

Social drivers of colony collapse disorder in Benin's beekeeping, West Africa

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Abstract. Amakpe F, Sinsin B. 2025. Social drivers of colony collapse disorder in Benin's beekeeping, West Africa. *Asian J Agric* 9: 391-401. The colony collapse disorder is a worldwide factor of the honeybee population decline. In the tropical African regions, recurrent bushfires, uncontrolled agricultural pesticide, unproper beekeeping system, pests, and diseases are contributing factors that worsen the colony collapse disorder in contrary to western beekeeping, where the phenomenon is better controlled. In addition to these environmental and managerial drivers, the beekeeping potential in Benin is handicapped by the countrywide massive destruction of honeybee colonies by unknown individuals. We assessed the impacts of this phenomenon, termed in this study the social colony collapse disorder, through surveys and group discussions on 96 apiaries, distributed in the entire country from January 2023 to January 2024. The investigations targeted apiaries bearing at least five honeybee colonies, and the respondents were the apiary owners. 31.4% of the country's honeybee colonies and 72.9% of apiaries were impacted. 7.3 ± 7.1 colonies were lost per apiary from January 2023 to January 2024. 99% of the impacts occurred during the honey season (October to May), and the honeybee colony thieves mainly operated at night. The departments of Zou (78.4% of its colonies), Collines (60.3%), and Donga (40.8%) were the most impacted, and experimental apiaries were not spared. It is a neglected key factor that discourages beekeepers and hinders beekeeping mainstreaming for poverty alleviation in Benin, where no operational mitigation approach is effective to date. Reinforcing the local mitigation attempts and improving the beekeeping legal framework will help reduce the attacks. This will require deeper investigations for elaborating the case-by-case eradication approaches per beekeeping region in Benin and for elaborating a regional synergetic mitigation action plan in the entire West Africa.

Keywords: Apiculture, colony collapse disorder, livelihood, pollination, poverty alleviation, West Africa

Abbreviations: ECOWAS: Economic Community of West African States, GPS: Global Positioning System, SCCD: Social colony collapse disorder

INTRODUCTION

The honeybees are universal pollinators that also improve crop quality and yields (Spivak et al. 2011; Hung et al. 2018). Numerous initiatives are therefore developed worldwide to sustain their services and curb pollinator decline through beekeeping. But the synergetic impacts of climate change, diseases, and anthropic actions are challenging the honeybee population worldwide (Zhao et al. 2022; Agathokleous et al. 2024). One key factor that jeopardizes the honeybee population is the colony collapse disorder (CCD), a decimation of the honeybee colonies in many parts of the world (Roy et al. 2018; Mohammadian et al. 2024). In European and American beekeeping, it was influenced by the queen's weakness, colony malnutrition, and acaricides, which led to pests' attacks and the dramatic loss of workers (VanEngelsdorp et al. 2009; Mohammadian et al. 2024). It is nowadays a leading challenge in the tropical and the Mediterranean African regions, where the phenomenon is worsening in contrast to the rest of the world (Brhich 2025). In fact, in most tropical African regions, recurrent bushfires that affect the flora in the dry season and kill many foraging workers make up great potential CCD factors in addition to uncontrolled agricultural

pesticide uses, wax moths, and small hive beetle invasion (Hailu et al. 2024; Mohammadian et al. 2024).

In addition to these environmental and well-documented anthropic factors that affect beekeeping worldwide, the entire Republic of Benin is facing the vandalism of honeybee colonies by unidentified individuals who mainly operate at night (Amakpe et al. 2023). This societal factor, termed in this study the Social Colony Collapse Disorder (SCCD), was registered since 2008 as a key beekeeping challenge from Nigeria to Togo, with no effective mitigation action (Ahouandjinou et al. 2016; Kugonza 2020; Hailu et al. 2024). In opposition to the CCD, it is committed by honeybee colony thieves who secretly vandalize apiaries in West African beekeeping. Though it is ignored by the international beekeeping community, which is more concerned about pollution, honeybee enemies, climate change, and land use impacts on the honeybees, it constitutes a major limit to many beekeeping initiatives in Benin. The phenomenon is all the more acute in Benin, where the Ministry in Charge of Agriculture and Husbandry, and the Ministry in charge of Forests and Natural Resources have targeted combating it in cooperation with the national beekeepers' association through many pleas in the media. A better understanding of this phenomenon, the socio-economic and ecological

determining factors, and the cartography of the involved actors is then required for a sustainable apiculture in Benin and the entire West Africa.

The country is characterized by a south-north ecological gradient, which also determines many socio-economic factors such as the agro-ecological region distribution, transhumant itinerary, and beekeeping regions (Azalou et al. 2019; Sinadouwirou 2023). We then assumed that such social and ecologic factors may influence the SCCD status in the different administrative and agro-ecological regions. We set out to determine if the diversity in the melliferous regions and the south-north ecological gradient in Benin influence the acuity of SCCD during the three main honey seasons. Using social surveys and apiary visits, we (i) assessed the number of vandalized honeybee colonies per melliferous region and (ii) analyzed the acuity of the phenomenon during the heart of the dry season (February to May 2023), the full rain season (Jun to August 2023) and the beginning of the dry season (October 2023 to January 2024).

In this research, an apiary is a site that bears a set of honeybee hives belonging to a beekeeper. A hive is any material a beekeeper establishes for keeping a honeybee colony. The colony is a group of honeybees made up of a laying queen, workers, and drones established in a hive at an apiary. A hive that bears a colony is also called a colony. Due to desertion or colonies' death at the apiary, a hive may host different colonies throughout the year.

MATERIALS AND METHODS

Study area

The investigations covered the entire Republic of Benin. It is a West African country that shares borders with the Republic of Burkina-Faso and Niger in the north, the Federal Republic of Nigeria in the East, and the Republic of Togo in the West. The country benefits from three main climatic areas with a high South-North and West-East gradients in which the south is cooler and more humid than the north, while the Eastern parts are more humid and cooler than the Western region (Adomou et al. 2006).

Based on the distribution of the melliferous flora, Amakpe et al. (2015) found six silvo-melliferous regions, which are grouped in three main melliferous areas. The south melliferous regions, which stretch from the coast to the south Soudano-guinean zone, are dominated by small-sized bees of *scutellata* and *iberiensis* genotypes. The melliferous flora in these regions is particularly poor, dominated by pollen-producing plants such as *Gmelina arborea* and *Elaeis guineensis*. Till the south of the department of Alibori, the central parts of Atacora, and the southern parts of Borgou stand the central melliferous regions. In this transition zone, *iberiensis*, *scutellata*, and *adansonii* genotypes coexist. The melliferous flora of these regions is well diversified, dominated by *Pterocarpus erinaceus*, *Terminalia leiocarpa*, *Anacardium occidentale*, and *Citrus* sp. orchards. Above the central regions, stand the north melliferous regions where *adansonii* genotypes dominate the bee population. The pest pressure in this

region is particularly low, limited to predators and the small hive beetle, *Aethina tumida* (Amakpe 2016).

The colony collapse disorder is almost ignored in the country where most references are targeted on the beekeeping system description, the involved actors, the melliferous flora, and hive products (Kenali et al. 2018; Amakpe et al. 2023). In the same line, the social colony collapse disorder issues are limited to registered or cited complains from victimised beekeepers, their associations, and students (Ahouandjinou et al. 2016; Amakpe et al. 2023; Kakpi et al. 2024; Kindji et al. 2025).

Studied apiaries and data collection

Beekeeping in the country is dominated by small-scale beekeepers, keeping five to ten Kenian top-bar or traditional hives. But since 2010, the number of business beekeepers with more than 40 Kenian Top bar or frame hives has been increasing in the central parts. The colonies are mainly obtained from natural swarms directly captured in baited hives, and artificial queen rearing is rare (Kakpi et al. 2024).

The investigated apiaries were selected from a database of established apiaries from 2008 to 2016 by local NGOs and partners that support beekeeping in Benin. The database available at the two most relevant support NGOs indicated more than 500 beekeepers in Benin. But geographic data and communication addresses were available on less than 150 apiaries, from which we discarded non-responding beekeepers, apiaries with no live colony in January 2023. A total of 96 apiaries (Figure 1) that were at least six years old and bore at least five honeybee colonies in January 2023 were considered (Amakpe 2016). They were contacted and their apiary was visited in June 2023, October 2023, and February 2024 using the provided addresses and geographic GPS coordinates for collecting the occurred SCCD and information on the adopted management approaches.

Once the apiary was identified in the fields, the geographic coordinates (X, Y) of the strongest hive were recorded again using a Garmin brand GPS. The year of first registered SCCD, the number of registered affected colonies, and the number of colonies that recovered after the attacks at each season were collected from the apiary owner using a standardized questionnaire. The different mitigation strategies and any relevant socio-economic factors that may impact the phenomenon were analyzed later in focus group discussions with beekeepers, herders, and relevant stakeholders in each region. The focus group discussions were conducted by the rapid rural appraisal methods of Gueye (1990) according to the adaptations of Bacque et al. (2024) and Olivier et al. (2024). Briefly, representatives of the involved stakeholders, such as beekeepers, hunters, herders, hive product sellers, and farmers, were invited to a meeting to analyze the phenomenon and mitigation actions. Table 1 summarizes the distribution of the investigated apiaries per region and the cities where the group discussions occurred.

The investigations covered 12 months, from 1 February 2023 to 31 January 2024. The data were collected in three

rounds at the end of each season, with the same actors and the same apiaries.

1 February to 31 May 2023: This is the heart of the honey season in Benin (Abiola et al. 2005). The data of this season were collected during June 2023.

1 June to 30 September 2023: This covers the full rainy season with poor honey production in the entire country. The data from this season were collected during October 2023.

1 October 2023 to 31 January 2024: Corresponding to the beginning of the honey season. The data of this period were collected during February 2024.

Regarding the ethics, theft issues are of great juridical concern in Benin. Therefore, the free prior consent of each beekeeper was first obtained before recording information

on their SCCD experience. No personal data was recorded, and the indications on the thieves were kept anonymous in accordance with the involved actors. The group discussion and questionnaire were conducted in local languages by experienced and familiar extension workers in the community. The collected data from the beekeepers and focus group discussion were confronted with the systematic field visits to each apiary, the testimonies from non-beekeepers in the same village, and information from the database and field reports of the support NGOs. Some beekeepers have also complained at the police station after they were stolen, and the official declaration papers from the police officer were also valued in the triangularization process.

Table 1. Distribution of the investigated apiaries per honey region and group discussion cities

Department	City of group discussion	Number of investigated apiaries			
		North honey region	Central honey region	South honey region	Total
Alibori	Kandi, Banikoara, Gogounou	22 (1 experimental apiary)	0	0	22
Atacora	Natitingou, Toukountouna, Boukoumbe	1	7	0	8
Atlantique and Littoral	Djidja	0	0	3	3
Borgou	N'dali, Parakou, Tchaourou	2	18 (1 experimental apiary)	0	20
Collines	Kokoro, Savalou	0	17 (1 woman beekeeper)	0	17
Donga	Bassila, Djougou	0	14	0	14
Mono	Lokossa	0	0	3	3
Plateau	Ketou	0	2	0	2
Zou	Djidja	0	7 (1 experimental apiary)	0	7

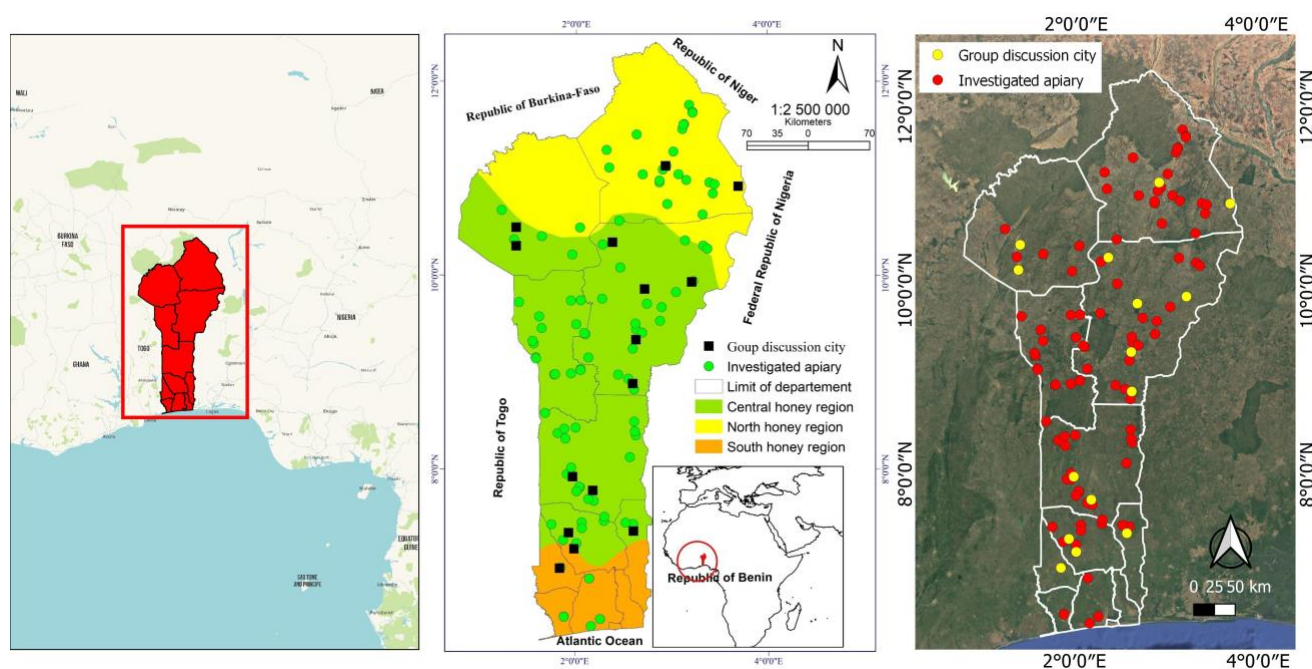


Figure 1. Geographic position of the investigated apiaries in Benin

Data analysis

The data on each apiary were built in a database and were analyzed by StatistiXL, an AddIn of Excel (Microsoft Office). The sites were first submitted to the analysis of variance based on the different departments, the melliferous regions, and seasons in order to determine the ones that best explained the susceptibility of an apiary to be impacted.

The geographic analysis of the phenomenon was done by projecting in the country Shape file, the Geographic coordinates of the apiaries using ArcMap software. This helped evaluate any geographic correlation to the different metadata on the apiary status. The south-north gradient was analyzed by the simple correlation between the total impacted colonies per apiary and the Universe Transverse Mercator (UTM) Values of the longitude of each apiary. The temporal dynamic of the phenomenon was analyzed by the first year it was reported at each apiary. The descriptive statistics analyses were done to determine the average number of vandalized colonies and their respective relative percentage at the apiary, honey region, and national levels. For the analysis of variance and correlation, a P value of 5% or lower was accepted as statistically significant.

The impacts on the country's beekeeping were analyzed by the proportions of the impacted apiaries (PIA) and impacted colonies (PIC) at the apiary per region or period, as indicated by equations (1) and (2).

$$PIA = 100 \times \frac{NIA}{TA} \quad (1)$$

$$PIC = 100 \times \frac{NIC}{TC} \quad (2)$$

Where:

PIA: proportion of impacted apiaries in the considered region or period;

NIA: Number of apiaries that registered at least one pillaged colony;

TA: total number of registered apiaries in January 2023 in the region or the period;

PIC: proportion of impacted colonies in the considered region or period;

TC: total number of colonies that were recorded in January 2023 in the region or period.

RESULTS AND DISCUSSION

The social colony collapse disorder as a key driver of CCD in Benin

As described by the victims, the social colony collapse disorder (SCCD) is a massive vandalism of honeybee colonies by people who decimate the bees by fire or pesticides. They take away any top bar or frame that bears comb, leaving behind a hive full of dead bees, firewood debris, and ashes. Figure 2 presents images from a vandalized experimental apiary located in the department of Zou after the offense in March 2023. The honeycombs are hand-squeezed at a hidden place where the brood combs are abandoned. The stolen honey may be sold in improper packages, such as pesticide or used beverage

bottles, at roadsides far away from the place where the offense was committed.

The honeybee colony thieves usually operate late at night, making them difficult to detect. In fact, only two apiaries (2.1% of the total impacted apiaries) in the department of Collines were looted during the day. 8.57% of affected colonies recovered, with very weak colonies that finally perished in the following days. As very few colonies recovered after the attack, most were vandalized only once, except in the Zou department, where 5.7% of colonies were looted twice.

At the country level, 70 apiaries out of the 96 investigated (a prevalence of 72.9%) were looted at least once from February 2023 to January 2024. The phenomenon impacted 700 out of the total of 2231 registered colonies in January 2023 when the study started, making an acuity of 31.4% of the national vandalized honeybee colonies in one year. Regarding the frequency, apiaries were impacted 1.5 ± 0.9 times during the year, and 7.29 ± 7.12 colonies were impacted per apiary.

Concerning the thieves, only one was arrested in the department of Zou in 2018. With this case, and despite it was statistically difficult and irrelevant to make a categorization of the honeybee colony thieves, most victims and stakeholders argued during the focus group discussion that the offenders were linked to young pastoralists and hunters who operate at night.

No socio-professional group was spared in the country. In fact, many sedentary herders and agro-pastoralists declared that their apiaries were usually vandalized. Elderly, young, disable people and women beekeepers were also impacted. The phenomenon is then a nationwide beekeeping challenge in Benin, in addition to the numerous documented environmental and managerial limits.

Determinant factors of the social colony collapse disorder in Benin

The multivariate variance analyses showed that the total lost colonies and the surviving colonies were significantly different between the different honey seasons and the regions ($F=2.136$; $Df=50$; $P=0.000$). The parameters that best discriminated the regions and apiaries were the total number of active colonies during the honey seasons, the number of pillaged colonies from October to February, and the number of impacted colonies from February to May ($F=3.834$; $Df=5$; $P=0.001$). The number of impacted colonies in the rain season and the number of surviving colonies poorly explained the difference between the regions and the apiaries.

The correlation analysis (Figure 3) indicated that the apiaries that were impacted from October to February were also likely to be pillaged from February to May ($R=0.5$ and $P=0.000$), while those vandalized from February to May were more susceptible to being looted from June to September ($R=0.35$, $P=0.001$). The bigger the apiary was, the more colonies it lost from February to May ($R=0.5$ and $P=0.000$). Therefore, big apiaries located in the central honey regions were the most impacted during the honey season.



Figure 2. Images from a vandalized experimental apiary in the central part of Benin. A. Vandalized Kenyan top bar hive, B. Vandalized frame hive, C. Hand-squeezed honeycombs, far away from the looted apiary, D. Abandoned broods and empty combs after the honeycombs were hand-squeezed

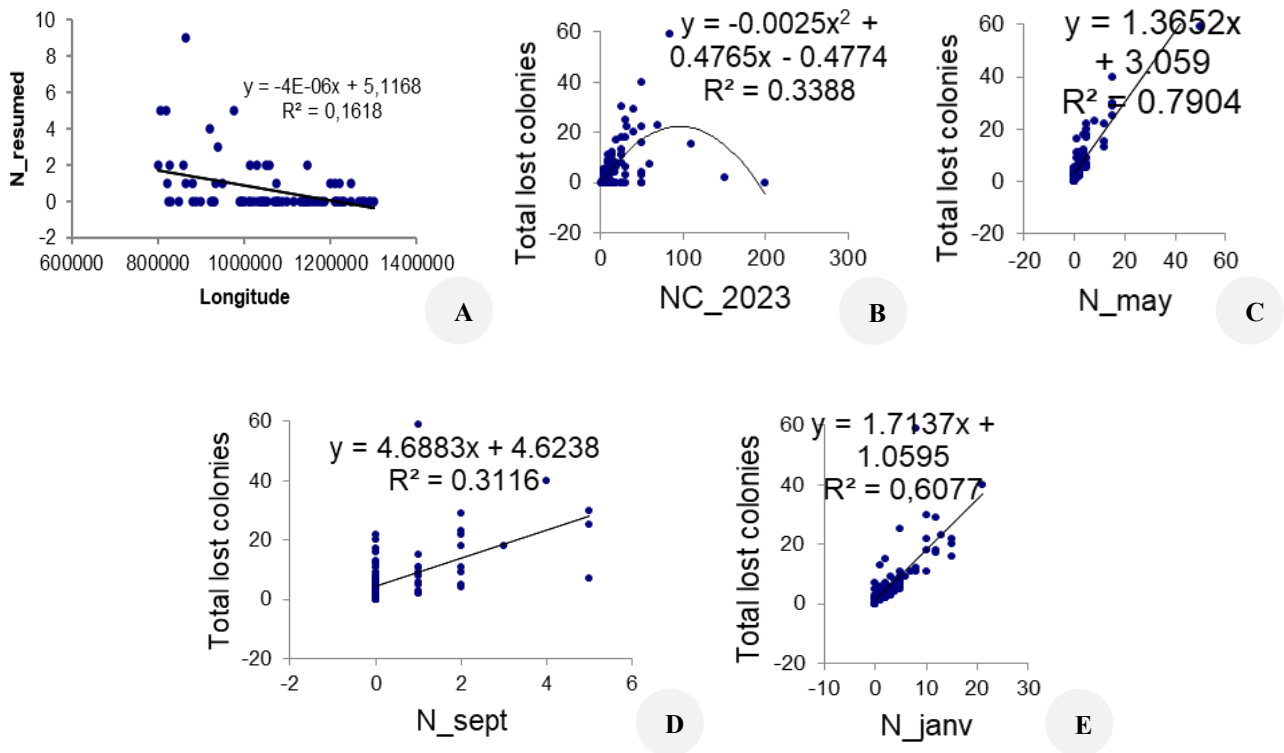


Figure 3. Correlation analysis of A. The total number of vandalised colonies, B. The number of recovered colonies, and C-E. The number of colonies at the beginning of the season. Note: N_resumed: Number of colonies that recovered after the attack, Cord_Y: Log of the UTM WGS84 Value of the hive longitude, NC_2023: total number of colonies at the apiary in 2023, N_may: Number of lost colonies from January to May, N_sept: Number of lost colonies from June to September, N_janv: Number of lost colonies from October to January

The global polynomial trendline of the correlation function between the total number of colonies at the apiaries and the number of vandalized colonies (Figure 3) showed that above a hive number, the apiary was less impacted ($R=0.6, P=0.000$). This was particularly the case in the departments of Collines and Borgou, where big apiary owners often set additional guards to prevent attacks.

Regarding the surviving colonies, the ones that were affected during the full rain season were likely to recover after the attack. Such survival was negatively correlated to the South-north gradient ($R=0.4; P=0.00$) in which the northern impacted colonies survived less than the ones located in the south.

Temporal dynamics of the social colony collapse disorder in Benin

The first affected apiaries were recorded in the department of Zou in 2008, followed by a constant number of new vandalized apiaries till 2018 (Figure 4). From 2018, a decline was registered in this department, showing that the most vulnerable apiaries had been looted (Figures 4 and 5). It seemed confined in this department until 2014, with 28.6% of new vandalized apiaries and a progressive spread to other regions. 17.6% of apiaries in the department of Collines registered their first experience from 2015, followed by 47.1% in the department of Borgou, and a spread to the entire north regions from 2017, where $6.0 \pm 7\%$ apiaries register their first attack. The most recent departments of occurrence were Atacora in 2020, with seven apiaries (37.5%), and the department of Plateau in 2021. From 2021, there was a general decline in new occurrences except in the department of Plateau.

The seasonality of the phenomenon (Figures 4 and 5) showed that most apiaries (99%) were impacted during the honey season in Benin (October to May). The central honey region was most impacted from February to May, when 47.7% of the annual total impacted colonies in the region occurred, while the north honey region was affected from October to January (77.8%). The full rain season starting from June to September, corresponding to the poor honey season, was less impacted, except in the department of Plateau, where 50% of the apiaries lost 70.7% of their colonies. Table 1 summarizes the registered impacted colonies and apiaries in the different regions and departments of the country.

Spatialization of the social colony collapse disorder in Benin

The geographic distribution of the impacted apiaries (Figure 5) showed that the central region was the most challenged, with 65.7% of lost colonies in 78.6% apiaries. The remaining 21.4% of impacted apiaries were located in the north region, where 12.3% of the colonies were vandalized. No honeybee colony theft was reported in the southern poor honey region, where beekeeping was limited to rare apiaries placed close to the owner's properties. As far as the departmental distribution was concerned, the most challenged departments were Borgou (PIA=28.0%; PIC=22.924.0%), Collines (PIA=60.3%; PIC=16.0%), Donga (PIA=40.8%, PIC=20.118.8% Alibori (PIA=10.17%; PIC=9.5%), and Zou (PIA=78.4%; PIC=5.0%). The departments of Atacora (5.7%) and Plateau (2.9%) were less impacted, as indicated in Table 2.

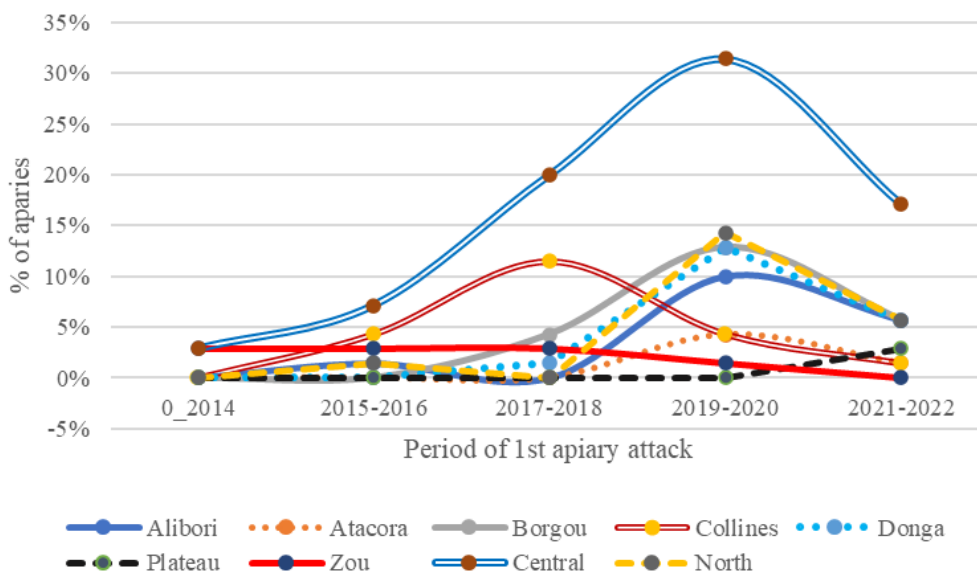


Figure 4. First time registered SCCD in the different departments and regions of Benin

Table 2. Social colony collapse disorder in the different administrative departments and beekeeping regions in Benin

Area	Parameters	Ist_year	N_Co_2023	N_Co_May	N_Co_Sept	N_Co_Jan	N_Co_re	Tot_co	%_A_Co_2023	%_bj_Co	%_bj_Co_2023	N_api_May	N_api_sept	N_api_jan	Critic season
Donga	Tot	2018	402	113	14	37	4	164	40.8	23.4	7.4	14	6	12	October to May
	Avg		28.7	8.1	1.0	2.6	0.3	11.7	57.6	1.7	0.5	1.0	0.4	0.9	
	Std		33.3	12.9	1.8	2.2	0.7	14.9	30.6	2.1	0.7	0.0	0.5	0.4	
	%		18.0	68.9	8.5	22.6	2.4	40.8	40.8	23.4	7.4	100	42.9	85.7	
Atacora	Tot	2020	114	5	0	8	2	13	11.4	1.9	0.6	1	0	4	October to January
	Avg		14.3	0.6	0.0	1.0	0.3	1.6	14.2	0.2	0.1	0.1	0.0	0.5	
	Std		6.4	1.8	0.0	1.2	0.7	2.4	17.7	0.3	0.1	0.4	0.0	0.5	
	%		5.1	38.5	0.0	61.5	15.4	11.4	11.4	1.9	0.6	25.0	0.0	100	
Zou	Tot	2014	111	48	9	30	15	87	78.4	12.4	3.9	7	4	4	October to May
	Avg		15.9	6.9	1.3	4.3	2.1	12.4	72.8	1.8	0.6	1.0	0.6	0.6	
	Std		12.7	5.7	1.8	5.0	2.1	12.0	33.1	1.7	0.5	0.0	0.5	0.5	
	%		5.0	55.2	10.3	34.5	17.2	78.4	78.4	12.4	3.9	100	57.1	57.1	
Collines	Tot	2015	358	92	16	108	24	216	60.3	30.9	9.7	14	8	14	The year-long
	Avg		21.1	5.4	0.9	6.4	1.4	12.7	50.9	1.8	0.6	0.8	0.5	0.8	
	Std		21.6	9.8	1.2	6.9	2.3	16.8	30.6	2.4	0.8	0.4	0.5	0.4	
	%		16.0	42.6	7.4	50.0	11.1	60.3	60.3	30.9	9.7	93.3	53.3	93.3	
Borgou	Tot	2018	536	35	9	106	10	150	28.0	21.4	6.7	14	5	16	The year-long
	Avg		26.8	1.8	0.5	5.3	0.5	7.5	36.6	1.1	0.3	0.7	0.3	0.8	
	Std		33.8	2.1	0.8	4.9	1.2	7.2	27.1	1.0	0.3	0.5	0.4	0.4	
	%		24.0	23.3	6.0	70.7	6.7	28.0	28.0	21.4	6.7	87.5	31.3	100	
Alibori	Tot	2015	659	15	3	49	4	67	10.2	9.6	3.0	6	2	12	October to May
	Avg		30.0	0.7	0.1	2.2	0.2	3.0	16.4	0.4	0.1	0.3	0.1	0.5	
	Std		41.5	1.5	0.5	3.9	0.4	5.3	22.1	0.8	0.2	0.5	0.3	0.5	
	%		29.5	22.4	4.5	73.1	6.0	10.2	10.2	9.6	3.0	50.0	16.7	100	
Plateau	Tot	2021	15	0	0	3	1	3	40.0	0.4	0.1	0	0	2	October to January
	Avg		7.5	0	0	1.5	0.5	1.5	20.0	0.2	0.1	0	0	1	
	Std		3.5	0.0	0.0	0.7	0.7	0.7	0.0	0.1	0.0	0.0	0.0	0.0	
	%		0.7	0.0	0.0	100	33.3	20.0	20.0	0.4	0.1	0.0	0.0	100	
South region	Tot	2021	36	0	0	0	0	0	0.0	0.0	0.0	0	0	0	The year-long
	Avg		6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Std		3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	%		1.6	-	-	-	-	0.0	0.0	0.0	0.0	-	-	-	
Central region	Tot	2008	1466	291	48	271	56	610	41.6	87.1	27.3	48	23	49	October to May
	Avg		22.6	4.5	0.7	4.2	0.9	9.4	45.6	1.3	0.4	0.7	0.4	0.8	
	Std		26.8	8.4	1.3	4.9	1.7	12.6	32.6	1.8	0.6	0.4	0.5	0.4	
	%		65.7	47.7	7.9	44.4	9.2	41.6	41.6	87.1	27.3	87.3	41.8	89.1	
North region	Tot	2020	729	17	3	70	4	90	12.3	12.9	4.0	8	2	15	October to May
	Avg		29.2	0.7	0.1	2.8	0.2	3.6	18.5	0.5	0.2	0.3	0.1	0.6	
	Std		39.5	1.4	0.4	4.5	0.4	5.6	21.5	0.8	0.3	0.5	0.3	0.5	
	%		32.7	18.9	3.3	77.8	4.4	12.3	12.3	12.9	4.0	53.3	13.3	100	
Benin (national)	Tot	2008	2231	308	51	341	60	700	31.4	100	31.4	56	25	64	October to May
	Avg		23.2	3.2	0.5	3.6	0.6	7.3	35.7	1.0	0.3	0.6	0.3	0.7	
	Std		18.4	3.7	0.8	3.5	0.9	7.1	27.0	1.0	0.3	48.6	38.5	44.4	
	%		100	44.0	7.3	48.7	8.6	31.4	31.4	100	31.4	80.0	35.7	91.4	

Note: Ist_year: first year of occurrence. N_Co: Number of vandalised colonies. Jan: From October 2023 to January 2024. May: from February to May 2024. Sept: from June to September 2024. N_Co_re: Number of vandalised colonies that resumed. Tot_co: total number of vandalised colonies. %_A_Co: % of lost colonies at the apiary. %_bj_Co: % of lost colony in Benin. N_apiary: Number of impacted apiaries. Tot: Total. Avg: average. Std: Standard error

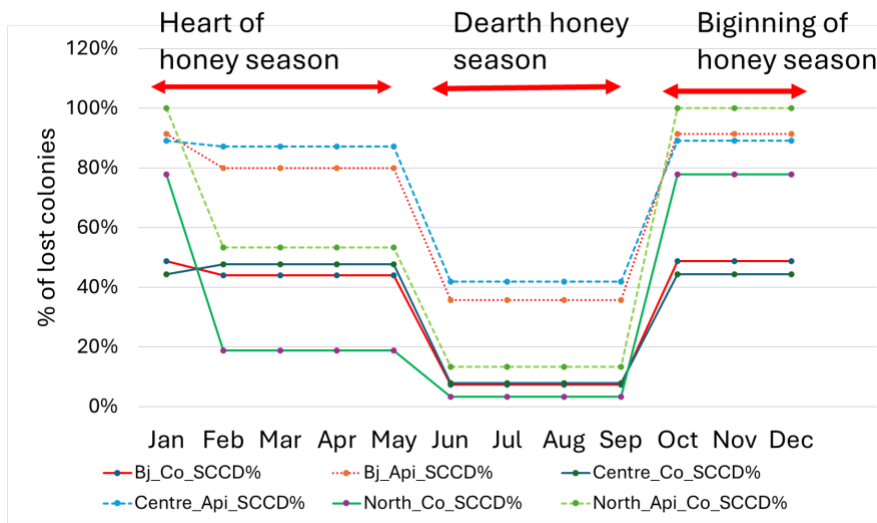


Figure 5. Seasonal dynamics of the social colony collapse disorder per honey region. Note: Bj: Benin (national level). Co: colony. Api: Apiary. Co_SCCD%: percentage of lost colonies. Api_SCCD%: percentage of impacted Apiaries; Centre: central honey region; North: north honey region

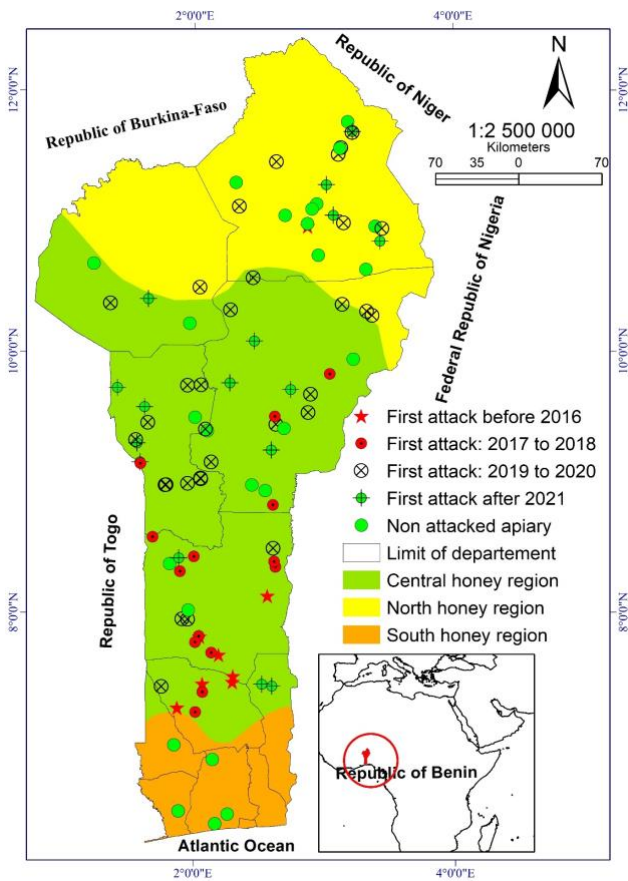


Figure 6. Spatial dynamics of the social colony collapse disorder in Benin

The spatiotemporal distribution of the impacted apiaries revealed four apiary theft regions in Benin (Figure 6).

The south free region: This overlaid the south poor honey region, including the departments of Mono, Littoral, Atlantic, Oueme, south Plateau, and south Couffo, where the phenomenon is absent till now. It bore 1.6% of the national investigated colonies in 2023.

The origin and establishment region: This covered the central parts of the country, including the departments of Zou and Collines, which registered the most impacted apiaries. This region bore 21.0% of the country's total colonies and 22.9% of the investigated apiaries. Most apiaries in this region, including experimental colonies, had been impacted at least once.

The central extension region: It included the departments of Donga, south of Borgou, and Atacora, which registered the most impacted apiaries. These regions bore 42.8% of the country's total colonies in 60.4% of the investigated apiaries in 2023.

The north extension region: including the departments of Alibori and north Atacora, bearing 34.6% of the country's colonies in 16.7% of apiaries. These regions are home to many traditional hives that are difficult to open by inexperienced people to open and were less impacted.

Discussion

Impacts on biodiversity conservation and beekeeping development in Benin

The Colony collapse disorder (CCD) is created by complex environmental and managerial factors that weaken the colony (Lee et al. 2015; Moritz and Erler 2016; Singh and Rana 2025). Our investigations revealed that the social colony collapse disorder was characterized by the active destruction of the colony by people who used prohibited methods. With a maximum of only 22.5% of collapsed colonies in Western countries, the CCD was considered a catastrophe to the worldwide honeybee populations (Johnson et al. 2023). On the other hand, the social colony collapse disorder impacted more than 31% of the honeybee colonies

in Benin in 2023 alone, and many apiaries were totally destroyed. As our investigations focused on apiaries of at least six years old, the situation may be worse than described. It is established in the entire country (Figure 6) and was also reported in Nigeria and Togo, where it is silently destroying many apiaries with no realistic mitigation action to date (Ahouandjinou et al. 2016; Kugonza 2020; Hailu et al. 2024). Broods and empty combs, the honeybee colony thieves abandoned on the floor, are contributing factors to the establishment and spread of predators, opportunist parasites, and fungal diseases that will scale up the CCD in the country (Kugonza 2020; Insolia et al. 2022; Robi et al. 2024). It is then a serious neglected challenge that will undermine the entire West Africa beekeeping and pollinator services.

In addition to these ecological impacts, the phenomenon had transformed beekeeping in Benin into a financially risky activity that is not worth investing in. As found by Mounirou (2015) and Ampadu-Ameyaw et al. (2017), the adoption of agricultural innovation is mainly governed by the direct financial and social profits the innovator gains from it. But the massive colony theft in Benin during the honey season jeopardizes the financial profitability of the activity. Many victims then abandoned their apiary, leading to a vicious beekeeping environment where the colony thieves freely compromise the household economy and livelihoods.

The spatial diffusion of the colony vandalism indicated that regions and seasons that were less impacted were those that shelter very few transhumant or poachers. In addition to the absence of the suspected honeybee colony thieves in the south, where most agriculturists and herders are sedentary people (Djenontin et al. 2012; Azalou 2019), these regions are located in poor beekeeping areas where apiaries rarely exceed 5 hives that are well secured. In the central parts, which were the most impacted, herd accompanying guys and poachers are suspected to profit from the forbidden night pasture and hunting to commit their offence (Kagone et al. 2006; Lesse 2016). The lower acuity of the phenomenon in the northwestern part of the country was mainly due to the fact that many hives in these areas are traditional types in jars, and tree trunks that the beekeepers place high in trees (Paraizo et al. 2012; Ahouandjinou et al. 2016). Such hives were more difficult to open than the widespread Kenyan Top bar or frame hives in the other regions of the country.

Beekeeping development requires deeper investigations on the native honeybee's aggressivity, hive product yields, genetic diversity, and resistance to diseases that determine their performance and socio-economic acceptability (Alemu et al. 2014). Unfortunately, experimental apiaries were also impacted, and many beekeeping research projects in Benin prematurely ended without any output. SCCD is then a leading cause that will limit scientific information available on the native bees in Benin and West Africa.

The collected honey from the social colony collapse disorder is of poor quality, extracted, and kept in very poor hygienic conditions. As it is also sold in pesticide bottles or prohibited packages that the honeybee colony thieves may collect from bins, it is therefore a great health issue that

may potentially poison and spread infectious diseases (Codex Alimentarius 1981; OIE 2015). In the collection chain, it may also contaminate the honey stock of wholesalers with pesticide residues, lead, and other heavy metals that are not accepted at the international markets (Hamilton et al. 2004; Reybroeck 2014). It is then a complex societal phenomenon that will jeopardize the whole national and regional beekeeping system. Urgent mitigation strategies in cooperation with the beekeepers, the local authorities, and the entire community are required for sustainable beekeeping.

Involved actors and mitigation approach

The colony collapse disorder mitigation includes global actions on pesticides, diseases and pests, pollution, landscape management, and friendly beekeeping systems, which are complicated in the global climate change context (Van Engelsdorp et al. 2009; Agathokleous et al. 2024; Singh and Rana 2025). The SCCD, which implies specific actors of the same territory, could then be easier to control if well-elaborated local and national strategies are developed in cooperation with the involved actors. The first mitigation approach may be preventive, focusing on the control of the prohibited associated activities. In this regard, the national laws N° 93-009 of 2 July 1993 on forest management, N°. 2002-16 on wildlife and N°2018-20 of 23 April 2019 on husbandry prohibited night pastoralism and night hunting activity in the Republic of Benin (Azalou 2021). The application of these regulations is essential for limiting the drivers of the SCCD. But, till now, no operational system targeting beekeeping is set to ensure this regulation is respected.

The focus group discussions revealed that the beekeepers are the direct victims. They invest in better protection, follow-up, and recruit guards to protect their apiary. But these precautions constitute additional huge production costs that are the main reason why vulnerable groups such as elders and women abandon beekeeping to improve their livelihoods in Benin (Andrianarison 2024). Others tried to lock the hives using padlocks; unfortunately, these special hives were regularly broken at night, and till now, the phenomenon is a real unsolved challenge to the entire beekeeping sector in Benin (Kakpi et al. 2024; Kindji et al. 2025). The most suspected social category was the herd guards. As such, the agro-pastoralist and herd owners should contribute to sensitizing their workers. The entire community should also cooperate to denounce and arrest the thieves. But the general solidarity in the country rarely allows people to denounce their relatives, whatever offense they may commit (Azalou 2021).

In addition to these preventive follow-up approaches, many beekeepers' associations established internal social rules for honey marketing in which only registered beekeepers are allowed to sell hive products. With these social rules, it would be difficult for the thieves to sell the stolen products. But the challenge to this approach, which fully benefits from the support of the local authorities and agro-pastoralists, is anchored in the entire national economic system in Benin. In fact, the informal sector represents more than 60% of the national Gross Domestic Product and

occupies more than 80% of the rural community (Igue 2019). Honey from authorized beekeepers and stolen hive products may be sold at the same informal market without any distinction.

In conclusion, the worldwide honeybee population decline due to colony collapse disorder is a great threat to agriculture, the economy, food security, and biodiversity conservation. Our investigations highlighted that the colony collapse disorder is worsened in the West African regions, and particularly in Benin, by the widespread social colony collapse disorder that discourages beekeepers and compromises the primary pollination function of the honeybees. This phenomenon is a neglected key limiting factor to sustainable beekeeping and biodiversity conservation. Mitigation actions for the worldwide colony collapse disorder should therefore fully integrate technical and socio-cultural responses to this driver. In addition to the poorly effective mitigation actions the victims had tried, reinforcing the national strategies to combat night pastoralism and night hunting is key to master and reduce the triggers of the phenomenon. Mitigation approaches should also focus on a clear national regulation on hive products marketing and the adoption of standardized honey packaging and labelling per beekeeping zone to help distinguish stolen honey from that produced by registered beekeepers.

The investigation focused on the occurrence of the SCCD in apiaries of six-year-old and older bearing at least five colonies. This approach potentially underestimated the phenomenon in small-sized and younger apiaries. Following apiaries for a longer time will also help evaluate the socio-economic and ecological impacts of this neglected apiculture challenge. Deepening the investigations on particular regions or specific apiaries will bring deeper insight into the causes and social determinants for designing effective case-by-case mitigation actions. As the Republic of Benin shares borders with other West African countries, these investigations opened a prospect to assess the SCCD issues in Nigeria, Togo, Burkina-Faso, and Niger, and the entire ECOWAS countries for synergetic regional mitigation actions.

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