shows the distribution of beekeepers according to their primary occupation. Agriculture was the primary economic activity for the majority of the beekeepers surveyed (80%). Trade was cited as the primary occupation by 13.33% of the beekeepers. Transport and dressmaking each accounted for the primary occupation of 3.33% of the beekeepers.

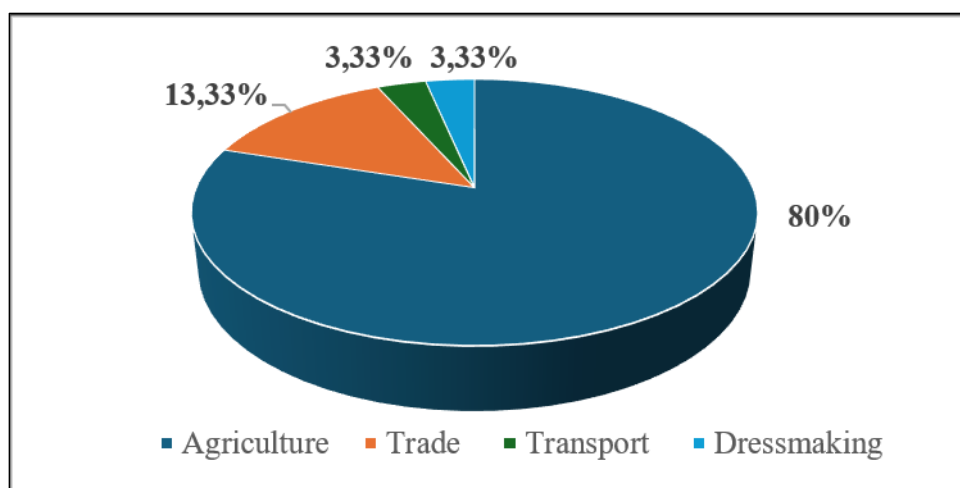


Figure 4: Distribution of beekeepers according to their main activity

3.1.4 Area of cashew farms

The study revealed that the areas of the cashew farms where beekeepers set up their apiaries ranged from 0.25 hectares to 25 hectares (Table 1). The total area of these cashew farms was 217.25 hectares, with an average of 7.24 ± 6.16 hectares.

Table 1: Number and area of cashew farms housing beehives

Parameters	Values
Number of cashew farms	30
Total area of cashew farms	217.25 hectares
Average area of cashew farms	7,24 hectares
Standard deviation of the area of cashew farms	± 6.16 hectares
Minimum area	0.25 hectare
Maximum area	25 hectares

3.1.5 Professional experience in beekeeping

The beekeepers' professional experience ranged from one to six years. The distribution of beekeepers based on professional experience is shown in Figure 5. Beekeepers with two to four years of professional experience made up the largest proportion (50%). Those with one year to two years of professional experience represented 26.67% of the beekeepers. Beekeepers with professional experience ranging from four years to six years constituted the smallest proportion (23.33%).

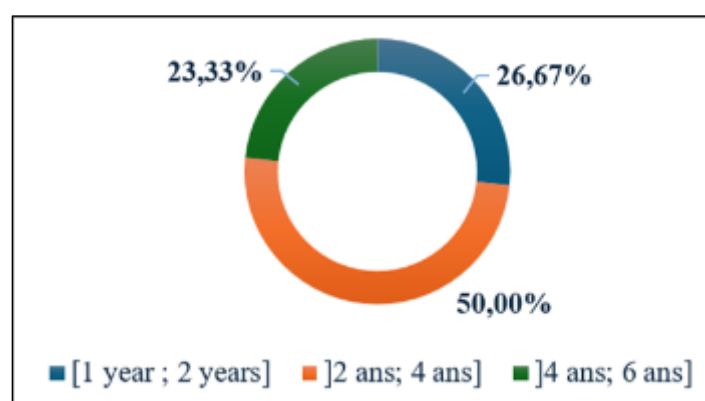


Figure 5: Distribution of beekeepers according to professional experience

3.2 Number and types of beehives installed in cashew farms

A total of 495 hives were counted in the cashew farms. The proportions of the different types of hives used by beekeepers are shown in Figure 6. Most of these hives were Kenyan hives (84.24%). Only 15.76% of the hives used by beekeepers were Langstroth hives.

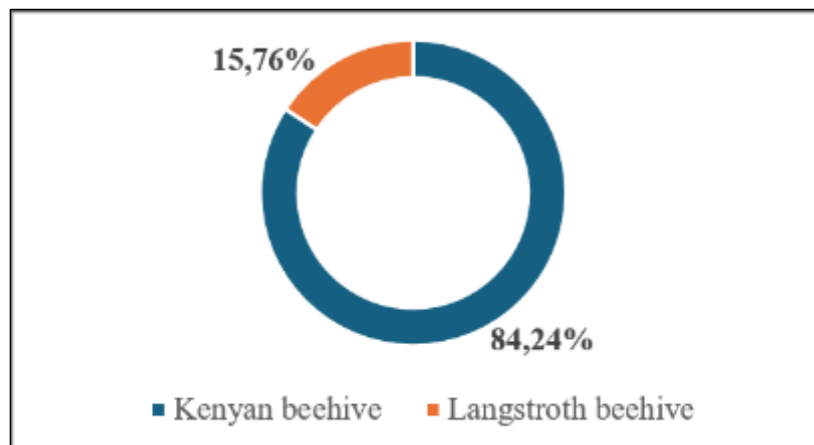


Figure 6: Proportions of the different types of beehives used by beekeepers

The number of hives per apiary ranged from 2 to 55. The distribution of apiaries based on the number of hives is shown in Figure 7. Apiaries with two hives to 30 hives accounted for the largest proportion (83.33%). Those with numbers of hives ranging from 31 to 125 constituted 16.67% of the apiaries.

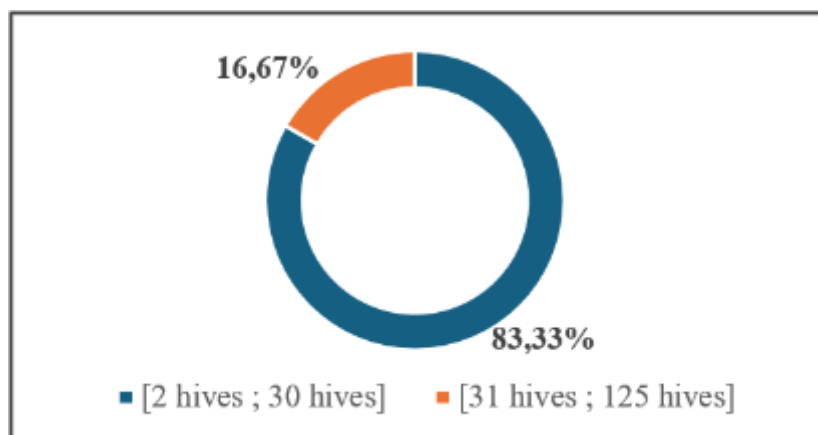


Figure 7: Distribution of apiaries according to the number of hives

3.3 Methods for populating beehives and occupation rates

Capturing wild swarms was the only method beekeepers used to populate hives. The hive occupation rates based on hive type are shown in Table 2. All Langstroth hives were occupied by bees, while the occupation rate for Kenyan hives was 91.37%. The occupation rate for all hives was 92.73%.

Table 2: Hive occupation rates according to hive type

Types of beehives	Number of beehives	Number of occupied beehives	Beehive occupation rate (%)
Kenyan hives	417	381	91.37
Langstroth hives	78	78	100
Total	495	459	92.73

3.4 Hive products harvested by beekeepers

Beekeepers harvested two hive products (Figure 8): honey, which was harvested by all beekeepers, and beeswax, which was harvested by 63.33% of beekeepers. The average honey production among the beekeepers surveyed was 111.23 ± 98.34 liters. As for the average beeswax production, it was 15.34 ± 12.55 kg.

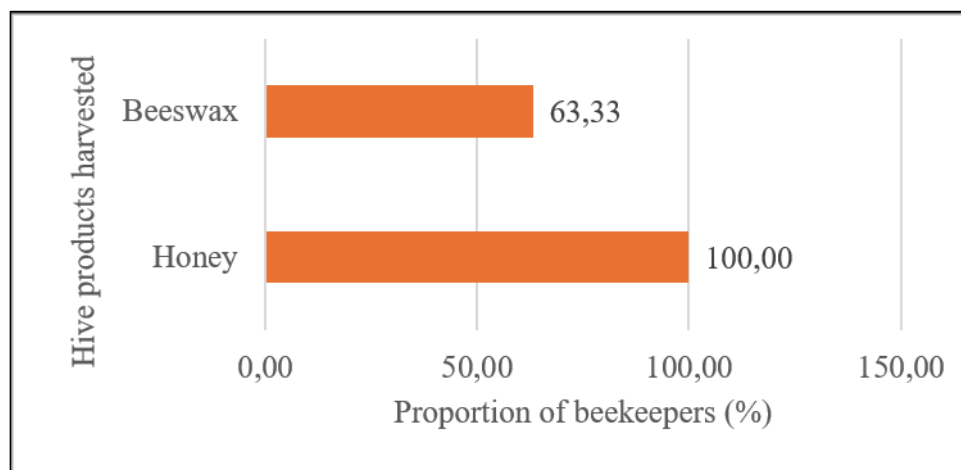


Figure 8: Proportion of beekeepers based on the hive products harvested

3.5 Relationship between beekeepers' professional experience and honey production

The correlation between beekeepers' professional experience and the quantity of honey harvested is shown in Figure 9. Beekeepers' professional experience is positively, moderately, and significantly correlated with the quantity of honey harvested ($r = 0.47$ and $p < 0.01$). The proportion of the quantity of honey produced that can be explained by beekeepers' professional experience is 96.99%.

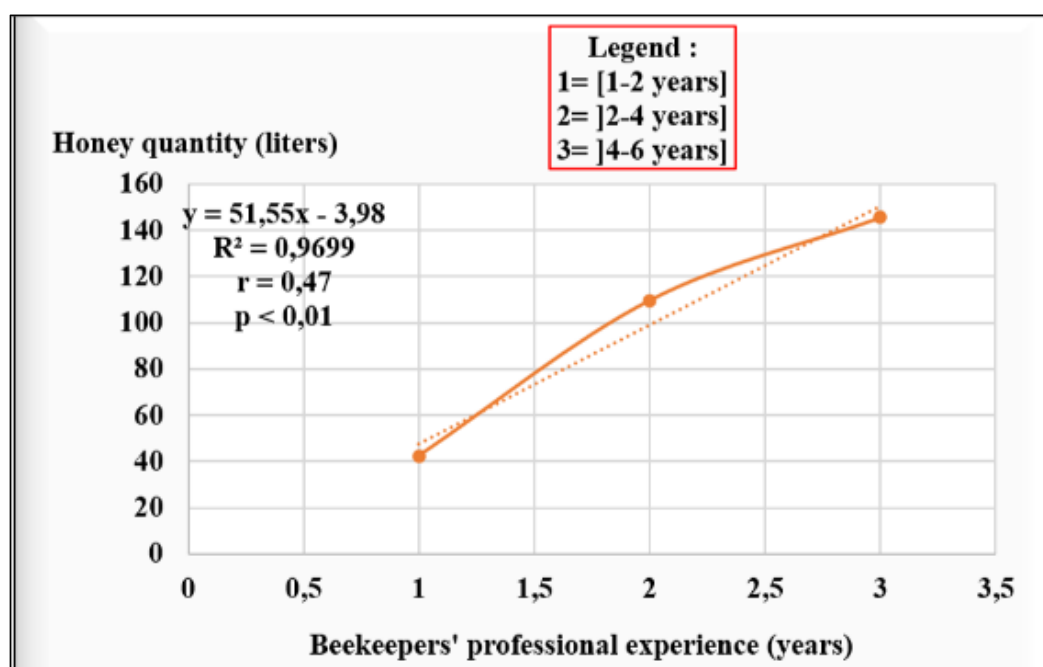


Figure 9: Correlation between the honey harvested and the beekeepers' years of experience

R^2 : coefficient of determination; r : Pearson's correlation coefficient ; p : probability limit.

3.6 Beekeepers' perceptions of the combination of beekeeping and cashew farms

The proportions of beekeepers based on their perceptions of the combination of beekeeping and cashew farms are shown in Figure 10. The majority of beekeepers (70%) perceived the combination of beekeeping and cashew farms as a practice that increases beekeeping production, cashew nut production, and income. For the remaining beekeepers (30%), this combination has no impact on beekeeping production, cashew nut production, or income.

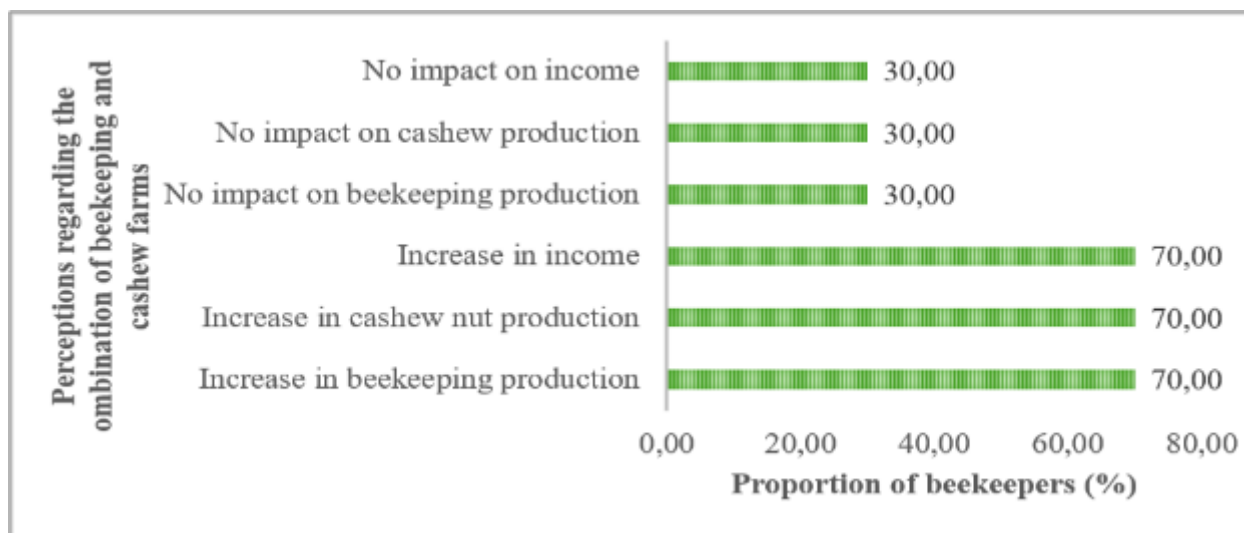


Figure 10: Proportions of beekeepers based on their perceptions of the association between beekeeping and cashew farms

4 DISCUSSION

Scientific research on the integration of beekeeping with cashew farms in Côte d'Ivoire is scarce. This study characterized beekeeping integrated with cashew farms and assessed beekeepers' perceptions of this integration in the M'Bengué subprefecture. The study revealed that beekeeping in combination with cashew farming was practiced exclusively by men. The fact that only men are involved in beekeeping activities is probably due to the physically demanding nature of the work and the associated risks of injury or bee stings [20]. According to [24], the aggressiveness of bees and the need to harvest honey in the middle of the night are factors that discourage women from engaging in beekeeping. This characteristic of honey production has been reported in several studies conducted in Côte d'Ivoire, Benin, and Togo. In fact, in Côte d'Ivoire, the same finding was reported in the Yamoussoukro district [25], in the Katiola department [26], in the Agboville department [24], and in the Tafiré subprefecture [27]. The same was observed in the municipalities of Natitingou and Tanguiéta in Benin [28] and in ecological zone IV of Togo [29].

However, this finding differs from that of several studies conducted in Benin and Burkina Faso, which noted the presence of women in modern beekeeping. Indeed, in the municipality of Cobly (Northwestern Benin), [30] noted that 5.71% of the beekeepers surveyed in that area were women. According to [31], women accounted for 24.3% of the beekeepers surveyed in villages bordering Corridor No. 1 of the Pô-Nazinga-Sissili Complex (South-Central Burkina Faso). In the Central-West region of Burkina Faso, [32] reported that 35.70% of beekeepers were women.

All of the beekeepers surveyed were Senoufo, the indigenous ethnic group of the M'Bengué subprefecture. This finding could be explained by the fact that beekeeping is a complementary activity to cashew farming, which requires access to land, something that is generally easier for indigenous populations to obtain. A similar finding was reported in the Tafiré subprefecture (North-Central Côte d'Ivoire) by [27].

The beekeepers' ages ranged from 23 years to 69 years, with 33.33% of them being young people (in the [18 years –35 years] age group). This finding is similar to that of [24], who reported that beekeeping was practiced by people aged 15 years to 70 years in the Agboville Department. The proportion of young people (33.33%) suggests their interest in beekeeping. This could be a significant asset for training in modern beekeeping, as well as for promoting and intensifying honey production in the area.

The beekeepers' professional experience ranged from one year to six years. This limited professional experience may reflect the fact that the combination of beekeeping and cashew farms is relatively recent in the M'Bengué subprefecture. This finding differs from those of [27] and [31]. Indeed, according to [27], in the Tafiré subprefecture (North-Central Côte d'Ivoire), the beekeepers' professional experience ranged from two years to 50 years. As for [31], they reported that beekeepers' professional experience ranged from two years to 40 years in villages bordering Corridor No. 1 of the Pô-Nazinga-Sissili Complex (South-Central Burkina Faso).

The types of hives found were Kenyan (84.24%) and Langstroth (15.76%). This result differs from that of [26] in Katiola department, where the proportion of Langstroth hives was 76.16%, compared to 23.84% for Kenyan hives. The predominance of Kenyan hives in this study is likely due to the beekeepers' limited professional experience. According

to [31], Kenyan hives are easy to handle. Consequently, Kenyan hives are likely the most suitable for novice beekeepers, such as those in this study. Langstroth hives, due to their more complex handling, are best suited for experienced beekeepers such as those surveyed by [26], whose experience in beekeeping ranged from two years to 50 years, with an average of 15 years.

The predominance of Kenyan hives in modern beekeeping in West Africa has been reported in other studies. In fact, in villages along Corridor No. 1 of the Pô-Nazinga-Sissili Complex (South-Central Burkina Faso), Kenyan hives accounted for 65.3% of the total [31]. According to [32], in the Central-Western region of Burkina Faso, modern hives consisted of Kenyan hives (57.20%), Langstroth hives (21.40%), and Dadant hives (21.40%).

Small apiaries (with between 2 hives and 30 hives) accounted for 83.33%, compared with 16.67% for medium-sized apiaries (with between 31 hives and 125 hives). The predominance of small apiaries could be explained by the fact that beekeeping is practiced within a family farming system [30].

The hive occupation rate was 92.73% for all hives. This high hive occupation rate is believed to be the result of several factors, such as the availability of bee swarms in the environment surrounding the apiaries, the effectiveness of the swarm-trapping method used, and good monitoring of the apiaries.

The average honey production among the beekeepers surveyed was 111.23 liters. This average honey production per beekeeper is lower than the production reported by [26] and [27]. In fact, [26] found an average honey production of 120 liters per beekeeper in the Katiola department (North Central Côte d'Ivoire). As for [27], they reported an average of 240 liters of honey per beekeeper in the Tafiré subprefecture (North-Central Côte d'Ivoire). These differences could be explained by the average number of hives managed per beekeeper and the beekeepers' professional experience.

For the majority of beekeepers (70%), the combination of beekeeping and cashew farming is a practice that increases honey production, cashew nut production, and income. For the remaining beekeepers (30%), this combination has no impact on beekeeping output, cashew nut production, or income. Thus, the perceptions of the respondents in this study regarding bee-crop interactions are more positive than those of the producers surveyed by [33]. In fact, on the outskirts of Comoé National Park (Northeastern Côte d'Ivoire), 12.4% of farmers believed that bee foraging causes flowers to wither and reduces crop yields [33]. For 53.6% of these farmers, bee visits had no impact on crop yields [33]. Only 34% of farmers believed that the presence of bees in crops increased agricultural yields [33].

The positive perception among respondents in this study regarding bee-crop interactions is a significant asset for the development of beekeeping in association with cashew farms. However, the sustainable development of this practice requires raising farmers' awareness of the role of bees in increasing agricultural yields and diversifying income sources, as well as providing training in modern beekeeping and professionalizing the beekeeping activity.

5 CONCLUSION

The practice of beekeeping integrated into cashew farms can help improve the productivity and sustainability of these agrosystems. The objective of this study was to determine the characteristics of beekeeping associated with cashew farms and beekeepers' perceptions of this integration in the M'Bengué subprefecture. The results show that the integration of beekeeping with cashew farms is relatively recent in the M'Bengué subprefecture. Most apiaries are small in size (83.33%). However, the majority of beekeepers (70%) perceive the integration of beekeeping with cashew farms as a beneficial practice for beekeeping, cashew nut production, and income. The results obtained provide baseline data that can be used to guide public awareness campaigns on the integration of beekeeping with fruit tree cultivation.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest related to this article.

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