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Perception and mechanisms for managing complaints and conflicts arising from the contamination of soil and crops by pesticides in the cotton zone of North-West Benin

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Abstract

To analyze the farmers' perceptions of the existence of conflicts, their management mechanisms, and common human diseases linked to the pesticide uses, 200 randomly selected farmers were interviewed throughout 20 villages in the Kérou and Péhunco municipalities in Benin. The results of the study indicate that the age of producers (40.18±1.30 years) is not significantly different ($p>0.05$). The largest areas allocated to different speculations are mainly found in the commune of Kérou ($p<0.01$ to $p<0.001$). The majority of farmers (96%) reported that pesticides are helpful in the pests and weeds control and foster good yields but their use harms health, impoverishes the soil, and disrupts aquatic ecosystems and plant life cycles. Furthermore, farmers (55%) revealed that the region faces problems of contamination or excessive toxicity of food products caused by pesticides, which is creating conflicts among cotton and food farmers. Dialogue (51%), the intervention of the farmers' association committee (25%) and the intervention of the Territorial Agency for Agricultural Development (ATDA) municipal unit (20%) were the main management mechanisms of conflicts. In perspective, it is possible to lay the foundations for preventive actions and responsible cotton production to avoid the emergence of land conflicts between farmers, promoting peace.

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Introduction

Chemical pesticides have been used worldwide to control crop pests and diseases since the second half of the 20th century (Soro *et al.*, 2018; Chen, 2019). Unfortunately, substituted ureas, triazines, organochlorines, pyrethroids, organophosphates, and other chemicals pesticides families can be found in ecosystems (Sharma *et al.*, 2018). Indeed, even at very low levels in the environment, some of them have toxic properties (Yao *et al.*, 2018). Their spreading in the environment through spraying or precipitation thus affects non-target organisms and causes an imbalance in the entire ecosystem. The World Health Organization (WHO) indicates that approximately 3 million cases of pesticide poisoning are reported each year, resulting in the deaths of more than 250,000 people worldwide (Oguh *et al.*, 2019). Although Africa uses fewer pesticides by volume, its pesticides arsenal is extensive in agriculture (Yao *et al.*, 2018). Unfortunately, suppliers, agricultural development stakeholders and farmers are rarely informed about their impact on health and ecosystems. Thus, by contaminating ecosystems, pesticides induce a drastic reduction in the nutritional potential of aquatic environments and agricultural fields, thus amplifying poverty in the population, particularly the disadvantaged segment of developing countries who make their living from farming and fishing activities (Sharma *et al.*, 2018).

In the Republic of Benin, one of the leading cotton producing countries in Africa, the non-organic sector represents the largest share of production (Sossou *et al.*, 2021). The latter uses both the addition of fertilizers and that of pesticides (fungicides, herbicides, and insecticides). To double its cotton production over the last seven years (2016 - 2023), the Beninese government has increased subsidies for chemical fertilizers and pesticides (Ayokpon-Hondo *et al.*, 2021). These pesticides are mainly distributed by the Society for the Development of Cotton (SODECO) but farmers can also find additional ones from agro-suppliers and on local markets. Although their effectiveness is obvious (Adechian *et al.*, 2015), the excessive use of pesticides in cotton production could cause soil and water pollution, the development of pest resistance, as well as the destruction of many useful organisms (Zaki *et al.*, 2020). In the cotton-growing producing areas of the northern Benin, farmers reported cases of discomfort including headaches, colds, rashes and fatigue after pesticide spraying (Ayokpon-Hondo *et al.*, 2021). In addition, studies conducted between 1996 and 2002 showed that pesticide levels in natural systems have continued to increase in Benin, particularly in protected areas constituting a serious obstacle to sustainable development in Benin (Ahouangninou *et al.*, 2019).

In the main cotton production areas in Benin such as the Kérou and Péhunco municipalities, intensive cotton production requires the use of pesticides to control pests and maximize yields (Ahouangninou *et al.*, 2019). Therefore, indirect contamination cases can arise when a farmer uses pesticides or chemical fertilizers that spread to neighboring farmers' land, thereby leading to crop losses and environmental damage. These incidents have negative consequences not only on farmers' income, but also on social relations within the farming community, creating conflicts between farmers (Werrie *et al.*, 2020). Contamination between farmers in the Kérou-Péhunco cotton area poses a major challenge in terms of managing agricultural conflicts. Between 2012 and 2016, the commune of Kérou recorded 235 cases of poisoning including 14 cases of death (Sambieni *et al.*, 2022). These preliminary data, which provide information on the problem of pesticides and the contamination of food crops, deserve to be deepened. In this context, it is crucial to conduct in-depth studies to examine strategies for appropriate management of conflicts between farmers after cases of environmental contamination between farmers to restore equity between communities and restore peace. Therefore, this study aims to analyze the perception and management mechanisms of conflicts resulting from soil contamination by synthetic chemical pesticides in the main cotton-growing producing area in the Republic of Benin.

Material and methods

Study area

The study was carried out in the Kérou and Péhunco municipalities (1°39'51" and 2°17' 18" of North latitude and 10°03'27" and 11°23' 46" East longitude) of the Republic of Benin (Fig. 1). This region has a climate type similar to Sudano-Guinean, which is characterized by a rainy season from mid-April to mid-October, and a dry season from mid-October to mid-April. They belong to an agroecological zone characterized by a rainfall that oscillates between 800 and 1100 mm of rain per year and spread over nearly 170 days. The average temperature is 26°C, with a maximum of 32°C during February. The Atacora range, which covers the Kouandé and Péhunco municipalities, has an average precipitation of 1200 to 1300 mm per year, with occasional rainfall exceeding 1400 mm. The development of agricultural activities is heavily dependent on rainfall in the study area. This drives farmers to sow more to increase production.

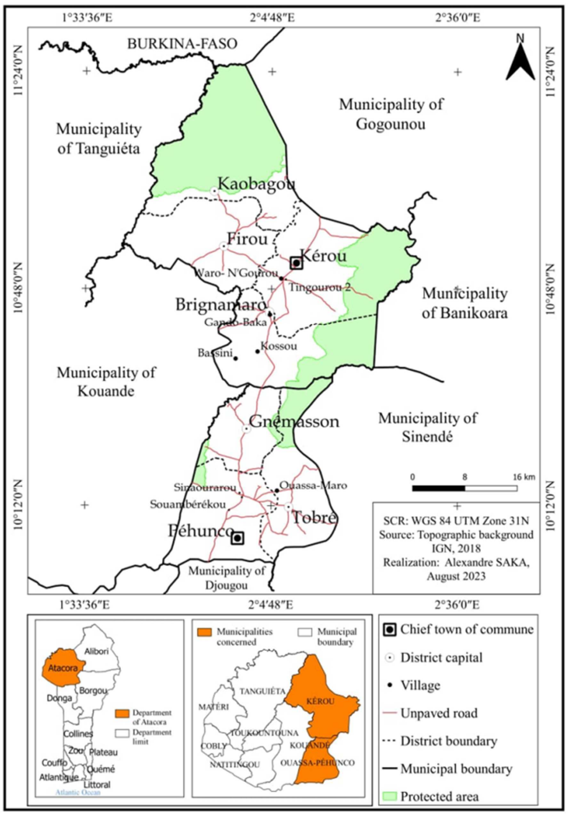

Fig. 1. Geographical and administrative situation of the Kérou and Péhunco districts

Choice of surveyed villages

The surveyed villages were chosen based on the cotton field areas, pesticides use, and village accessibility. Based on this, 20 villages were selected both municipalities (Table 1). An exploratory study was carried out in April 2023 to obtain an overview of the use of pesticides by farmers and the methods of conflict management (Shrestha *et al.*, 2022).

Survey sample size

The sample size (N) was obtained using the normal approximation of the binomial distribution proposed by Dagnelie (1986): $N = \left[\left(U_{1-\frac{\alpha}{2}}\right)^2 \times p(1-p)\right]/d^2$

With $U_{1-\alpha/2}$ the value of the normal random variable for the probability value of $1-\alpha/2$, α being the risk of error. For α = 5%, the probability $1-\alpha/2 = 0.975$ and we have $U_{1-\alpha/2}= 1.96$. P is the proportion of farmers using or not using pesticides and having knowledge of conflict management processes resulting from pesticide applications in adjoining fields and d (1% ≤ d ≤ 15%), the margin of error of estimate, retained at 5% in this study. Using the p values (0,70) from the results of the exploratory phase of the study, 200 farmers were selected (120 in Kérou and 80 in Péhunco). In each locality, the surveyed farmers were identified using a simple random sampling (Bello *et al.*, 2017; Avaligbé *et al.*, 2021).

Survey process

In each village, farmers with an age greater than or equal to 30 years and having knowledge on the mechanisms for managing conflicts arising from the use of pesticides and at least 8 years of experience in agricultural production were selected with the help of the village chief. The individual survey was carried out according to the method described by Bello *et al.* (2017) and Sambieni *et al.* (2022) and involved 200 cotton farmers. Data were collected using a semi-structured questionnaire whose questions were related to the socio-demographic characteristics of the surveyed households (sex, age, household size, level of education, years of experience in agricultural production, workforce employed, size of farms, farming methods, acquisition of land, main speculations, cotton yields, and areas sown). Farmers' perceptions of the use of synthetic chemical pesticides, and the mechanisms for managing conflicts between farmers according to the overuse of pesticides were also documented. The actual areas considered are those corrected by the difference obtained between the declared values and those measured with the Garmin eTrex 20 brand GPS from a sample of 10 producers per district (Bello *et al.*, 2017; Tajudeen *et al.*, 2022).

Table 1. List of the surveyed villages according to the sociolinguistic groups

Municipalities	Districts	Villages	Sociolinguistic groups
Kérou	Kérou-centre	Gantodo, Karigourou, Ouoré, Sinagourou, Tingourou, Warou N'gourou	Bariba, Gourmantché, Peulh, Yoruba,
	Firou	Bobéri, Djoléri, Kabongourou, Sokogourou, Tokongourou	
	Brignamaro	Bassini, Kossou, Gando Bakar, Brignamaro	
Péhunco	Péhunco-Centre	Gbérasson, Sinaworou, Soamborékoun, Tokoro	Bariba, Peulh, Ditamari
	Tobré	Wassa-maro	

Table 2. Socio-economic characteristics of surveyed farmers in the study area (n = Sample size)

Variables	Terms	Percentage of respondents (%)					Total (n=200)[1]
		Kérou			Péhunco		
		Brignamaro (n = 5)[1]	Firou (n=55)[1]	Kérou-centre (n=60)[1]	Tobre (n=23)[1]	Péhunco - centre (n=57)[1]	
Marital status	Single	20	12,7	8,3	8,7	17,5	12,5
	Married	80	87,3	90	87	75,4	84,5
	Divorced	-	-	-	-	1,8	0,5
	Widower	-	_	1,7	4,3	5,3	2,5
Age	age ≤ 35	20	45,5	40	26,1	29,8	36,5
	35 < age ≤ 60	80	52,7	56,7	73,9	66,7	61
	age > 60	-	1,8	3,3	-	3,5	2,5
Sex	Female	-	5,5	10	-	7	6,5
	Male	100	94,5	90	100	93	93,5
Origin	Allochtonous	20	7,3	8,3	-	5,3	6,5
	aboriginal	80	92.7	91.7	100	94.7	93.5
Level of education	Noone	80	49.1	50	60.9	63.2	55.5
	literate	-	7.3	3.3	13	12.3	8
	Primary	20	12.7	18.3	13	10.5	14
	Secondary	-	23.6	20	13	10.5	17
	University	-	7.3	8.3	-	3.5	5.5
Main activity	Farmer	100	90.9	93.3	100	84.2	91
	Craftsmen		5.5	1.7	-	-	4
	Teacher	-	3.6	3.3	-	5.3	3.5
	Market gardener	-	-	1.7	-	10.5	3.5
Experience in agriculture	Exp ≤ 10	80	56.4	51.7	26.1	57.9	52.5
	10< Exp ≤ 20	20	30.9	31.6	34.8	26.3	30
	Exp > 20	-	12.7	16.7	39.1	15.8	17.5
Cultivable area	5ha < Sup ≤ 10ha	20	18.2	26.7	47.8	26.3	26.5
	Sup > 10 ha	80	81.8	73.3	52.2	73.7	73.5

Data analysis

The data collected were coded and analyzed with descriptive statistics using SPSS software version 20. The quantitative collected data were subjected to an analysis of variance (ANOVA) using the PROC GLM procedure of the SAS (Statistical Analysis System) software version 9.2. Multiple mean comparisons were carried out using the Student Newman-Keuls test (Dagnelie, 1986). To describe farmers' perceptions linked to knowledge and pesticide uses, data was coded 1 if the farmer has knowledge about pesticides and 0 if not, and the obtained matrix was subjected to a Principal Component Analysis (PCA). The same analytical approach was carried out to analyze the conflict management mechanisms according to the surveyed district. For each district, the number of farmers who opted for each identified mechanism was calculated. Correspondence Factor Analysis was performed on the resulting contingency table using Minitab 14 software (Bello *et al.*, 2017).

Results

Socioeconomic characteristics of the surveyed households

The majority of the surveyed farmers were male (93.5%), married (84.5%), and illiterate (55.5%). The age of the surveyed farmers throughout the study area was between 30 and 85 years, with an average age of 40 years. There was no significant difference (p> 0.05) between the districts concerning farmers' age (Table 2).

Table 3. Quantitative data (mean values ± standard errors) on producers in the five districts

Municipalties	District	Age (year)	Experience in agriculture (year)	Cultivable area (Ha)	Area allocated to speculation (Ha)	Quantity of pesticide (L/ha)
	Kérou-centre	40.11±1.38a	13.16±0.84ab	12.85±0.44ab	3.39±0.27b	1.8±0.08a
Kérou	Firou	36.96±1.09a	12.07±0.94b	13.63±0.36ab	5.24±0.37a	1.74±0.08a
	Brignamaro	38±2.09a	8.8±1.82b	15±1.51a	5.4±1.46a	2±0.31a
Péhunco	Péhunco - centre	42.45±1.94a	13.43±0.82ab	12.77±0.4ab	3.30±0.24b	2.05±0.13a
	Tobré	40.82±1.7a	18.21±1.39a	11.87±0.69b	2.39±0.29b	1.82±0.1a
F value		1.8	4.29	1.93	9.98	1.42
Probability		0.13	0.0024	0.01	0.0001	0.23

Means followed by the same alphabetical letters are not significantly different (p > 0.05) according to the Student Newman-Keuls test.

The farming experience of the majority of respondents varied between 5 years and 25 years with surveyed farmers of Péhunco district having more experience ($p<0.01$) compared to those of Kérou district. The great majority of the surveyed farmers (55.5%) was illiterate. All the surveyed farmers cultivate on land inherited from their parents, and the majority of them (91%) have farming as main activity. In the study area, the majority (73.5%) of the surveyed farmers sown cotton over large areas (greater than 10 ha), with those on Brignamaro district (Kérou municipalities) significantly ($p<0.01$) cultivating the largest areas (Table 3). The surveyed farmers have very little access to credit and work on their own funds (78%). Likewise, very few of them belong to farmers' organizations (20%).

Table 4. Eigen value of the first three (03) components

Axe de PC	Eigen value	Proportion	Cumulative proportion
PC1	7.6248	0.477	0.477
PC2	5.2274	0.327	0.803
PC3	2.3257	0.145	0.949

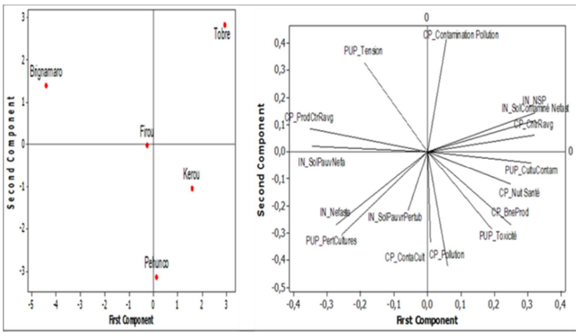

Fig. 2. Projection of farmers' perceptions of the advantages and disadvantages of pesticides using a Principal Component Analysis (PCA)

The words bearing CP stand for Pesticide Knowledge, those bearing CP stand for negative impacts, and those bearing PUP stand for Problems of Pesticide Use.

Farmers' knowledge on the pesticide uses

The results of the Principal Component Analysis (PCA) indicate that the first two axes explain 80.3% of the total information (Table 4). The projection of farmers from the five districts in the axes defined by the different perception of pesticide (Fig. 2) revealed that farmers living in the Kérou-centre district know that pesticides are benefits for cotton production. These farmers state that contamination is one of the negative impacts linked to pesticides. In addition, they believe that the contamination of crops by the use of these pesticides is at the root of the problems of conflicts between cotton producers and food crop producers. In the Brignamaro district, producers think that pesticides allow good production and fight against pests and weeds, but also think that they deplete the soil and are harmful to aquatic ecosystems. Farmers in Firou district state that pesticides are harmful to both human health and aquatic ecosystems. Pesticides are believed by these farmers to deplete the soil and disrupt plant life cycle. According to them, the problems related to the use of pesticides between cotton producers and food crop producers are due to their toxicity. According to cotton producers in the Péhunco -center and Tobré districts, pesticides contaminate crops and pollute water, air and soil. Their belief is that when crops are lost, there are problems related to the use of pesticides among producers. In addition, farmers in the Tobré district also mentioned the problems of tensions or conflicts between farmers following the use of pesticides (Fig. 2).

Table 5. Analysis of the contingency table

Axes	Inertia	Proportion	Cumulative
1	0.0660	0.6301	0.6301
2	0.0257	0.2450	0.8751
3	0.0082	0.0779	0.9531

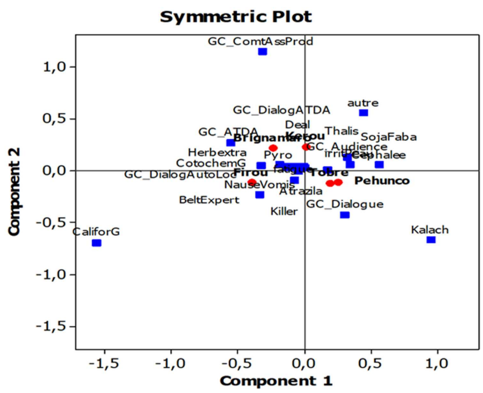

Fig. 3. Result of the Correspondence Factor Analysis (CFA) related to the conflict management between farmers

Factors driving GC are conflict management mechanisms.

Pesticide use and management of conflicts related to their use

Surveys indicate that there are multiple ways to manage conflict among farmers who acknowledge the existence of disputes related to pesticide use. Dialogue between the concerned farmers (51%) was mentioned as the main action for conflict management, following by the intervention of the committee of the producers' association (25%), the intervention of the Territorial Agency for Agricultural Development (ATDA) (20%), and the court hearings (4%). The Correspondence Factor Analysis (CFA) carried out to describe the relationships between these different mechanisms according to the five districts showed that the first two axes explain 87.51% of the total information (Table 5).

The results of the CFA showed that in the Kérou-centre and Brignamaro districts, the court hearings, the intervention of the farmers' association committee, the intervention of the ATDA were the different mechanisms for conflict management between farmers (Fig. 3). The primary way to resolve disputes in Tobré and Péhunco -center districts is through dialogue. In Firou district, local authorities and dialogue are the main sources of assistance for farmers. Furthermore, pesticides such as Thalis, Soja Faba, and Deal are commonly used by cotton producers in the Kérou-Centre district. Califor G, Belt-Expert, Atrazila, Killer and Cotochem G pesticides were more commonly used in the Firou district. However, Herbextra, Pyro, and Kalach pesticides were more commonly used by farmers in the Brignamaro, Péhunco-center, and Tobré districts respectively (Fig. 3).

Table 6 provides information on the characteristics of pesticides utilized by cotton producers in the two municipalities. Cotton farmers experience certain ailments after using these pesticides in their fields. For Kérou-Centre producers, the conditions include skin irritation, headaches, and other illnesses such as colds, coughs, and fevers. After spraying, Firou producers report nausea and vomiting, while Brignamaro producers experience fatigue. In Péhunco -center and Tobré, cotton producers faced common ailments such as skin irritation, headaches, and fatigue (Fig. 3).

Table 6. Pesticide commonly used by the surveyed cotton producers in the study area

Pesticides	Trade name	Active ingredient	Families
Herbicide	Killer 480SL	Glyphosate	Organophosphates
	Cotochem G 560SC	Fluometuron 250g/L Prometryn 250 g/L Glyphosate 60 g/L	Substituted ureas Triazines Organophosphates
	Callifor G 560SC	Glyphosate 60g/L Fluometuron 250 g/L Prometryn 250 g/L	Substituted ureas Triazines
	Deal 110D	Trifloxysulfuron	Substituted ureas
	Herbextra	2.4D amine salt	Phenoxy-herbicides (aryloxyacides)
	Atrazila	Atrazine	Triazines
	SojaFaba	Diuron	Substituted ureas
	Kalach	Glyphosate	Organophosphates
Insecticide	Thalis 112 EC	Emamectin benzoate 48 g/L + Acetamiprid 64 g/L	avermectins + Neonicotinoids
	Belt-Expert	Flubendiamide (240 g/L) Thiacloprid (240 g/L)	Benzoyl Ureas Organochlorines
	Pyro FTE 472EC	Cypermethrin 72 g/L + Chlorpyrifos- ethyl 400 g/L	Synthetic pyrethroids Organophosphates

Discussion

The majority of the surveyed cotton producers were young, illiterate, and affiliated with a farmers' organization. According to (Yai *et al.*, 2022), younger sections of the population have difficulty accessing land that can be used in the long term for perennial species. This is why they are enthusiastic about growing annual crops, especially cotton and food crops. According to (Ogouniyi *et al.*, 2017), the problem of illiteracy among farmers, especially those who produce food and cotton crops, is prevalent in the West African sub-region. The importance of men in cotton and food crops production can be explained by customary rules, which restrict the rights of women and do not favor women in access to land ownership (Avaligbé *et al.*, 2021). The same observation was made among yam producers in North-West Benin where women represent 7.33% of producers with 58% illiterate (Aza *et al.*, 2020). Most of the surveyed farmers sown areas greater than 10 ha in the two municipalities. The importance of the areas given to the cotton and food crops in the two municipalities reflects the enthusiasm that farmers have for these two crops. According to (Adechian *et al.*, 2015), this result can be explained by the fact that cotton cultivation allows producers to also have inputs on credit for other speculations in Benin.

According to the surveyed farmers, the negative impacts related to pesticides are contamination. In addition, they believe that the contamination of crops by the use of these pesticides is at the root of the problems of conflicts between cotton producers and food producers. In the Brignamaro district, producers think that pesticides have some benefits for crop production, but they also think that pesticides deplete the soil and are harmful to aquatic ecosystems. Several authors have also reached similar conclusions in Benin (Sambieni *et al.*, 2022; Ahouangninou *et al.*, 2011), Burkina Faso (Son *et al.*, 2017), Ivory Coast (Wognin *et al.*, 2013), Togo (Kanda *et al.*, 2013) and Democratic Republic of Congo (Ngweme *et al.*, 2019; Korangi *et al.*, 2021). According to these authors, large quantities of pesticides are used due to the drastic decline in soil fertility and to obtain better yields. Similarly, Ngweme *et al.* (2019) and Sambieni *et al.* (2022) in their studies demonstrated that producers use pesticides to combat crop pests and increase yield. Our observations are in line with the results that Son *et al.* (2017), who state that pesticides help to simplify the work of producers. Cotton producers in Firou district state that pesticides have a negative impact on human health and aquatic ecosystems. These producers also believe that pesticides deplete the soil and disrupt the life cycle of plants. According to them, the problems related to the use of pesticides between cotton producers and food crop producers are due to their toxicity. According to Tchamadeu *et al.* (2017) and Ake *et al.* (2023), the lack of labor due to rural exodus explains the use of herbicides by producers. Likewise, the decline in capacity with age is a constraint to which farmers are subject and which explains the use of pesticides according to Tchamadeu *et al.* (2017).

According to Chen *et al.* (2019), contamination through the use of pesticides presents risks to human health, biodiversity and the environment in general. Ngalimat *et al.* (2021) reported that pesticides cause the disruption of the local ecosystem, air pollution, soil and water contamination. Ramírez *et al.* (2020) and Tchamadeu *et al.* (2017) highlighted the health and environmental risks linked to the use of pesticides. Similarly to Ngalimat *et al.* (2021), our research has shown that contamination of food crops caused by pesticides is at the origin of conflicts between neighboring producers. This is why it's crucial to emphasize what may relate to the genuine conflict of simple tensions on a local scale. Our research indicates that proximity has a certain impact on the daily life and practices of farmers.

The high level of illiteracy among farmers in the study area could explain ignorance or a lack of assimilation of the recommended instructions for pesticide use. This could explain the poor pesticide use practices and the environmental risk observed among producers, especially since the labels are always in French or English (Ake *et al.*, 2023; Toé *et al.*, 2013). According to Compaoré *et al.* (2019), illiteracy and lack of training constitute a limit to compliance with good practices for the pesticides use, in particular the wearing of appropriate personal protective equipment, the method of preparation, and pesticides use. The health risks associated with pesticide exposure could be explained by this. These health risks are in agreement with those cited by Ahouangninou *et al.* (2011) and Tyagi *et al.* (2015), who showed that farmers did not regularly protect themselves when using pesticides due to the high cost of equipment and, above all, lack of awareness of the dangers to which they are exposed. They are most often satisfied with minimal protection of daily clothing such as pieces of fabric.

Our results revealed that among the pesticides used by cotton producers in the two municipalities, organophosphates, organochlorines, substituted ureas and triazines are the most used. Sossou *et al.* (2021) had already revealed that organophosphates, organochlorines, synthetic pyrethroids, substituted ureas and carbamates are the main families of pesticides used in Benin. However, Adechian *et al.* (2015) showed that organochlorines were the most used by farmers in cotton cultivation. Farmers believe that pesticides sometimes cause conflicts because they contaminate crops belonging to other producers in the area. The survey carried out revealed that the mechanisms for managing these cases of conflicts between neighboring producers are, among other things, dialogue (exchanges and understandings) between the concerned producers. Korangi *et al.* (2021) reported similar cases of conflict management between farmers in the Democratic Republic of Congo with intervention of local authorities to resolve them.

Conclusion

Increasing productivity and improving farmers' income requires the use of pesticides in agriculture. The diagnostic study highlighted a predominance of aging men and active women in demographic terms, but their level of education and training regarding the use of pesticides is limited. The lack of knowledge creates the possibility of health and environmental contamination. The way farmers perceive this problem has a significant impact on its response. Therefore, it is important to raise awareness among farmers about the risks associated with overusing pesticides, as well as about more eco-friendly alternative methods. Establishing open and transparent communication channels is crucial for handling complaints and resolving conflicts between producers. Farmers must be able to report problems related to soil contamination and the effects of pesticides on their health, without fear of reprisal. It is necessary for local authorities and relevant organizations to mediate conflicts and find solutions acceptable to all parties involved.

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