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Analysis of Beekeeping and Agricultural Practices on the Bee *Apismellifera* in the Central Region of Togo

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ABSTRACT **Original research paper**

Beekeeping is practiced in all regions of Togo and plays an important role in the country's economy and sustainable development. Bees ensure better agricultural production through pollination. However, simultaneous agricultural and beekeeping practices have an impact on bee colonies (*Apis mellifera*) as well as solitary bees. However, little is known about these potential impacts. This study, conducted in the central region of Togo, aims to analyze the beekeeping and agricultural factors that lead to a reduction in bee colonies. It was carried out through a survey of 291 beekeepers. Data analysis using binary regression and correlation tests was performed using SPSS version 20 software. The results showed a decline in bee colonies. Pearson's correlation analysis showed an inversely proportional relationship between 50% non-colonization of hives and colony decline, and a strong relationship between 50% desertion of hives and pesticide use on agricultural plots. These results, which constitute a scientific database, have shed light on the potential impacts of agricultural and beekeeping practices on bee colonies.

Keywords: Agricultural Practices, Beekeeping Practices, Potential Impacts, Desertion of Hives, Decline in Colonies, Bee Colonies, Central Region.

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1. Introduction

All over the world, the agricultural landscape has changed profoundly in recent decades. Modern agrosystems are converging towards intensification, leading to a high degree of homogenisation of landscapes and a reduction in the number of species cultivated. These new agricultural practices are also characterised by an increase in the use of plant protection products and a decrease in biodiversity (Jauzein, 2001). This has led to extreme changes in resource availability, causing a significant decline in pollinators worldwide (Gallai et al., 2009). Environmental factors such as lack of flowers and exposure to pesticides lead to a decline in diversity, loss of floral resources for honey production, air pollution and climate change. Similarly, biotic factors characterised by the presence of parasites and pathogens affect bee colonies (Requier and Le Féon, 2016). The intensity of these factors varies from region to region. Parasites and pathogens are a major problem in Europe and North America. However, habitat loss, inadequate beekeeping practices and excessive pesticide use are relevant factors for the African continent (Maus et al., 2003).

In Togo, this problem is proving to be critical. Owingto the uncontrolled use of pesticides around apiaries, unregulated beekeeping practices and the action of predators, the central region of Togo is directly impacted by the decline of pollinating species. This decline is due to the ravages of the parasitic mite *Varroa destructor,* the single-celled fungus *Nosema ceranae*, the intensification of agricultural practices, the fragmentation of their habitats and the misuse of pesticides (Van Der Zee et al., 2012). It is therefore important to analyze the potential impacts of beekeeping and agricultural practices on bee colonies, however, very few studies mention these impacts. There isan insufficient knowledge understanding of the potential impacts of beekeeping and agricultural practices on bee colonies, and solitary species in the central region. In addition, the interactions between agricultural and beekeeping techniques require in-depth analysis in order to develop effective conservation strategies. The objective of this study is to analyze the beekeeping and agricultural factors that lead to a reduction in bee colonies in the central region. This research aims to fill in the exciting gaps and provide an understanding of the factors contributing to bee decline.

2. Materials and Methods

2.1 Presentation of the Study Area

This study was conducted in the central region of Togo (Figure 1). The region has an area of 13,182 km², 20% (approximately 2,700 km²) of which is protected areas (Fazao-Malfakassa National Park and Abdoulaye Forest) (Kombate et al., 2023). The central region is bordered to the north by the Kara region, to the south by the Plateaux region, to the east by Benin and to the west by Ghana. It is located between parallels 8° and 15° north latitude and meridians 0°15 and 1°35 east longitude (Kombate et al., 2023) and it is part of ecological zones II, III and IV as defined by Ern (1979). It comprises five prefectures: Tchaoudjo, Tchamba, Sotouboua, Blitta and Mô. With this ethnic diversity, the population derives its income from agriculture, livestock farming, hunting and trade. The following soil types are observed: tropical ferruginous soils, vertisols, ferralitic soils, poorly developed erosion soils and hydromorphic soils (Lamouroux, 1969). The terrain is irregular and belongs to the Sudanian phytogeographic domain (White, 1986). Depending on the ecological zone, it consists of plains, valleys and trays dominated by old, rugged mountain ranges with contrasting features (Kombate et al., 2023). The climate is Sudano-Guinean with a unimodal regime.Rainfall varies between 1,000 mm and 1,400 mm (White, 1986), characterised by a 6-month rainy season (May to October) and a 6-month dry season (November to April). Temperatures vary between 20°C and 32°C. Low temperatures are recorded during the Harmattan and high temperatures during February and March (Samarou, 2011). It is a high-altitude area (400 to 500 m) located in the centre of the Sudanese endemism zone. The vegetation consists of semi-humid forests, dense forests, dry forests, open forests and wooded savannahs with the *Isoberlinia* spp, and gallery forests along watercourses (Kombate et al., 2023).

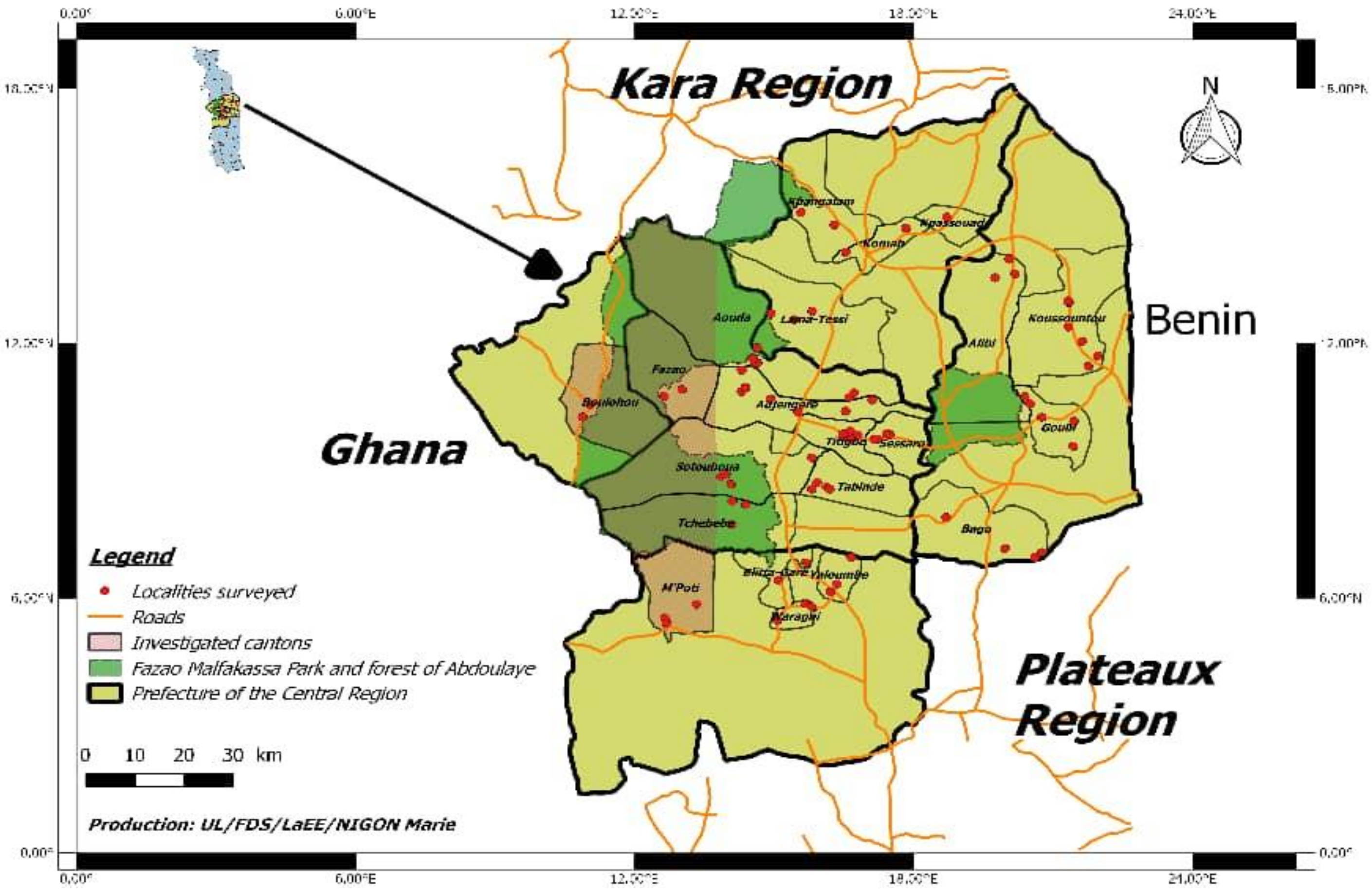

Figure 1: Map of the study area

2.2. Sampling

Inthe central region, individual beekeepers were interviewed at their apiary (beehive). According to data from the NGO VétérinairesSans FrontièresSuisse (VSF-Suisse) Togo, there are 1,300 beekeepers in the central region. This data was entered into the Dagnelie (1998) formula to determine the size of the representative population sample. The formula is as follows:

$$n = (U^2_{1-\alpha/2} \times P(1-P))/d^2.$$

In this formula: n is the size of the sample considered, P = 0.94 represents the proportion of beekeepers surveyed and it is the result of the exploratory survey, $U_{1-\alpha/2}$ is the value of the normal distribution at the probability value $_{1-\alpha/2}$ with α = 5%, d is the margin of error expressed as an estimate set at 5% ($_{1-\alpha/2}$ = 0.975 and $U_{1-\alpha/2} \approx 1.96$).

Based on these assumptions, the sample size for our study is 297. However, given the difficulties encountered in the field and the inaccessibility of certain localities, we surveyed 291 beekeepers. The main activity of those surveyed is agriculture, so beekeeping is their secondary activity. Using simple random sampling, interviews were conducted in 22 cantons in the five prefectures of the central region. The questionnaire, written in French, was administered to respondents in the local language. The main data collected relate to the identity of the respondent, their beekeeping and farming practices and the difficulties encountered in their beekeeping practices.

2.3. Data Analysis

The completed survey form was saved on the Kobotoolbox server and then deployed for use in the field via a smartphone. After the surveys, the forms were redeployed to the Kobotoolbox server and then downloaded as an Excel file. Excel 2019 was used for descriptive statistics and SPSS version 20 software was used for the binary regression and correlation analyses. The results were expressed with a significance threshold of 5%.

Binary logistic regression proved to be important in predicting the decline in bee colonies. This analysis allows us to see whether the presence of agricultural plots within 5 km of apiaries and the use of pesticides on these plots significantly predict the decline in colonies.

3. Results

3.1. Socio-Demographic Characteristics of Beekeepers

The data collected provided information on the population studied. Table 1 presents general information on beekeepers, including gender, level of education, number of years of experience and age. Men are more represented, with 90.72% compared to 9.28% for women. Regarding educational level, 40.89% of respondents have a secondary education, 37.11% have a primary education, 3.44% are university graduates, and only 18.56% have no formal education. 60.5% of the beekeepers surveyed have less than 5 years of experience, 27.1% have 5 to 10 years' experience, 8.2% have 10 to 15 years' experience, 2.7% have 10 to 20 years' experience and 1.4% have more than 20 years of experience. However, it should be noted that only 44.67% of those surveyed have completed at least one training course in beekeeping. According to the quantitative data, the average age of beekeepers is 39.78 years, with a variance of 66.41 and a standard deviation of 8.15.

Table 1: Socio-demographic characteristics of the beekeepers surveyed

Qualitative variables			
Variables	Parameters	Number	Percentages (%)
Gender	Male Female	264 27	90.72 9.28
Level of education	No schooling Primary Secondary University	54 108 119 10	18.56 37.11 40.89 3.44
Experience in years	Less than 5 years 5–10 years 10–15 years 15–20 years More than 20 years	176 79 24 8 4	60.5 27.1 8.2 2.7 1.4
Training in beekeeping	Yes No	130 161	44.67 55.33
Quantitative variables			
Variables	Mean	Variance	Standard deviation
Age	39.78	66.41	8.15

3.2. Beekeeping Practices

3.2.1. Types of Hives

Five (5) types of hives are used in the central region (Figures 2a and 2b). Kenyan hives are the most widely used, accounting for 53.46% of the total, followed by traditional hives (26.42%), Dadant hives (9.22%), elongated hives (8.6%) and Kenyan concrete hives (2.31%).

Figure 2a: Types of hives

Figure 2b: Photos of different types of hives

3.2.2. Periods for Capturing New Colonies

The periods for capturing new bee colonies, also known as the hive colonisation period, are the ideal times to set up hives for possible colonization. Three (3) main periods have been identified (Figure 3). The longest period is December–March, during which 49.57% of beekeepers place their hives for the capture of new colonies, followed by September–November (27.23%) and April–August (22.55%). However, it should be noted that 0.64% of beekeepers set up their hives at any time during the year.

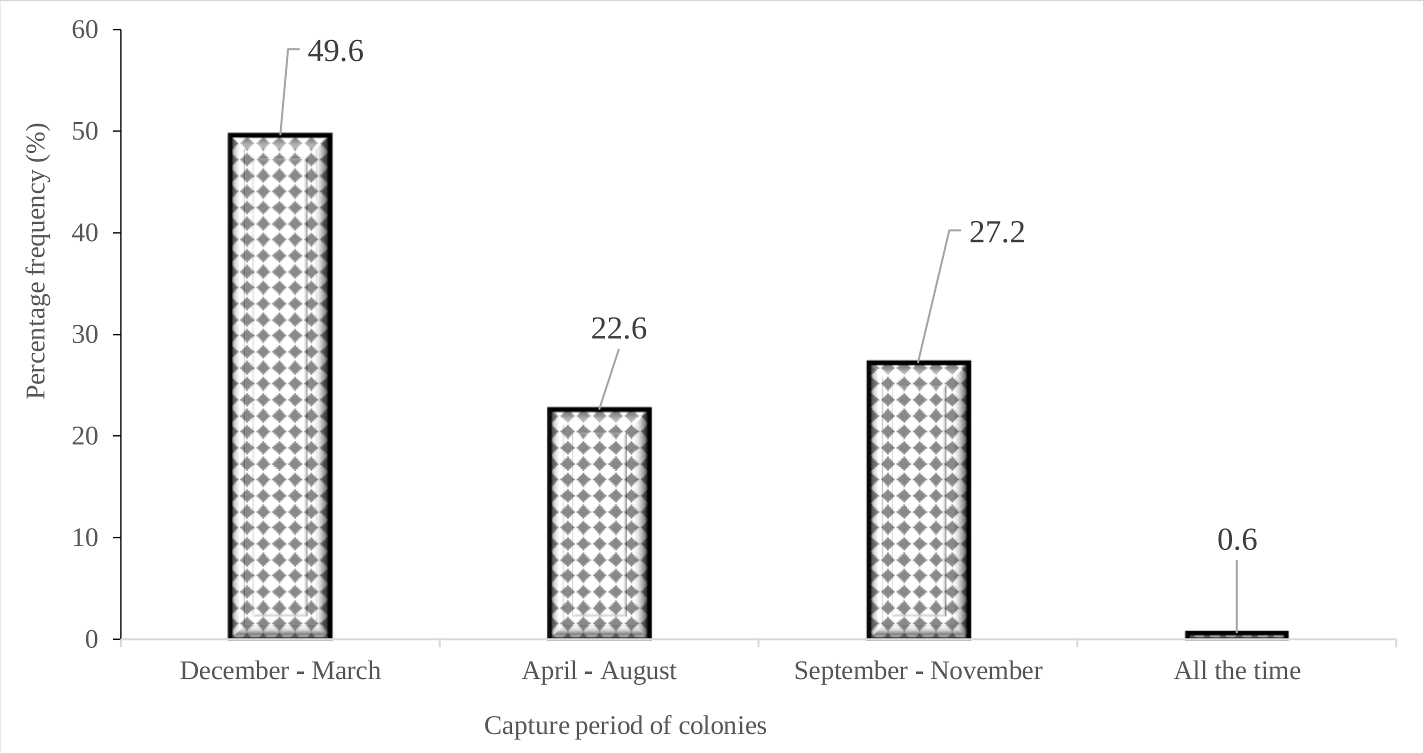

Figure 3: Periods for capturing new colonies

3.2.3. Impact of Beekeeping Practices on Bee Colonies

The causes of hive desertion are shown in a cross-tabulation between: is half of your hives deserted? and honey harvesting techniques (Table 2). This result reveals that beekeepers who use smoke to harvest honey have 96.9% of their hives colonised after harvesting. On the other hand, the hives of beekeepers who use straw are all deserted after harvesting. In total, 50% of the hives of 24.1% of those surveyed are deserted.

Table 2: Causes of hive desertion

			Is half of your hives deserted?	
			Yes	No
Honey harvesting techniques	Water	Frequencies	17	34
		Percentage (%)	33.3	66.7
	Smoker	Frequencies	6	187
		Percentage (%)	3.1	96.9
	Straw	Frequencies	47	0
		Percentage (%)	100	0
Total		Frequencies	70	221
		Percentage (%)	24.1%	75.9%

3.3. Agricultural Practices

3.3.1. General Information on Agricultural Practices

The data gathered during the surveys provided us with information on agricultural practices (Table 3). It shows that 90.7% of beekeepers have agricultural plots within a radius of less than 1 km around their apiaries. On these agricultural plots, the use of herbicides-insecticides (56.2%), herbicides (41.6%) and insecticides (1.5%) was noted. A total of 88.3% of the beekeepers surveyed practice bush burning on their agricultural plots.

Table 3: Agricultural practices

Variables	Parameters	Frequencies	Percentages (%)
Presence of agricultural plots within a 1 km radius of the apiary	Yes No	264 27	90.7 9.3
Pesticides used on agricultural plots	Fungicides Herbicides Herbicides – Insecticides Insecticides	2 114 154 4	0.7 41.6 56.2 1.5
Bush burning on agricultural plots	Yes No	34 257	88.3 11.7

The table 3 shows clearly that agricultural practices such as pesticide use and bush burning on agricultural plots within a 1 km radius of apiaries have a negative impact on bee colonies.

3.3.2. Impact of Agricultural Practices on Bees

The results of the binary regression analysis are shown in Table 4.

Table 4: Binary regression

		B	S.E	Index	Df	Sig	Exp(B)	95% C.I for Exp(B)	
								Lower	Upper
Variables	Agricultural plot	-1.634	0.467	12.242	1	0.000	0.195	0.078	0.487
	Pesticide use	-1.429	0.439	10.608	1	0.001	0.239	0.101	0.566
	Constant	1.342	0.502	7.149	1	0.007	3.826		

B: Constant; S.E: Standard error; Df: Degree of freedom; Sig: Significance; Exp (B): Odds ratio; 95% C.I for Exp (B): Confidence interval.

According to this result, it appears that the presence of beehives in agricultural plots and the use of pesticides on these plots have a significant effect on colony decline, with constants of -1.634 and -1.429 respectively; standard errors of 0.467 and 0.439 and p values of 0.000 and 0.001 (Table 4).

The overall significance of this binary regression model is the Chi2 test with a value of 34.868 and p = 0.000. These values indicate that the presence of agricultural plots around apiaries and the use of pesticides on these plots are associated with bee decline.

This regression model clearly explains that the lack of colonisation of most hives is due to their location around agricultural plots that are treated with plant protection products. Nevertheless, the effect of bush burning on these plots is not negligible, as it has a direct impact on bees.

3.4. Simultaneous Impacts of Beekeeping and Agricultural Practices on Bee Colonies

Table 5 shows the correlation between the non-colonization of 50% of hives and the decline in bee populations. The Pearson correlation coefficient is -0.388 with p = 0.000. This negative value implies an inversely proportional correlation.

Table 5: Correlation between the non-colonization of 50% of hives and the decline in bee populations

Pearson correlation coefficient	Decline in bee populations	Are 50% of your hives colonised?
Decline in bee populations	1	-0.388
Are 50% of your hives colonised?	-0.388	1
p value	0.000	0.000

This negative coefficient clearly shows that the lack of colonisation of hives is due to the decline in bee populations. Thus, effective colonisation could be observed if the hives were moved away from agricultural plots or if there were no decline in bee populations.

Table 6 also shows a positive relationship between bee decline and pesticide use on agricultural plots. The Pearson correlation coefficient is 0.407 with p = 0.000. This positive value indicates a strong relationship between bee decline and pesticide use on agricultural plots. Indeed, the positive Pearson coefficient clearly explains that the decline in bees is partly caused by the presence of agricultural plots around apiaries and the use of pesticides on these plots.

Table 6: Correlation between the decline in bee populations and pesticide use on agricultural plots

Pearson's correlation coefficient	Decline in bee populations	Pesticide use on agricultural plots
Decline in bee populations	1	0.407
Use of pesticides on agricultural plots	0.407	1
p value	0.000	0.000

4. Discussion

4.1 General Information about Beekeepers

The high proportion of males (90.72%) involved in beekeeping activities can be explained by the fact that men are more courageous when it comes to approaching bees and therefore more likely to practice honey gathering (a system of collecting honey in forests), an activity that requires skill and expertise. However, with the modernisation of beekeeping involving the use of hives, women can easily practice it. This result is similar to those of Nombre (2023) and Lamboni (2024) in the central region, which showed a high proportion of men, 97.62% and 95.42% respectively. In contrast, a study in Côte d'Ivoire found a high proportion of women (43.3%) harvesting honey from stingless bees due to the aggressiveness of the *Apis mellifera* bee (Soro et al., 2020). Regarding the level of education, even though beekeeping does not necessarily require intellectual background, beekeepers are educated. The high proportion of beekeepers with less than five years of experience explains why modern beekeeping is a recent development in this region. According to Ouro-Djéri (2012), the modernisation of beekeeping is characterised by the rearing of bees in manufactured hives to produce good honey. The average age of beekeepers in our study is clear evidence that modern beekeeping is in its infancy. This result is similar to that of a previous study, which showed that 35-44 is the most common age group for beekeepers in this region, accounting for 21.55% of the total (Sokemawu, 2016).

Training in beekeeping is very important. In our study area, it is organised by NGOs such as Vétérinaire Sans Frontière Suisse, which works to share its knowledge with beekeepers. However, we have noticed that these training courses focus much more on techniques for setting up hives, colonising them and harvesting honey. This means that beekeeping practices are not mastered. However, training is essential because it promotes better colony management (diseases, parasites and predators) and reduces the dropout rate. This result is comparable to a study that highlights the importance of training in promoting sustainable beekeeping practices, strengthening the resistance of bee colonies to climate change and ensuring colony stability (Kakpi et al., 2023).

4.2. Beekeeping Practices and Their Impact on Bee Colonies

Five (5) types of hives are used. However, it should be noted that Kenyan hives are made of wood and easy to manufacture. They are also very easy to handle, can contain large colonies and therefore produce a large quantity of honey. This explains why they are preferred by beekeepers. This result is similar to the work of Sokemawu (2016), which showed that the proportion of beekeepers using Kenyan hives was high, at 51.43%, because these hives are cheaper than Dadant hives. On the other hand, traditional hives are made from jars or palm tree trunks, which makes them difficult to handle. However, according to Nombre (2023), these hives are less susceptible to wax moth infestation, which is why they are preferred by beekeepers. The period from September to November is more conducive to the colonisation of hives as it corresponds to the flowering period of fruit trees. This result confirms the work of Sokemawu (2016), which showed that cashew, mango, orange and mahogany plantations are very conducive to beekeeping in the central region.

Inappropriate beekeeping practices result in hives not being colonised. Hence the need for beekeepers to master beekeeping practices which, according to Fay (2012), are important for reducing colony desertion. Similarly, other studies affirm that mastering beekeeping practices is one of the key factors in improving the management of bee colonies (Couvillon et al., 2015). Bee desertion, known as Colony Collapse Disorder (CCD), is a phenomenon that poses serious problems for agriculture, beekeeping and the environment in general. Given the crucial importance of bees in the ecosystem, particularly in the central region where populations depend on agriculture for their livelihood, it is important to take measures to reduce their desertion.

4.3. Agricultural Practices and Their Impact on Bees

The presence of agricultural plots within a radius of less than 5 km around apiaries and the use of pesticides on these plots is one of the causes of bee desertion. Bees cannot tolerate the toxic effects of these pesticides and leave the hives. This finding corroborates research carried out in Benin, which highlighted the toxicity of three herbicides used in agriculture on bees (*Apis mellifera*). These are: Roundup containing 360 g/L of glyphosate, Glycel containing 410 g/L of glyphosate and Alligator containing 400 g/L of pendimethalin (Zoclanclounon et al., 2017). Not to mention the work carried out in Ghana, which identified traces of 13 low-dose pesticide residues in honey and wax, even though the beekeepers involved in the study claimed not to have used pesticides around their apiaries (Llorens-Picher et al., 2017). According to Gong and Diao (2017), the negative effects of pesticides on bees can affect crop yields and reduce seed vigour. Bush burning practices coincide with one of the periods of hive colonisation, causing damage such as the destruction of hives and late harvests. They are therefore another cause of non-colonisation of hives. It should be noted that these practices can decimate several colonies while destroying hives. This result is similar to that obtained by Tchoumboue et al. (2001), who identified uncontrolled bush fires as a cause of colony desertion and a constraint on beekeeping.

The use of pesticides on agricultural plots and the fact that they are less than a kilometer away from apiaries would lead to a decline in bee colonies, resulting in the non-colonisation and desertion of hives. This result is similar to that of a previous study that proved that systemic or semi-systemic pesticides used to treat crops, directly contaminate bees. These bees collect the contaminate nutrients (pollen and nectar) and bring them back to the hives, thereby increasing the risk of poisoning the colonies, leading to a reduction in colony size or even their destruction (Dively and Kamel, 2012). This confirms the result of Chauzat et al. (2006), who identified 19 pesticide residues in pollen, and that of Skerl et al. (2009), who identified traces of insecticides and fungicides in bee bread and pollen a few days after these products were applied to apple trees. We cannot forget the recent study carried out in the municipality of Banikoara in Benin, which detected the presence of pesticide residues in honey, identifying 35 active molecules belonging to 16 chemical families, the most prevalent of which are: organophosphates (17.14%), pyrethroids (17.14%), triazoles (14.29%), triazines (11.43%) and neonicotinoids (8.57%) (Kindji and Yehouenou Azéhoun Pazou, 2024).

4.4. Simultaneous Impacts of Beekeeping and Agricultural Practices on Bee Colonies

Correlation analyses in our study showed an inversely proportional relationship between the non-colonization of hives and the decline in bee populations. The negative Pearson coefficient indicates that hive colonization would be effective and complete if the colonies had not declined. However, correlation between this decline in bee populations and pesticide use on agricultural plots shows a strong positive relationship. The correlation analysis also showed that 50% of hives were not colonised because of the decline in bee colonies in the study area. This clearly shows that the decline in colonies is due not only to the lack of mastery of beekeeping practices that favour the action of parasites, diseases and predators, but also to the inappropriate and uncontrolled use of pesticides on agricultural plots near apiaries. Studies have been carried out and the results have shown that the insecticides used to treat varroa mites contain flumethrin, which is highly toxic to both bees and varroa mites (Perez-Santiago et al., 2000). Hence the need to implement sustainable agricultural practices to preserve bees and the environment.

Conclusion

Our work has shed light on the potential impacts of beekeeping and agricultural practices on bee colonies in central Togo. The results showed that beekeepers do not have a good grasp of beekeeping practices, with only 44.67% having undergone training in beekeeping, and even then, this training focused more on techniques for installing hives. Of the five types of hives available, Kenyan hives (53.48%) are the most widely used, and the most favourable period for capturing new bee colonies is September to November. The lack of mastery of beekeeping practices is one of the causes of colony desertion. The cross-tabulation between: 'Are half of your hives deserted?' and harvesting techniques showed that beekeepers who use straw as a harvesting technique have all their hives deserted afterwards. The result of the binary logistic regression explains that the decline in colonies is due to the presence of agricultural plots around hives and the use of pesticides on these plots. Pearson's correlation analyses show that the non-colonisation of hives is due to the decline in bee colonies, which is in turn caused by the use of pesticides on agricultural plots around apiaries.

These results highlight the importance of training beekeepers on the health and management of their colonies, and the need to promote good agricultural and beekeeping practices that respect the ecosystem.

Future research could focus on analysing honey and wax from this region to ensure that they do not contain pesticide residues. Training beekeepers in good beekeeping and agricultural practices to develop sustainable and effective conservation strategies, while promoting sustainable beekeeping and agriculture in central region of Togo.

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