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First tick and tick damage perception survey among sedentary and transhumant pastoralists in Burkina Faso and Benin

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Abstract

Background: Transhumance, a main ancestral animal production strategy of the West African Countries (WAC), can favour the spread of vectors and vector-borne diseases within and/or across countries. Transhumance has been implicated in such spread as well as that of related tick-borne diseases (TBD).

Methods and principal findings: Using a questionnaire survey and statistical modelling, this study explores the perception of herders about ticks and TBD in cattle, their practices in tick control and the social groups involved in cattle farming in eastern Burkina Faso (46 random herds) and in the northern Benin (44 random herds). Results show that most of the herders (79%) are from the Fulani social group. The principal and secondary activities of herders are respectively cattle farming and agriculture. The mean age of pastoralists is between 40 and 50 years depending on the province of origin and 60% of the surveyed herds practice internal or transboundary transhumance. Herders have a clear knowledge of different genus of ticks except the genus *Rhipicephalus*. Their knowledge of TBD is very limited. These results also reveal that herders in Benin use less acaricides treatment calendar compared with those in Burkina Faso. Transhumant pastoralists (i.e. transhumant cattle farmers) plan more acaricide treatment and have more cows with lost teats (i.e. tick damage) than the sedentary ones. In addition, amitraz appears to be the main acaricide compound

used by herders for tick control (68%) but its use is inappropriate and its source is frequently the unregulated market.

Conclusions and significance: All of these findings can induce acaricide resistance especially as the inefficacy of amitraz against *Rhipicephalus* (*Boophilus*) *microplus* has already been reported in previous studies. Such results would help to elaborate suitable strategies of control and prevention of ticks and TBD in Burkina Faso and Benin.

KEYWORDS

Benin, Burkina Faso, pastoralist, socio-epidemiological survey, tick-borne diseases, ticks, transboundary diseases, transhumance

1 | INTRODUCTION

Transhumance is a livestock production and management system, which refers to an ancestral practice of moving herds seasonally and according to specific paths, repeatedly every year (Abiola, 2005). It is an animal production system adapted to the context of grassland savannah and steppe zones (Wagenaar et al., 1986). This type of animal farming is usually practiced in the dry season in West Africa, from Sahelian countries to the coastal countries following rangelands (Fournier et al., 2014). It has historically enabled pastoralist communities to survive major weather crises in Africa (Bouslikhane, 2015). This practice often raises serious concerns, including social conflicts and animal health problems (Abiola, 2005). In West Africa, cross-border transhumance is a common animal sustainable production strategy. The major droughts of the 1970s and 1980s forced a mass movement of herders in the Sahel towards the south, with most converting into agro-pastoralists and some completely settling. However, it is not known how many have been able to return to their previous transhumance systems. In addition to preserving the sahelian livestock, transhumance contributes to regional integration and the supply of animal products to an increasingly large and urbanized population. It contributes to the production of more than 65% beef meat, 40% meat of small ruminants and 70% milk of the sub-region (FAO, 2012), which represents 661,750 tons of meat annually and 1,435,000 tons of milk.

The movement of animals in search of water, pasture or markets sometimes leads them to areas where they have increased risks of becoming infected by specific infectious diseases (e.g.): fields contaminated by anthrax during previous outbreaks, reservoirs of ticks for heartwater, tsetse areas for trypanosomiasis, swampy areas with an abundance of arthropods that carry arboviruses (Abiola, 2005). Thus, the transhumance system has changed the epidemiological map of cattle diseases in West and Central Africa with the appearance of some diseases in areas where they were previously absent. Livestock movements represent the third cause of the spatial dynamics changes of animal disease after climate change and market concentration (Perry et al., 2013). The transhumant herd (i.e. cattle herds raised by the transhumance system) can rapidly disseminate contagious diseases during its movements. For example, transhumance has been cited among the vehicles of the spreading of rinderpest in the past. This may impede the livestock health within some regions, or even a whole country. The problem becomes particularly serious in the case of cross-border transhumance (Lesse et al., 2016). Examples include , the appearance of the invasive tick, *Rhipicephalus* (*Boophilus*) *microplus*, with the related transmitted diseases (i.e. babesiosis and anaplasmosis) in the northern part of Côte d'Ivoire (Madder et al., 2007) and in Benin (Madder et al., 2012). Formerly, its introductory sites are located in the south of each of these countries (de Clercq et al., 2012). It has also invaded other West African bordering countries such as Burkina Faso, Mali, Nigeria and Togo (Adakal et al., 2013; Adedayo & Olukunle, 2018; Musa et al., 2014; Opara & Ezeh, 2011).

Considering the direct and indirect losses of livestock due to ticks in West Africa (Sutherst, 1987) and the practice of transhumance, which has become a way of life for some farmers (Cabot, 2017), it is necessary to understand the role of transhumance in the spread of ticks and associated pathogens in order to propose some improvements for an integrated pest management. However, this type of information is very rare.

Therefore, a first epidemiological survey was conducted in the eastern region of Burkina Faso and in northern Benin to investigate the putative role of the transhumance in the spread of ticks and tick-borne diseases (TBD) and practices of pastoralists that may have contributed to these.

The aim of this study is to investigate on the perception of herders about ticks and TBD in cattle, their practices in tick control and the social groups involved in cattle farming in Burkina Faso and Benin. The survey was carried out in dry season, just before herders start moving for transhumance from Burkina Faso to Benin.

2 | MATERIALS AND METHODS

2.1 | Study area and design

This survey was conducted in two West African bordering countries: Burkina Faso and Benin. The study area includes three provinces in the eastern region of Burkina Faso (Gourma, Kompienga and Tapoa), which represent the departure area and four departments in the north of Benin (Alibori, Atacora, Borgou and Donga), which

represent the arrival area of the transhumant herds from Burkina Faso (Figure 1).

The climate of the eastern region of Burkina Faso is of south-Sudanese type, characterized by a rainy season of 5 months, from May to September, and 7 months of dry season, from October to April (Ibrahim et al., 2012). A shrubby savannah in the north and a wooded savannah in the south characterize the vegetation of the region. The eastern region belongs to the Sudanese phytogeography domain, with very variable precipitation both in number of rainy days and in quantity of water (between 900 and 1100 mm/year). Three types of vegetation occur in this region: the steppe, the savannah and the forests established of galleries (i.e. Pendjari). The region has an abundance of reserves of fauna and national parks covering the provinces of Gourma, Kompienga and Tapoa (Ministère de l'Economie et des Finances, 2009).

In the province of Kompienga, all of Pama's rivers are tributaries of Pendjari's river. Pendjari and its tributaries do not flow in the dry season. However, numerous puddles or permanent restraints are situated on the course of the river. An important artificial restraint (Kompienga) was realized on the river Ouali. The storage capacity is 2.5 billions of m^3. In the province of Tapoa, the river system gets organized with regard to Tapoa, which is the only permanent stream. There is also not a permanent water source to Kankandi (Ministère de l'Economie et des Finances, 2009).

In addition to these main areas, there are anthropogenic formations forged mainly by agro-pastoral activities. These formations are dominated by spared species spread by man (*Vitellaria paradoxa*, *Parkia biglobosa*, *Acacia albida*) in the management of agricultural spaces and species that have been planted as part of reforestation activities (e.g. *Eucalyptus camaldulensis*, *Mangifera indica*) (Portail sur le développement du Burkina Faso, 2008).

The northern part of Benin has a Sudanese-type climate with a rainy season of 5 months (May to September) and a dry season of 7–8 months (October to April). Rainfall is between 700 and 1,100 mm of water/year. The external temperatures are between 22°C and 37°C throughout the country with daily thermal amplitudes in the north (greater than 10°C) (Adam, 1993). Two river basins water the northern of Benin: the Pendjari river basin and the Niger river basin. The Pendjari river basin (length of 420 km in Benin) is composed of three main drainage axes. These three main areas of drainage are: the Kounne (550 km^2 for a length of 46 km and 200 m of vertical drop), the Tigou (317 km^2 for a length of 27 km and 300 m of vertical drop) and the Sarga (567 km^2 for a length of 48 km and 300 m of vertical drop) (Le Barbé, 1993).

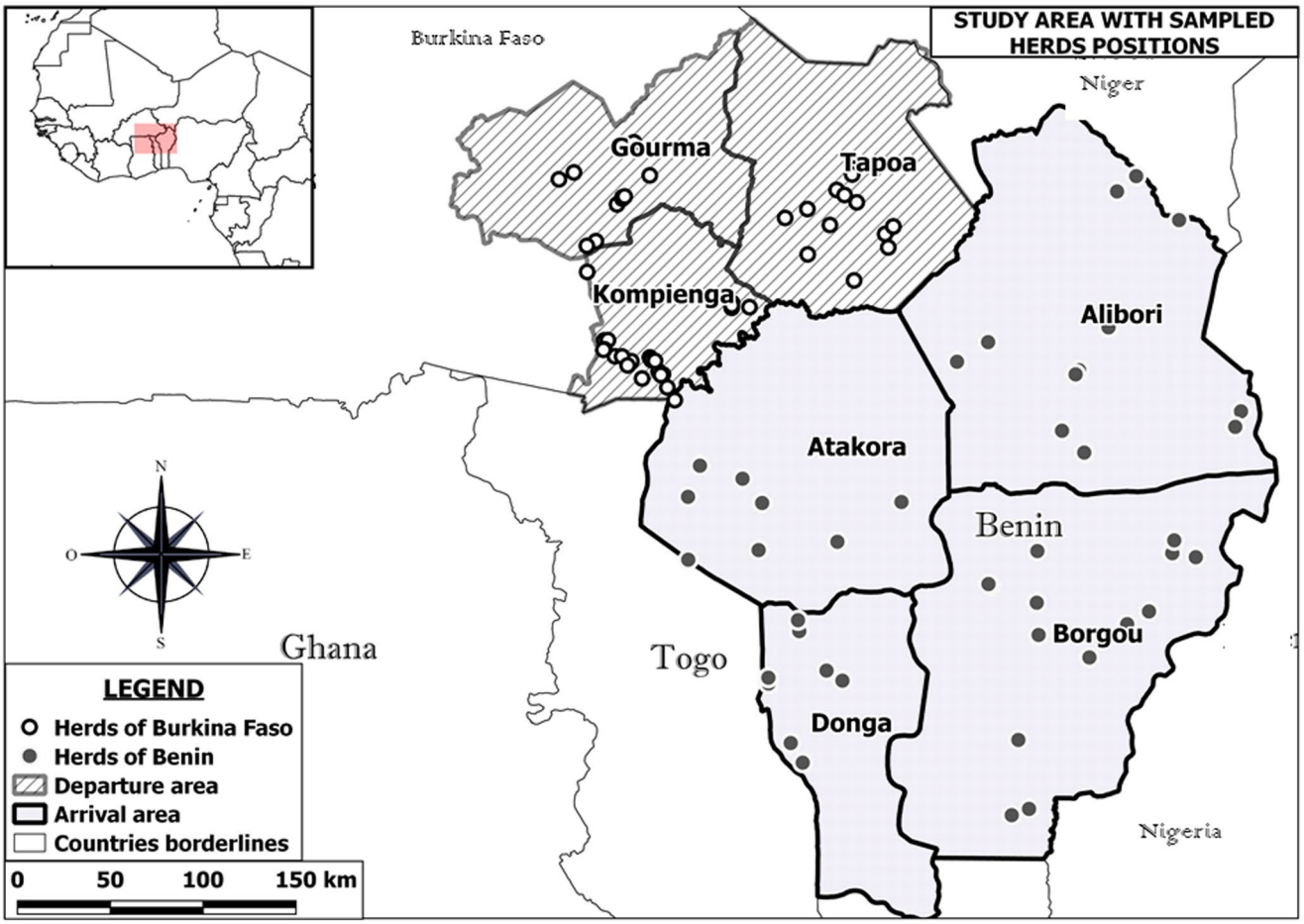

FIGURE 1 Study area with the geographical positions of the 90 sampled herds in Benin and Burkina Faso

Over 135 km, the Niger River represents the natural border for Benin and Niger. Its watershed in this region is close to 1 000 000 km^2. On this short route, the Niger has a straight-line oriented NW-SE and receives on the right bank the contributions of four tributaries, which are from west to east: Mekrou (10,500 km^2), Kompa Guru (1,980 km^2), Alibori (13,740 km^2) and Sota (13,360 km^2). Southeast of the Sota basin are the high basins of Nigerian which tributaries include Wara and Oli (Le Barbé, 1993; Olivry et al., 2005).

The north of Benin is characterized with its Sudan-Sahel type climate located between 10° N and 12° 30' N, it has shrubby and wooded savannahs; clear forests with *Anogeissus leiocarpa* (deep soils) or with *Isoberlinia doka* (siliceous soils); and forest galleries (Aregheore, 2009).

Pastoral exploitation is the work of sedentary and transhumant Fulani herders, who graze their flocks in the various plant formations of the Atacora mountain chain (Wala, 2010).

2.2 | Herds sampling and distribution

A total of 90 herds were selected from a pastoralists' list provided by the veterinary offices of each country. The selection was made by choosing randomly the name of a pastoralist in the list, calling him and having his agreement for the survey. When the picked pastoralist did not agree, another one was chosen randomly until we had the required number for each area. The size of the sampling was related to logistical constraints. The main criteria of inclusion of livestock keepers in the study included ownership of at least 50 cattle and whether or not they practiced transhumance. The minimum of 50 cattle per herd was set because transboundary transhumant herds often have a herd size of at least 50 animals. It was necessary to harmonize the herd size class among the transhumant and non-transhumant herds to make comparisons without bias. Furthermore, distance between herds in each province is at least 3 km. Also, effort was made to have herds distribution covering the whole study area within each province to ensure representability (Figure 1).

In the transhumance departure zone (east region of Burkina Faso), 46 herds were selected according to the density of the population, the extent of the area and the natural constraints: 16 herds in the province of Gourma, 15 in the province of Tapoa and 15 in the province of Kompienga. In the transhumance arrival area (north region of Benin), 44 sedentary cattle herds were selected and distributed applying the same criteria as in Burkina Faso: 8 were chosen in the department of Atacora, 14 in the department of Alibori, 8 in the department of Donga and 14 in the department of Borgou. The eastern region of Burkina Faso and the north of Benin hosted respectively 51% and 49% of the sampled herds.

2.3 | Collection of socio-epidemiological data

A questionnaire survey was administrated to pastoralists during biological sample (ticks and cattle blood) collection that was carried out in cattle herds for another purpose (acarological and parasitological survey). The questionnaire survey included questions about the type of husbandry, the herd size, the cattle breeds on the farm, the presence of transhumant cattle in the area of stay, the knowledge of the herder about ticks and TBD and the use of acaricides (Data S1). The knowledge of herders about ticks was evaluated by providing tick specimens (available ones) and pictures of ticks for identification. The herders were asked if they had already seen such species and what was the name of that species in the local language. The knowledge of herders about the ticks was assessed according to their aptitude to recognize easily the specimens or the picture, and giving their name in local language. The interviews were done one to one in French or local language with the help of an experimented interpreter if needed. The geographical coordinates of each site were recorded using a handheld Global Positioning System (GPS), for the generation of distribution maps using the Quantum Geographic Information System (QGIS) software (Quantum GIS Development Team, 2016). The field data collected were encoded in an MS Access database.

2.4 | Statistical analysis

Various models were used accordingly to find out if certain factors are associated with the variables of interest. The linear regression was used for continuous dependent variables, logistic regression for binary dependent variables and Poisson or negative binomial regression for count variables (Petrie & Watson, 2013) using STATA SE 14 (StataCorp, 2015).

The linear regression helped to find out the factors associated with the variations of the continuous dependent variables (e.g. herders age, experience in cattle farming, seniority in the surveyed herd). The purpose of such analysis was to appreciate the effect of the variation of the different independent variables (e.g. country, mode of farming) on these continuous variables.

The logistic regression helped to appreciate the effect of the variation of the independent variables (e.g. country (Benin or Burkina Faso), the mode of farming (transhumant or sedentary)) on the categorical-dependent variables such as acaricide used (e.g. amitraz, cypermethrin or deltamethrin), origin of acaricide (e.g. unregulate market, veterinary source), and presence of species of ticks. The Poisson regression helped to analyse the effect of independent variables on the countable dependent variables (e.g. herd size, number of goats, number of sheep, number of donkeys).

These various models were performed to allow us to notice if the variables (e.g. presence of ticks; season of abundance; acaricides used by breeders; origin of acaricides; and the use of treatment schedule) are influenced by country, farming method (sedentary or transhumant) and season.

Multiple correspondence analysis (MCA), a classical multivariate data analysis technique was used to group the herders based on socio-economic and epidemiological factors registered during the survey using the package 'FactoMineR' of R free software (Lê et al., 2008). MCA analysis was performed to: (a) provide a typology of the individuals from a multidimensional perspective (b) to assess

the relationships between the variables and (c) to link the study herds and the variables in order to characterize the individuals using the variables. Initially intended for qualitative variables, the MCA may also deal with quantitative variables, if they are made qualitative.

Another way to study the similarities between individuals with respect to all the variables was to perform a hierarchical clustering, which was performed after the MCA. This analysis used the coordinates of the individuals on the principal components for the hierarchical classification by an hierarchical clustering on principal components (HCPC) (Husson, 2010). The principal component representation was also used to visualize the partition in a 3D-map (factor map) to better understand the data.

For the epidemiological group (concerning perception of herders on tick and tick-related damage) partition of 90 herders, the MCA was also used with 52 variables. The principal variables retained are 19 (e.g. presence of various species of ticks, season of abundance of ticks and tick-related damages on cattle) and the remaining are supplementary variables (Data S2 and S3). Regarding socio-economic group analysis, MCA was performed considering all herders described by 55 variables (Data S2 and S3).

3 | RESULTS

3.1 | Characteristics of herders

The questionnaire respondents were mainly the herd owners who belong to the Fulani social group. They represented more than 79% ($n = 71$) of all herders in both Benin and Burkina Faso. However, there were more Fulani herders in Burkina (85% of herders) than in Benin (73% of herders). Only three ethnic groups had been found in Burkina Faso herders, whereas Benin herders belong to eight different ethnic groups. The herders belonging to social groups of 'Gourmantché' and 'Mossi' are found only in Burkina Faso whereas the ethnic groups of 'Gando', 'Bariba', 'Dendi', 'Kountéba', 'Mokolé', 'Tanika' and 'Yorouba' are found only in Benin (Table 1).

TABLE 1 Ethnic group of surveyed herders

Ethnic group	Benin	Burkina Faso	Total	Percentage
Bariba	3	0	3	3%
Dendi	1	0	1	1%
Gourmantché	0	6	6	7%
Kountéba	1	0	1	1%
Mokolé	1	0	1	1%
Mossi	0	1	1	1%
Fulani	32	39	71	79%
Gando	4	0	4	4%
Tanika	1	0	1	1%
Yorouba	1	0	1	1%
Overall total	44	46	90	100%

The level of education of the herders was very low; 52% had no formal education, whereas 24% had attended Koranic schools. Only 10% of the herders had attained primary education, 9% had secondary or higher level of education and 5% were Fulfulde literate.

All the 36 interviewed transhumant cattle farmers in Burkina Faso were men. Those that come from the province of Kompienga belonged all to the Fulani social group, whereas in Tapoa they were 83% Fulani and 17% Gourmantché and in Gourma they were 90% Fulani and 10% Gourmantché. The principal activity of all of them was cattle farming and agriculture represents their secondary activity. The highest average experience in cattle farming was 39.7 years in Kompienga province, but the most experienced cattle farmer was from the Tapoa province with 70 years of activity. The transhumant cattle keepers of Kompienga were the least literate (90%), whereas those of Gourma were the least illiterate (38%) (Table 2).

This survey revealed that 40% of all the sampled herds in the study area practiced transboundary transhumance and 20% of herds practiced internal transhumance. The remaining 40% of herds represents a sedentary population. Internal transhumance is performed during all seasons and transboundary transhumance took place during the dry season (Figure 2). Farmers confirmed that their herds moved to uncultivated areas during the rainy season to allow farmers to cultivate crops and avoid conflicts between cattle keepers and farmers. Herds can come back to cropped areas during dry season, after farmers harvested crops, to graze on the crops wastes.

Negative binomial regression in Stata demonstrated that there were no significant ($p > 0.05$) differences between the numbers of herds, which practice transhumance in the two countries. Thus, the country of membership has no influence on this cattle farming technique.

3.2 | Socio-economic groups

The MCA revealed that the first 23 dimensions are needed to have 80% of the total variance. The first two dimensions only explain 14.7% of the total variance. The clustering (HCPC) results show that the social group and the principal activity led to the partitioning of the herders in different socio-economic groups (Data S4). The clustering analysis also revealed seven clusters among which we have two main ones with more than 80% of herders (Figure 3). The first cluster (cluster n°1) regrouped 43% of herders and was characterized essentially by the practice of transboundary transhumance and the origin from Burkina Faso. The second one (cluster n°2) regrouped 44% of herders and was characterized by the non-practice of transhumance and not giving food supplements to their cattle. In addition, the third, the fourth, the fifth and the sixth clusters have respectively only one member each. The seventh and last socio-economic group includes seven members. This cluster is characterized by 'Agriculture' as principal activity and 'Cattle breeding' as secondary activity.

TABLE 2 Comparison of the Burkina Faso transhumant ($N = 36$) profiles according to the province of origin

Parameter	Provinces			Overall Burkina Faso transhumant (N=36)
	Gourma (N=10)	Tapoa (N=12)	Kompienga (N=14)	
Social group	90% Fulani & 10% Gourmantché	83% Fulani & 17% Gourmantché	100% Fulani	92% Fulani and 8% Gourmantché
Age (year)	Mean: 40.4 (±8.3)	Mean: 49.5 (±15.9)	Mean: 47.1 (±9.8)	45.94 (±12.19)
Secondary activities	60% farmers & 40% traders	100% farmers	64% farmers & 36% traders	75% farmers and 25% traders
Cattle farming experience (years)	Mean: 32.5 (±9.3)	Mean: 35.7 (±13.4)	Mean: 39.7 (±11.3)	Mean: 35.9 (±12.93)
Level of education	38% No level 38% Koranic school 12% Fulfulde literate 12% Primary school	60% No level 20% Koranic school 10% Primary school 10% Secondary school and beyond	90% No level 10% Fulfulde literate	64% No level 22% Koranic school 6% Fulfulde literate 6% Primary school 3% Secondary school and beyond
Herder as manager	100%	83%	100%	94%

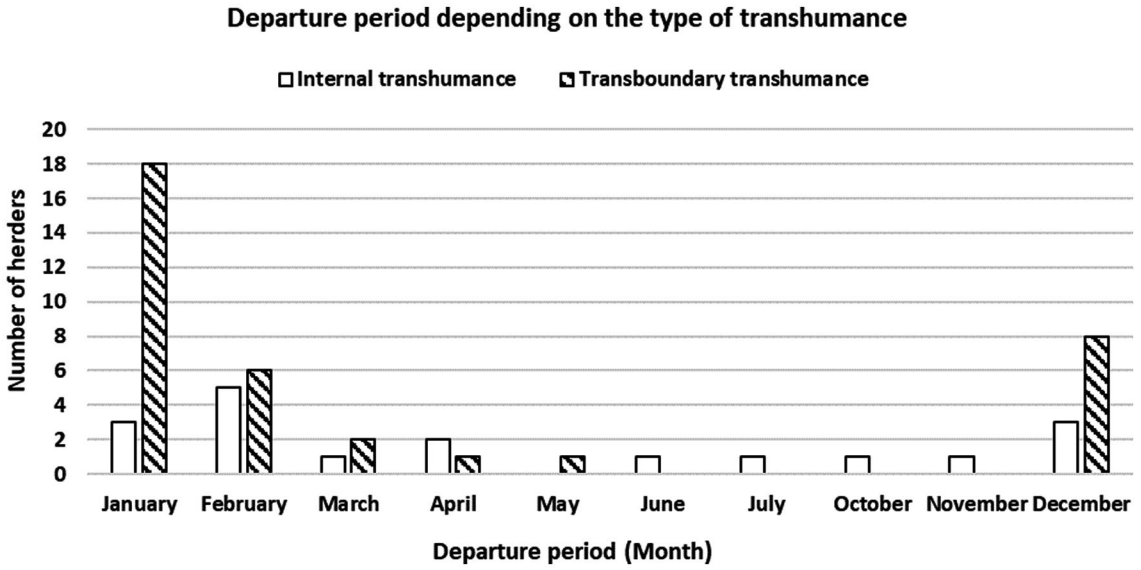

FIGURE 2 Departure period depending on the type of transhumance

3.3 | Ticks and tick-related damages on cattle perception groups

The results of the MCA and the HCPC are depicted in Data S5 and Figure 4. The presence of *Hyalomma* spp., *Amblyomma variegatum* and *Rhipicephalus* (*Boophilus*) spp. in the herds lead the clustering of the herders according to their perception of ticks and tick-related damages on cattle (Data S5). The MCA revealed that the first 12 dimensions were needed to account for up to 80% of the total variance. The first two dimensions explain only 22.68% of the total variance. Five epidemiological clusters were revealed by the HCPC (Figure 4). Two main clusters are highlighted (i.e. cluster n°2 and cluster n°4). The cluster n°2 including 39 herders is characterized by low implication of ticks in milk drop and dermatosis, whereas the cluster n°4 with 33 members is characterized by a high implication of ticks in milk drop and dermatosis. The cluster n°1 contains two members characterized by their ignorance of the seasonal abundance of *A. variegatum*, the absence of this tick in their herds, the use of cypermethrin as the main acaricide and the location of the herd in the department of Borgou in Benin. The cluster n°3 gathers eight members mainly characterized by their ignorance of the abundance season of the ticks belonging to the sub-genus *Boophilus* and the absence of those ticks in their herds. The cluster n°5 also groups eight members characterized by their ignorance of the seasonal abundance of the tick genus *Hyalomma* and the absence of those ticks.

In addition, the Figure 5 shows the abundance of different tick species in function of the season.

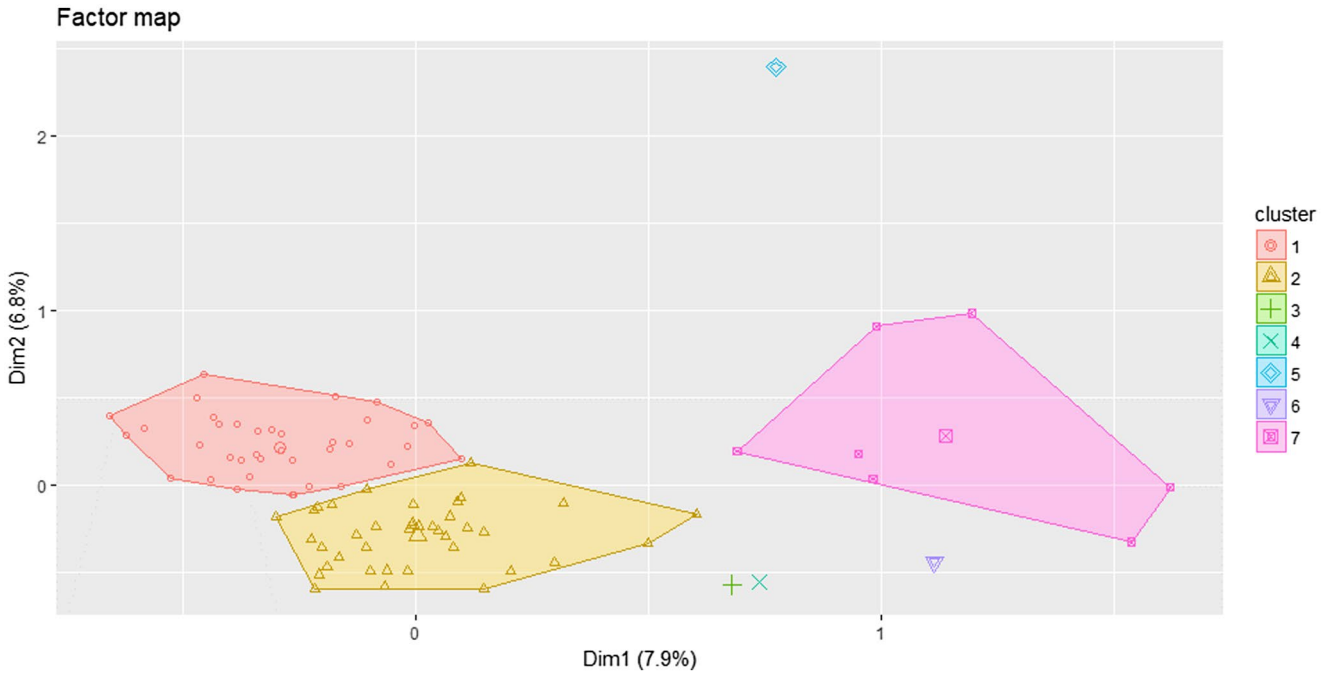

FIGURE 3 Socio-economic factor map of the herders

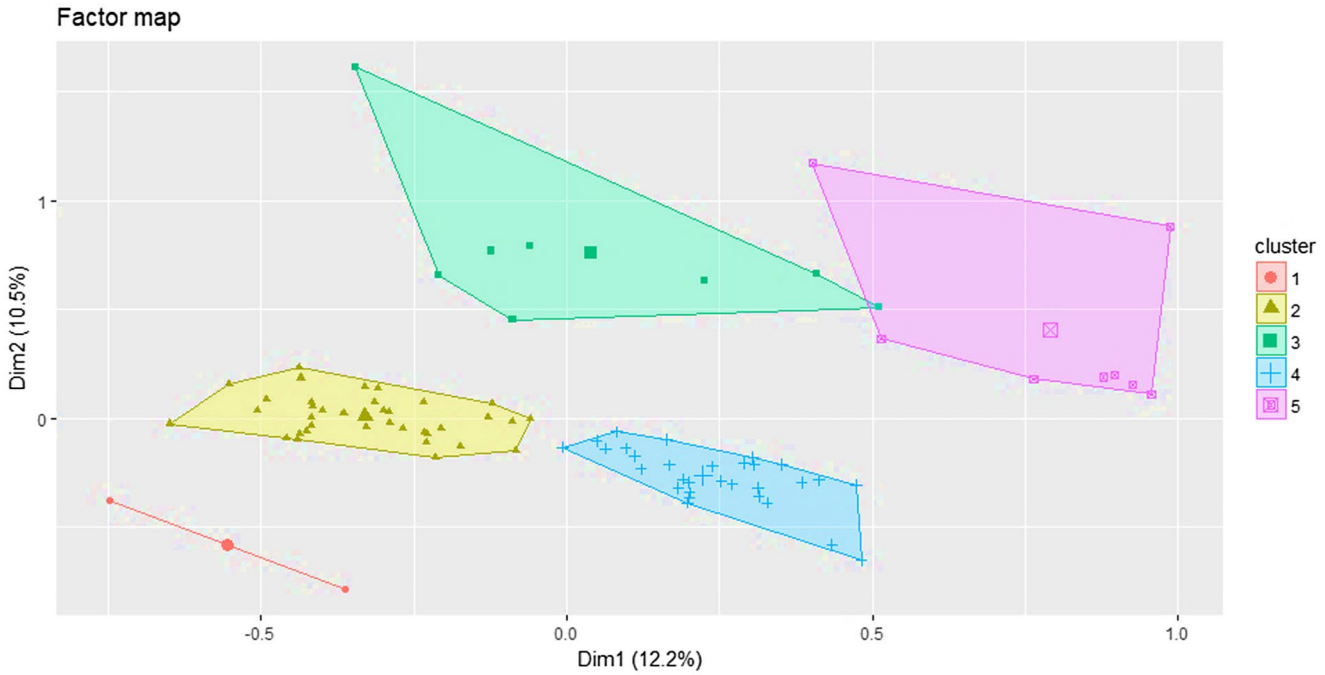

FIGURE 4 Ticks and tick-related damages perception factor map of the herders

In the control of ticks, herders mentioned that they used both conventional methods such as veterinarian products (acaricides) and unconventional methods such as manual removal and insecticidal sprays. Additionally, application methods of products may differ accordingly.

The majority of herders (97%) used acaricides to treat their cattle against tick infestations. The main active substance used by 68% of the herders is amitraz. The principal origin of the acaricides is the 'unregulated market' (51%) and 47% of herders are supplied by the veterinary services in both countries. Interestingly, there is no significant difference concerning the place of supply in acaricidal products according to the country ($p > 0.05$). The majority of herders do not follow the usual dose of this acaricide. The survey revealed that 84% of the herders overdosed amitraz when they used it and 5% of them underdosed it. A multinomial logistic regression model showed that there was no significant difference in the frequency of use of the various acaricides between the two countries ($p > 0.05$).

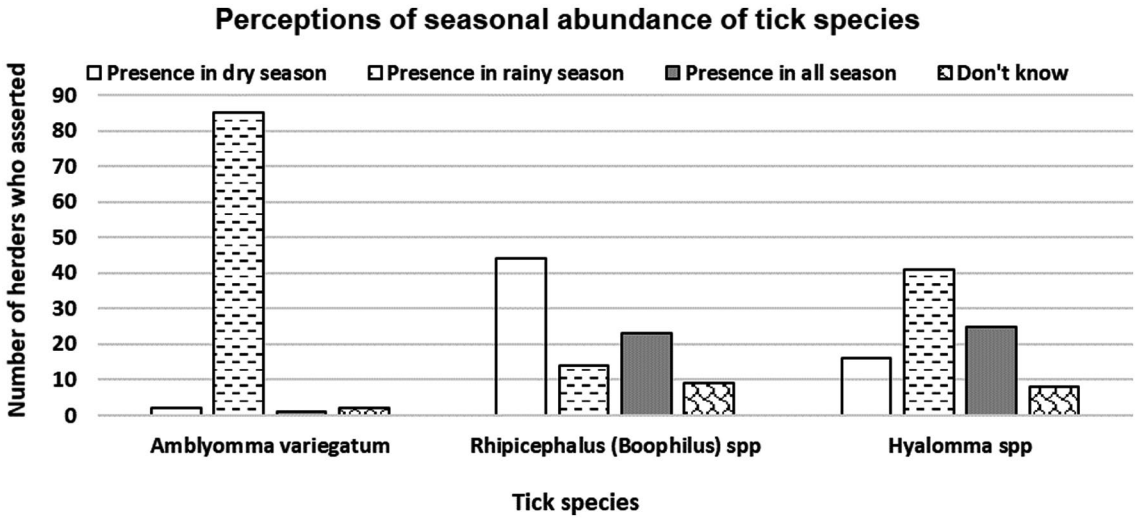

FIGURE 5 Perceptions of seasonal abundance of tick species

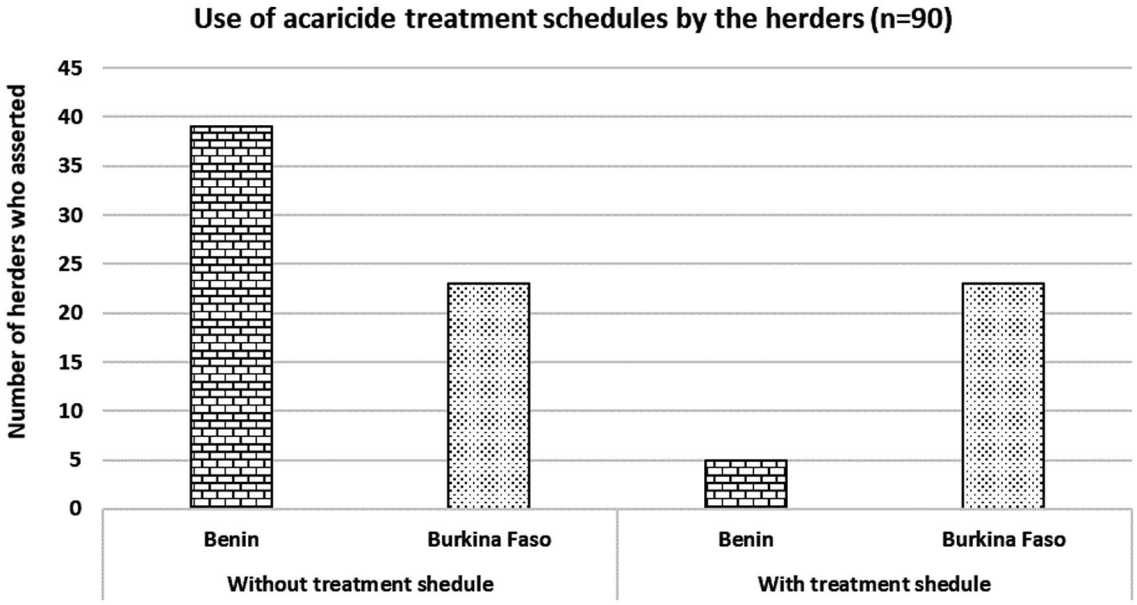

FIGURE 6 Use of acaricide treatment schedules by the herders ($n = 90$)

During this survey, information were collected on five main methods of tick control. The most frequently reported method was swabbing (56%). This method is used to apply the main acaricide which contains amitraz. They also use manual spraying (23%), pour-on (16%), manual removal (6%) and insecticidal sprays (1%).

Results also indicated that cattle herders in Benin planned acaricide treatment less frequently compared to those in Burkina Faso (Figure 6). A logistic regression model showed that Benin breeders used almost eight times less acaricide schedules (Odds ratio = 7.8; $p < 0.05$). In both countries the herders who practice transhumance used significantly almost three times more acaricide treatment schedules compared to those who are sedentary (Odds ratio = 3.22; $p < 0.05$).

3.4 | Perception of herders on tick-related damages on cattle

Dermatosis is the most frequently cited damage caused by ticks (i.e. 96% of the cattle herders reported it). In Burkina Faso, all herders reported this disease as the major consequence of the presence of ticks on the cattle, whereas in Benin, 91% of them asserted it. Lameness (2%) is the less reported consequence of tick's presence on cattle. In Burkina Faso, 4% of herders declared ticks cause lameness but in Benin, no cattle keeper mentioned it as a consequence of ticks presence on their cattle (Table 3).

Injuries (57%), milk reduction (48%) and mortality (47%) are the other important consequences of the presence of ticks on cattle according to the cattle keepers. Herders also reported TBD (18%),

TABLE 3 Tick-related damages on cattle

Departments	Injuries	Teats lost	Dermatosis	Milk reduction	Mortality	Abortion	Weight loss	Lameness	Tick-borne diseases	Myiasis
Alibori	8	10	10	6	7	0	5	0	1	1
Atacora	7	7	8	4	5	2	1	0	3	0
Borgou	9	14	14	6	6	0	0	0	5	0
Donga	6	8	8	7	2	3	3	0	3	0
Benin (Herders)	30	39	40	23	20	5	9	0	12	1
Benin percentage (%)	**68**	**89**	**91**	**52**	**45**	**11**	**20**	**0**	**27**	**2**
Gourma	6	15	16	6	9	1	1	2	0	0
Kompienga	9	11	15	9	8	1	3	0	0	0
Tapoa	6	15	15	5	5	2	0	0	4	4
Burkina Faso (Herders)	21	41	46	20	22	4	4	2	4	4
Burkina percentage (%)	**46**	**89**	**100**	**43**	**48**	**9**	**9**	**4**	**9**	**9**
Overall total	51	80	86	43	42	9	13	2	16	5
Percentage (%)	**57**	**89**	**96**	**48**	**47**	**10**	**14**	**2**	**18**	**6**

The bold values are the percentage of the herders who asserted that the corresponding tick-related damages are recorded in their herds. The percentages are calculated by each country (Northern Benin and Eastern Burkina Faso) and in all the study region (Overall values).

weight loss (14%), abortion (10%) and myiasis (6%) as damages caused by ticks.

Teats loss is one of the most tick-related damages on cattle reported by 89% of herders. A Poisson regression model with the incidence rate ratio (IRR) option allowed us to notice that there were significantly 1.35 times less cows which lost teats because of ticks in Benin compared to those in Burkina Faso (IRR = 1.35; $p < 0.05$). In addition according to the statements of herders in the both countries, transhumant herds presented 1.40 times rate more cows which have lost teats because of ticks compared to the non-transhumant herds (IRR = 1.40; $p < 0.05$).

Hyalomma spp. were most cited as responsible for teat losses of cows in Burkina Faso, whereas *A. variegatum* was most cited in Benin but there was no significant difference (multinomial logistic regression) with regard to the species of tick responsible for the teats' losses of cows.

4 | DISCUSSION

4.1 | Social groups

Several social groups were present within the study area, but the Fulani group were more dominant, and mainly engaged in livestock keeping. This corroborates the findings in the study of Basset *et al* (Bassett & Turner, 2007). The majority of herders (78%) were from this social group as also demonstrated in other previous studies (Adehan et al., 2018; Alkoiret, 2009). The Fulani also known as Fulbe, constitutes one of the largest and most widely spread social groups in Sub-Saharan Africa. They are living in some 20 African countries from Senegal to Sudan and bearing at least 13 names in West Africa alone (Iro, 1994). They are known for their pastoral traditions, although in the course of their long migration from the Senegal Basin eastwards after the 10th century, some of them had given up pastoralism and the nomadic way of life and shifted to agriculture or various urban sources of livelihood (Virtanen, 2015). Cattle farming is ancestral, cultural and sociological in this social group. This activity is exclusively dedicated to men. Women are associated to the management of milk, one of the cattle farming products (Ayoade et al., 2009; Micere Njuki et al., 2016; Yisehak, 2008). Transhumance is the main farming mode practiced by Fulani herders (Ayantunde et al., 2014; Bassett & Turner, 2007; FAO, 2012). The history identifies the Fulani as people who use mobility as production and consumption strategy. Movements in search of water, markets, pasturage, salt licks and the highly priced crop residues account for the spread of the Fulani in Sub-Saharan Africa. A good knowledge on the social groups that manage the cattle farming is an important asset useful for veterinary services for disease control and elaborate adapted awareness messages.

4.2 | Main activity and the level of education of the herders

The principal activity of the herders is cattle farming (91%) and they start this activity at a very young age. Similar finding was observed in Nigeria, where Fulani own over 90% of the livestock population, which accounts for one-third of agricultural GDP and 3.2% of the entire GDP of the country (Iro, 1994). This activity is passed on from father to son. The son starts leading cattle to grazing at around 7 or 8 years

old (Ouoba, 2018). He does not get the opportunity to attend primary school. His principal activity until he gets married is to lead cattle to pasture. When he reaches the age to get married, his father will give him a part of the family herd to provide for his wife and children. It will be the same thing with his son. However, some of herders attend to Koranic School (24% of them according to this study). A few of them attained primary education (9%) and secondary or beyond (10%). The literacy rate of adults over 15 years of age was around 34.5% in Burkina Faso in 2014 (Institut national de la statistique and et de la démographie (INSD) Burkina Faso, 2015) and 38,4% in Benin in 2015 (Ministère du Plan et du Développement du Bénin, 2018). The literacy rate of cattle farmers from the present study is lower than the overall rate in their respective countries. The elaboration and implementation of various diseases control strategies should consider this situation.

4.3 | Practice of transhumance

Globally, 60% of the herders involved in this study practice transhumance. According to the World Bank, pastoralism represents an important part of the entire stock-raising sector in West Africa, where it covers between 70 and 90 per cent of cattle raising and 30–40 per cent of small ruminants (SWAC/OECD, 2007; World Bank, 2013).

Internal transhumance is practiced during all seasons. The herders (20%), in partnership with farmers, stay in the farms during the dry season when their bovines eat crop residues and fertilize the farms with their faeces. It is a win–win partnership between farmers and cattle keepers. When the rain starts, they move towards the uncropped areas to graze. These movements are local in the same country. The transboundary transhumance takes place in the dry season. In some areas such as Sahelian countries, harvested residues cannot feed all the livestock. Hence, a relatively big proportion of the livestock (40%) have to move towards less dry countries to find water and grass. Agro-pastoral livestock farming is prevalent throughout West Africa. Animals move within Sahelian countries, from Sahelian countries to coastal countries and within coastal countries (SWAC/OECD, 2014).

Otherwise, animals' mobility (e.g. transhumance) is cause of disease spread. This cattle farming strategy has the double effect of bringing pathogens or vectors to the arrival area or exposing healthy animals to new diseases by leading them to contaminated places (Kardjadj et al., 2019). For instance, the north of Benin is known to be infested by the invasive tick species *R. microplus* that is not yet found in the eastern Region of Burkina Faso. These frequent movements of cattle between the two countries can lead to the contamination of the free areas. The veterinary authorities should increase herder's awareness of this issue.

4.4 | Knowledge of herders on cattle tick seasonality

The surveyed herders assert that ticks are more abundant in the rainy season than the dry season as many authors have already shown (Biguezoton, 2016; Fantahun, 2012; Farougou, 2006, 2007; Keesing et al., 2018; Mattioli et al., 1997; Mulilo, 1985). This pattern is most characteristic for two or three-host tick species (*Amblyomma* spp. *Hyalomma* spp. and *Rhipicephalus* spp.) (Biguezoton et al., 2016). However, ticks belonging to the genus *Rhipicephalus* (*Boophilus*), mainly one-host tick species, are reported to be more present in the dry season, compared to rainy season (Adehan et al., 2018; Biguezoton et al., 2016). In fact, one-host tick species adult stage is observed mainly during dry season in contrast to two-or three-host tick species for which dry season mainly correspond to nymph stage. During rainy season when adult stage of two- and three-host tick species occurs, *Rhipicephalus* (*Boophilus*) adult ticks are also present but with less abundance than in dry season. Herders could not perceive such differences. However, possible confusion of the engorged nymph of *A. variegatum* with engorged female of *Rhipicephalus* (*Boophilus*) spp. could be raised from perception of herders on ticks.

The other ticks of the genus *Rhipicephalus* spp. (not *Boophilus*) are not well known by herders. This genus is rare among cattle herds, so cattle keepers are not familiar with them. The only one species we collected in our study area is *Rhipicephalus sanguineus*, a species usually found on dogs and herders who know it clearly called it 'Dog's tick' in the local language.

4.5 | Tick control

In general, this study shows that herders do not comply with withdrawal periods for milk and meat. One explanation of the apparent absence of intoxication will be that the main acaricide used is amitraz, which has no residues in milk and meat (De Meneghi et al., 2016). Furthermore, herders avoid applying the acaricide directly on cow's udders and teats to avoid mechanic contamination of milk during cow's milking. This mode of treatment highly decreases the risk of milk contamination by those acaricides. A study should be carried out to determine the eventual contamination of milk by these acaricides according to their real mode of application.

Assessment of the origin of the acaricides showed that 51% came from unregulated markets where the sellers do not comply with the storage conditions (temperature, lighting and humidity) prescribed by the manufacturers. Such practice can affect the quality of the products and favour the emergence of resistance of ticks to these acaricides. The origin and quality (real nature and dosage of the active substance) of these products sold on the unregulated market is unknown. This is a great challenge for the veterinary authorities in charge of veterinary drug control to break up the supply chain of these products. The West African Economic and Monetary Union (UEMOA) policies on veterinary drugs control require a community Marketing Authorization (MA) for all veterinary drugs before their introduction in any country of the union since 2006. Unfortunately, majority of the acaricides used by cattle keepers are from the black market without Marketing Authorization. Authorities should better regulate the sector to allow effective control of ticks with registered acaricides

of good quality. Cattle keepers need good quality acaricides at affordable prices to abate the invasive resistant ticks in their herds. *R. microplus* is known to be an invasive tick species spreading in West Africa since 2000 and is resistant to most of the usual acaricide applied by West African herders. *R. microplus* had shown its resistance to Amitraz and Alpha-cypermethrin (Adehan et al., 2016; Muyobela et al., 2015). The non-compliance with the prescribed dosage of acaricides can also affect their efficacy on ticks. Our survey revealed that 84% of the herders overdosed the most commonly used acaricide "amitraz" when they use it and 5% of them underdosed it. Furthermore, herders in Benin used less acaricide treatment schedules than those from Burkina. The sedentary herders used less acaricide treatment schedules compared to their transhumant counterpart. This behaviour of herders can favour the emergence of ticks' resistance to acaricides and complicate tick control. Veterinary services should develop simple and clear protocols for acaricidal treatments with precise timetables. Then, training and awareness-raising sessions for cattle farmers on the importance of adherence to these procedures should be organized on a periodic basis until these measures are fully adopted.

4.6 | Tick related damages on cattle

Ticks are responsible for many damages on cattle. For instance, 69% of the surveyed herds had cow that had lost teats because of ticks. The first consequences of this situation will be the reduction of milk production of these cows and the increase in the mortality of calves because of malnutrition. According to this survey, the species of ticks cited mostly by herders as responsible for teats losses are respectively *Hyalomma* spp. (53%) and *A. variegatum* (36%). However, the proportions change according to countries. In Benin, herders asserted that *A. variegatum* (28%) and *Hyalomma* spp. (25%) are the ticks mainly responsible for injuries and teats lost. This is not different from previous results in the region (Adehan et al., 2018; Biguezoton et al., 2016; Farougou, 2007). On the contrary, Burkina Faso herders assert that *Hyalomma* spp. (48%) is the first tick responsible for injuries and teats lost, followed by *A. variegatum* with 22%. There was no significant difference concerning the species of tick responsible for the teats' losses of cows. According to the previous abundance studies implemented in this region, the *Hyalomma* genus is more abundant in the eastern of Burkina Faso than *Amblyomma* genus and vice versa in the northern of Benin (Biguezoton et al., 2016; Farougou, 2006, 2007). This observation corroborated the perception of cattle herders about the ticks responsible for cow's teats losses. These two genera reported by herders as responsible for skin damages on cattle are all long hypostome ticks. Therefore, the structure and the size of the hypostome participate to the level of skin traumatism of the tick's bites. Furthermore, many studies have revealed that the predilection sites of *Hyalomma* and *Amblyomma* species on cattle bodies are the perineum region, udder/scrotum and under tail were its hiding sites (Alemu & Chanie, 2012; Meskela & Gashaw, 2017; Ndhlovu et al., 2009; Rehman et al., 2017).

According to some herders, these ticks cause injuries on cow's teats and these injuries attract flies. The presence of flies and ticks maintains wounds that become infected and do not heal quickly. Sometimes flies lay their eggs inside these injured tissues and the larvae develop as part of their life cycle inside the wounds and cause the decay of teats.

Our results also show that herds in Burkina Faso comprise significantly more cows with teats lost than those from Benin. Transhumant herds comprise more cows that lost teats compared to sedentary herds. To avoid milk contamination with acaricides, herders do not apply the product on cow teats. Ticks are removed manually on teats. During transhumance, this method is difficult to apply because animals are too excited and the contention is complicated. Therefore, this cattle management strategy (i.e. transhumance) increases the damage caused by ticks in the herds.

Another finding of this survey is that cattle keepers of the area have little awareness and knowledge of TBD. Only 18% of them asserted that ticks could transmit diseases to their host cattle. Some of TBD and trypanosomiasis have similar symptoms. Most of herders often use drugs against trypanosomiasis. As trypanosomiasis is a frequent disease they face in herds in this part of Burkina and Benin, it is easy for them to mistaken trypanosomiasis for TBD. Moreover, some products use to control trypanosomiasis are also effective against some TBD.

4.7 | Ticks and tick-related damages on cattle perception groups

Epidemiological clusters 2 and 4 indicate an almost even split in the perception of the importance of ticks for milk drop and dermatosis, suggesting the herders have no consensus. It also means a large portion of herders' opinions is incorrect. If the cause is not correctly associated with the condition, control strategies will not adequately address the issue.

Epidemiological clusters 1, 3 and 5 indicate that some tick species, unknown from the herder, can be not perceived as a problem and will therefore not be controlled effectively. This is because they are unfamiliar with these tick species, which were not present in their areas before, and/or they have not been receiving any information about them either from other herders or from information sources. If these tick species are present but not recognized by uninformed transhumant herders, this can lead to tick range expansion and possible associated acaricide resistance.

If the information is not shared uniformly between herders, the knowledge clumps among certain people, probably related to geographic distance. This results into divergent perceptions and strategies for animal management and disease control. These divergent strategies will cause gaps in animal and disease management practices, which can induce the spread of ticks and especially, in case of transhumant herders.

Indeed, in case of irregular release of information by word-of-mouth, the information tends to remain localized. In order to prevent further knowledge and practice gaps, it is therefore crucial to recommend proper and uniformed channels of information to the herders. In addition, a special attention should be given to the seasonal activities of the tick species and the seasonal treatments by acaricides.

5 | CONCLUSION

This study enabled a better understanding of the perception of herders about ticks and tick-related damages on cattle. Cattle keepers demonstrated a high level of awareness on the seasonal tick abundance and their main visible effects on cattle such as dermatosis, wounds and teat losses. Tick-borne diseases did not appear to be well known by breeders. Therefore, sensitization campaigns are needed especially on the various diseases transmitted by ticks and the available suitable treatments. This is very important because there are some zoonoses transmitted by ticks that can represent a real hazard to the cattle herders. The survey also permitted us to appreciate the way the herders managed and controlled tick infestations in their herds. The principal active substance in the acaricides currently used to control the tick infestations in the cattle herds in the study area is amitraz. The majority of the herders do not follow the dosage of acaricides used. Unfortunately, more than 50% of the acaricides used are provided by the unregulated market, where quality is not guaranteed. This highlights a serious problem, given that the source and quality of veterinary drugs are contributing factors that induce the development of acaricide resistance. This study shows also that transhumance is contributing factor to cow's teats losses. Furthermore, the frequent stay of transhumant herds from Burkina Faso in the north of Benin could result in the spread of *R. microplus* in the eastern region of Burkina Faso where this species has not yet been found.

ETHICS STATEMENT

The activities of the research project 'Support to epidemio-surveillance networks for animal diseases and associated sociological aspects in West Africa (Acronym: TransTicks)' have received the favourable opinion of the Ethics Committee of the International Centre for Research and Development on Livestock in Subhumid Zones (CIRDES) (Ref. 001-02/2017/CE-CIRDES) under the strict respect of the protocol submitted to the members of the Committee and their unannounced control.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Olivier Zannou: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Validation; Writing-original draft. **Achille Ouedraogo:** Formal analysis; Investigation; Validation; Writing-review & editing. **Abel Biguezoton:** Conceptualization; Funding acquisition; Project administration; Resources; Writing-review & editing. **Patrick Yao:** Conceptualization; Funding acquisition; Investigation; Project administration; Writing-review & editing. **Emmanuel Abatih:** Methodology; Writing-review & editing. **Souaibou Farougou:** Conceptualization; Supervision; Writing-review & editing. **Laetitia Lempereur:** Conceptualization; Funding acquisition; Investigation; Project administration; Supervision; Validation; Writing-review & editing. **Claude Saegerman:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing-review & editing.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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