Farmer-Herder Conflicts and Livelihood Vulnerability Nexus: An Indexing Approach Based on Structural and Processual Perspectives

Suhiyini Issah, Alhassan[1, 2]; Marième, Pouliot[2]; Boateng, Kyereh[1]; Mercy Afua Adutwumwaa, Derkyi[3]

[1]Department of Silviculture and Forest Management, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[2]Global Development Section, Department of Food and Resource Economics, University of Copenhagen, Denmark

[3]Department of Forest Science, University of Energy and Natural Resources, Sunyani, Ghana

Correspondence: issahsuhiyini@yahoo.com

Abstract

This paper assessed livelihood vulnerability to farmer-herder conflicts using an indexing approach and Tobit regression. Primary data was collected through focus group discussion, key informant interviews and a survey conducted on 500 randomly selected households in Asante Akim North and Sekyere Afram Plains Districts in Ghana. The results show significant differences in livelihood vulnerability to FHC among different occupational groups. Whereas livelihoods of sedentary herding and farming households are the most exposed to FHC, transhumant herding households' livelihoods are most sensitive to FHC. Overall, the results show that conflict exposure and sensitivity contribute more to livelihood vulnerability to FHC than lack of adaptive capacity. Crop/cattle damage, access to land and proximity of farming and cattle grazing sites significantly increase households' vulnerability to FHC. Based on these findings, the paper concludes that policy interventions should focus on conflict exposure and sensitivity factors, such as improving farmer-herder relations through dialogues and building trust in the institutions managing the conflicts.

Key Words: Farmer-Herder Conflict, Livelihood, Vulnerability, Weighted Vulnerability Index

1.0 Introduction

In many African countries, farmers and herders engage in conflicts over natural resources to grab and control the right to use land and other natural resources and secure their livelihoods (Benjaminsen, 2009; Nwangwu & Enyiazu, 2019). Efforts to understand these conflicts tend to focus on the causes of the

conflict (Yakubu et al., 2021; Kugbega & Aboagye, 2021; Benjaminsen et al., 2009; Benjaminsen & Ba, 2021; Brottem, 2016; Diogo et al., 2021, Moritz, 2010; Dary et al., 2017; Wafula et al., 2022). These studies have used environmental scarcity (Scoones et al., 2019; Tonah, 2006; Abubakari & Longi, 2014; Oyama, 2014; Walwa, 2020; Ntangti et al., 2019), political ecology (Bukari, 2022; Moritz, 2006; Mbih, 2020; Benjaminsen & Ba, 2019; Benjaminsen et al., 2009; Okoli & Atelha, 2014) or processual perspectives to understand the conflicts (Moritz, 2010; Bukari, 2017; Malthaner, 2017; Hansen & Natland, 2017).

According to Herbert (2017), long-term or systematic reasons for conflict embedded in a society's norms, structures, and policies are known as structural conflict drivers. The structural factors are also known as the root, underlying or proximate factors responsible for the conflict and include climate change, increased livestock and human population densities, crop destruction/killing of cattle, rapes and competition for land and water (Tonah, 2006; Walwa, 2020; Yakubu et al., 2021). The environmental scarcity approach views conflicts as emanating from competition over scarce resources (Homer-Dixon, 1999). Environmental scarcity attributes conflict over the natural resources to absolute, relative, and political scarcity of resources. On the other hand, political ecology approaches natural resource conflicts from the perspective of the relationships among political, economic and social factors with changes in environmental issues. It relies on power relations to explain how environmental resource governance leads to conflicts (Benjaminsen et al., 2009). Thus, based on the political ecology approach, vulnerability to farmer-herder conflicts result from environmental changes, national governmental land-use policies, economic interests of government administrators, rent-seeking behaviors of corrupt government officials, and failure of national and international institutions to satisfy demands of natural resources users (Mbih, 2020; Benjaminsen & Ba, 2019; Bukari (2022). The major limitation of the structural approach is that if all conflicts were to be explained by the same underlying factors as portrayed, then the intensity of conflict would have been the same, which is never the case (Moritz, 2010). Thus, the intensity of conflict vulnerability depends on the process leading to the conflict outcome not just the triggers or underlying conflict drivers.

The processual approach to studying conflict vulnerability emphasizes the process leading to conflict over natural resources. It theorizes that the process or relationships between conflicting parties influence conflict dynamics as much as structural factors do. From the observations of Moritz (2010), the factors responsible for the process of conflict vulnerability between farmers

and herders differ by culture, participation in conflict resolution and relationship between conflicting parties. Thus, the intensity of farmer-herder conflict vulnerability differs by the process leading to the conflicts. He also notes that structural or processual factors alone cannot explain the complexity of farmer-herder conflict vulnerability, but, a combination of both (Moritz, 2010). This paper does not intend to contribute to the discourses on the causes of farmer-herder conflicts. Instead, using the structural and processual conflict theories, we go goes beyond the conflict causes to assess the differences in livelihood vulnerability to farmer-herder conflict among different socio-economic groups. Whereas conflict causes are the sources or triggers of conflicts, conflict vulnerability is affected by the sources of the conflict as well as the dynamics, trends, consequences and impact of conflict based on the interaction of internal idiosyncratic capacities of an individual or group and external factors (Ahmed & Gassmann, 2010).

In recent times, vulnerability has attracted attention due to its importance in assessing the impacts of natural hazards and other shocks, such as conflicts, and the responses they generate. This field of study draws on various scholarly traditions, including political economy, risk/hazard studies and ecology (Cutter 1996; Eakin & Luers, 2006; Wisner et al. 2004). Vulnerability has been defined as a state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt (Adger, 2006; IPCC, 2007). Vulnerability is, thus, commonly viewed as a function of three interactive components: exposure to stresses, sensitivity to those stresses and adaptive capacity to respond to the consequences of those sensitivities (IPCC 2001, 2007; Lei et al., 2013; Sen, 1981). Whereas exposure is the extent to which an individual/group of individuals is/are unprotected from the risk or shock of a change or conflict (IPCC, 2007, Turner et al., 2003), sensitivity refers to the level an individual or group of individuals is/are affected by risk, shock or conflict either positively or negatively, covertly or overtly (Fussel & Klein, 2006; IPCC, 2007). Adaptive capacity, on the other hand, refers to the ability of an individual or group of individuals to reduce the possible consequences of a shock or risk using prevailing opportunities (IPCC, 2007; Adger, 2006).

There is general agreement that vulnerability is a more precise concept than poverty in analyzing the process, causes and impacts of shocks (Hilhorst & Bankoff, 2022). Not all poor people are

vulnerable to shocks, and the vulnerability of poor people has different roots. Additionally, some people who are not poor can still be considered vulnerable. For efficient assessment of household- and community-level livelihood susceptibility to hazards such as conflict, research that categorizes the five livelihood assets (human, social, physical, natural and financial) into the three vulnerability components (exposure, sensitivity and adaptive capacity) is needed (Lin and Polsky, 2015). However, this has not been given much attention in the livelihoods literature. While the main advantage of the vulnerability concept is the universal application of its three components to different types of stresses and human-environment systems, one of its main challenges is that vulnerability is not easily measured (Adger, 2006). As a dynamic phenomenon, the measurement of vulnerability must be based on socioeconomic processes and material outcomes within complicated socio-ecological systems (Adger, 2006).

In the social sciences, and particularly in the field of sustainable livelihoods, there have been efforts to develop quantitative metrics for vulnerability to study how it develops across time and locations (Kamanou & Morduch, 2004; Alwang et al., 2001; de Leon, 2006; Fletcher et al., 2013; Gertitz et al., 2014; Adger, 2006). One of the most promising developments about measuring vulnerability has been the design of indices which incorporate indicators of households' exposure, sensitivity and adaptive capacity (e.g. Hahn et al., 2009, Okpara et al., 2017, Sen, 1981; Alhassan et al., 2018, 2019; Huang et al., 2015). The benefit of the indexing approach is that it goes beyond using income for poverty analysis to include livelihood asset deprivation of marginalized populations. Also, in the indexing approach, it is possible to identify specific assets deprivation which development interventions can then target to improve livelihoods (Hahn et al., 2009). Studies on vulnerability using an indexing approach such as Hahn et al. (2009), Okpara et al. (2017), Alhassan et al. (2018, 2019), Fletcher et al. (2013), Gerlitz et al. (2017) and Carraro & Ferrone (2023) assessed households vulnerability to climate change, environmental risks, shocks and hazards. However, these studies are limited by the use of equal weights for vulnerability indicators, lack of theory underpinning the studies and are often centred on spatial vulnerability by comparing vulnerability across different locations. Thus, the concept of livelihood vulnerability to natural resource conflicts has not been given much attention (Andrade-Ayala et al., 2019; Gaillard et al. 2009; Lazarus, 2011), especially how livelihood vulnerability to natural resource conflicts vary across different livelihood strategies (Lin & Polsky, 2015).

This study answers two main questions: First, which livelihood strategy (farming, sedentary herding, transhumant herding, agro-pastoralists and other occupations) is most vulnerable to farmer-herder conflicts? Second, what factors influence households' livelihood vulnerability to farmer-herder conflict? We contribute to the literature on livelihood vulnerability to conflict by combining access to livelihood assets into vulnerability indicators based on structural (environmental scarcity and political ecology) and processual conflict theories to conceptualize livelihood vulnerability to farmer-herder conflict using empirical evidence from households in farmer-herder conflict hotspots in Ghana. In this paper, we argue that whereas transhumant herders' livelihood vulnerability is driven by environmental factors and poor relations with other natural resource users, physical location factors such as siting farms along cattle movement routes are responsible for farmers' livelihood vulnerability. We also argue that exposure and sensitivity factors contribute more to livelihood vulnerability to conflict than lack of adaptive capacity among households. In view of the above, we demonstrate that measuring vulnerability and studying its determinants is an essential tool for policy recommendation as it enables researchers to identify the livelihood strategies most affected by a conflict and how they are affected.

2.0 Methodology

2.1 Description of Study Area

The study was conducted in Asante Akim North Municipality and Sekyere Afram Plains District in the Ashanti Region, two conflict hotspots in Ghana. Asante Akim North Municipality has a total land area of 1218 km^2, constituting 5% of the Ashanti Region's total land size and 0.5% of the total land area of Ghana with a population of 85,788 inhabitants (GSS, 2021). The population of Sekyere Afram Plains District is 32,640 and covers a total land size of 3436 km^2, constituting about 14.1% of the region's land area (GSS, 2021). Four seasons are distinguishable in the two districts: the main dry season (December – April), the first rainy season (May – July, peaking in June), the minor dry season (July – August) and the second rainy season (September – November). The main vegetation in the two districts is open forests, closed forests and wooded savannah, with elephant grasses conducive for crop cultivation and livestock rearing. The indigenous Ashantis and different groups of migrants cohabit in the study area. The migrant ethnic groups include some Akans, Dagombas, Gonjas, Nanumbas, Konkobas, and Grunsi (from

Northern Ghana), Ewes from southeastern Ghana and the Fulbe (Fulani) from northern Ghana, Burkina Faso, Nigeria, and Niger (GSS, 2012; Tonah, 2006). The Afram River passes through the two districts and attracts migrant farmers and herders from adjourning districts from Ashanti, Eastern and Northern Ghana. The main economic activities in the area are farming and herding, with farmers cultivating mainly plantain, yam, cassava, maize, rice, and vegetables (GSS, 2019). Figure 1 is a map of Asante Akim North Municipality and Sekyere Afram Plains District, showing the study communities.

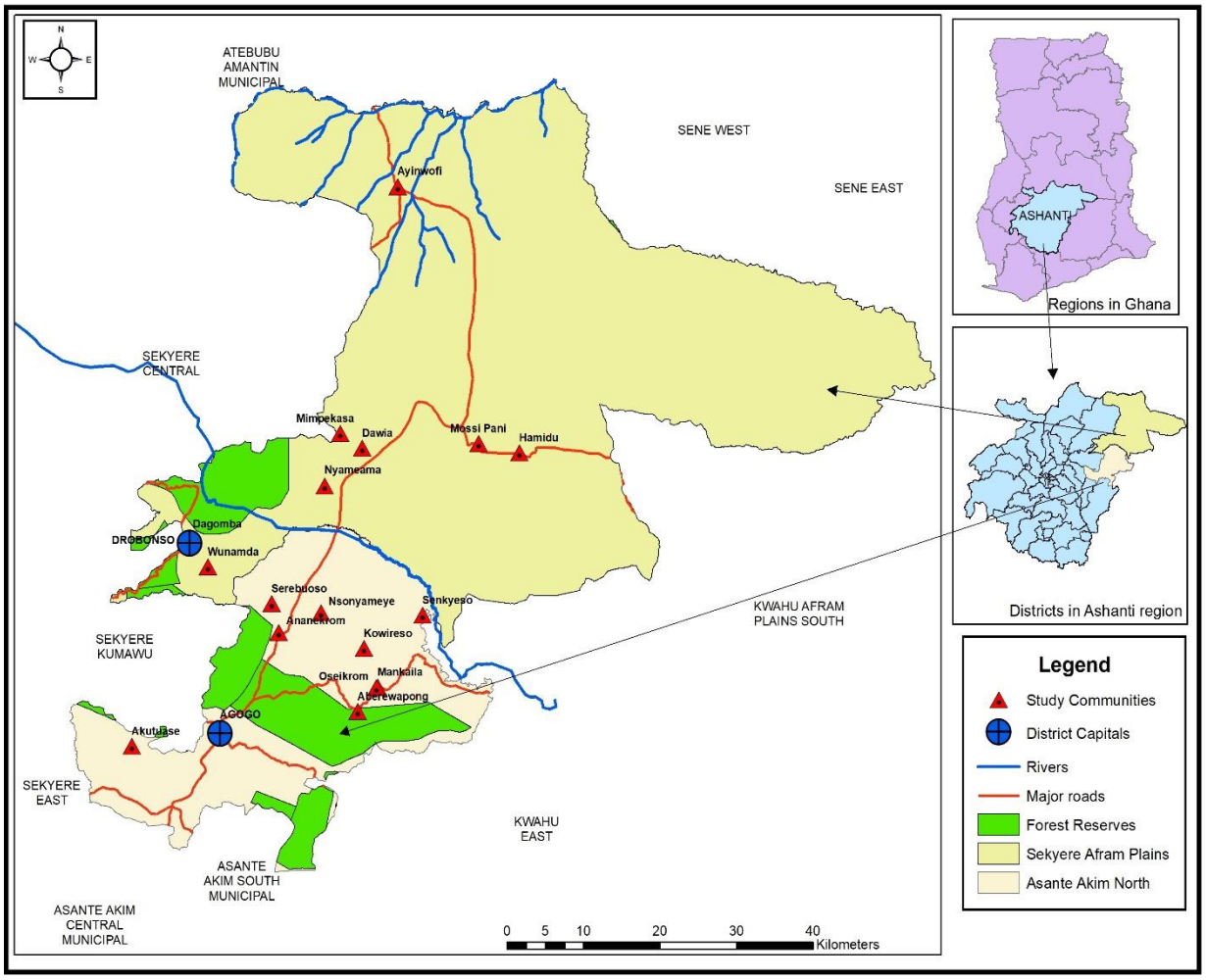

Figure 1: Map of Asante Akim North Municipality and Sekyere Afram Plains District showing Study Communities

Source: Department of Geography and Resource Development, University of Ghana, 2022

2.2 Sources of Data and Sampling Techniques

The main data source for this study was collected from 500 households through a household survey. A multi-stage sampling technique was used to select respondents for the household survey. In the first stage, Ashanti Akim North and Sekyere Afram Plains Districts were purposively selected for a case study because these are farmer-herder conflict hotspots in Ghana. Also, farmers in Ashanti Akim North are largely indigenes with access to land, while Sekyere Afram District is primarily inhabited by migrants from other regions of Ghana who have limited access to land and other productive resources. In each district, a list of communities was obtained from the district assembly and clustered into conflict-prone communities (Dawia, Dagomba, Hamidu, Wunamda, and Nyameama № 2 in Sekyereh Afram Plain District and Kowiresu, Nsonyemenye, Mankala, Oseikrom, Serebuoso, and Senkyeso in Asante Akim North District) and non-conflict-prone communities (Mimpekassa and Anyinofi in the Sekyere Afram Plains District and Akutuase and Abrewapong in the Asante Akim North District). This was done with the help of staff from the District Assembly and assembles members. A community is considered conflict-prone if farming and herding activities have been undertaken in the community in the past five years, and they have reported crop destruction by cattle, cattle-killing, and/or violent confrontation between herders and farmers. Within each community, we listed households through a mini census to ascertain the total number of households. Households were then stratified based on occupation. The number of households selected from each community was proportional to the total number of households in the community. Finally, simple random sampling was used to select households. Selected households were visited to explain the study's essence, sought their consent, and administered a questionnaire to the household head and/or representative(s).

In addition, four focus group discussions were conducted (two in each district) to assign weights to farmer-herder conflict vulnerability indicators and main components. Each FGD comprised the assembly person for the electoral area, a committee member from each of the study communities within the electoral area, a representative of the community chief, women and men leaders, as well as leaders of farmers and herders associations. Participants of FGDs were asked to assign weight to each conflict indicator and main component based on their perceived relative importance of the indicator/component to conflict vulnerability. Participants used stones to complete this exercise by assigning more stones out of 50 stones to conflict indicators or components based on their perceived contribution of the indicator or component to households'

vulnerability to conflict. We ensured all-inclusive participation and consensus among participants in assigning weights. The weights from the four FGDs were averaged for each indicator and component to ascertain common weights for computing the index. Also, qualitative data were collected through key informant interviews (staff of the Ministry of Food and Agriculture, assemble members, leaders of farmer and herder groups) and focus group discussions with male and female farmers and herders. The purpose of these qualitative data was to triangulate and provide explanations for the results of the household survey quantitative data.

2.3 Methods of Data Analysis

2.3.1 Computing the Livelihood Vulnerability to Farmer-Herder Conflict Index (LVFHCI)

Before collecting data, the specific conflict vulnerability indicators were identified through a literature review. The applicability and relevance of these indicators were done through an initial field visit to the study area during which farmers, herders, chiefs, district assembly staff and assembly persons, NGOs and Civil Society Organisation working in the area, Ministry of Food and Agriculture stakeholders were asked to review the data collection instruments. Thus, some of the conflict indicators identified in the literature were dropped because they are not relevant in the current study area, while other indicators which were originally not identified from the literature but were identified as relevant by respondents (example, the presence of Konkomba ethnic group in communities, farm or kraal location, type of crop cultivated, number of economic activities and number of different crops cultivated or livestock reared by household) during the field visit were included in the list of conflict indicators in the actual survey. As indicated earlier in the introduction section, these conflict indicators included structural and processual conflict vulnerability indicators and which are grouped into seven main categories (appendix A).

Given that conflict and livelihood indicators are measured using different units and scales, it is practically infeasible to aggregate them into a uniform index (Alhassan et al., 2019; OECD, 2008). Therefore, the first stage in computing the LVFHCI is to bring the structural and processual conflict indicators (appendix A) to a uniform and comparable scale for aggregation into a single index using the OECD (2008) zstandardization formula. Based on Alhassan et al. (2019), equation (1) is used where the conflict indicator has a positive effect on livelihood vulnerability to conflict, while equation (2) is used for conflict indicators with a negative effect

on livelihood vulnerability to conflict based on literature and respondents' perception on the effect of conflict indicators on LVFHCI (appendix A).

$$SVI_{hi} = \frac{VI_h - Min_{VI}}{Max_{VI} - Min_{VI}} \quad (1)$$

$$SVI_{hi} = \frac{Min_{VI} - VI_{hi}}{Max_{VI} - Min_{VI}} \quad (2)$$

Where SVI_{hi} is the standardized or normalized value for conflict vulnerability indicators *i* for household *h*, VI_{hi} is the observed value of indicator *i* for household *h*, and Max_{VI} and Min_{VI} are the maximum and minimum values, respectively, for the indicator *i* in the combined data.

The second stage in computing the LVFHCI is multiplying the standardized conflict indicators by their respective weights (%) assigned during the community-focused group discussion discussed in Section 2.2. Thus, since all indicators do not contribute equally to livelihood vulnerability to conflict, the standardized conflict indicators are weighted using equation (3).

$$SVI_{hiw} = SVI_{hi} \times VI_{wi} \quad (3)$$

Where SVI_{hiw} is the weighted standardized value of livelihood vulnerability indicator *i* for household *h*, and VI_{wi} is the weight assigned to livelihood vulnerability indicator *i*. The weighted standardized livelihood vulnerability indicators constituting each main vulnerability component is summed to ascertain the value of the main conflict vulnerability component, as shown in equation (4).

$$MC_{hc} = \sum_{i=1}^{n} SVI_{hiw} \quad (4)$$

Where MC_{hc} is the value of main component *C* for household *h*, and *n* is the number of conflict vulnerability indicators constituting main vulnerability component *C*.

Given that all conflict components do not contribute equally to vulnerability, the main components are also weighted by multiplying the values of each MC_{hc} by their respective weights assigned through community engagement.

$$MC_{hcw} = MC_{hc} \times C_{wc} \quad (5)$$

Where MC_{hcw} is the weighted index for main component *C*, MC_{hc} is the computed value of main component *C* for household *h*, and M_{wc} is the community assigned weight or score for main conflict component *C*.

The LVFHCI is computed from the weighted indices of the main vulnerability components by aggregating the weighted values of all seven main vulnerability components as presented in equation (6).

$$LVFHCI_h = \sum_{c=1}^{7} MC_{hcw} \quad (6)$$

Where $LVFHCI_h$ is the computed Farmer–Herder Conflict Vulnerability Index for household *h*. The $LVFHCI_h$ is a ratio that ranges between 0 and 1. The higher the index, the higher the vulnerability to farmer-herder conflict and vice versa.

To compute the livelihood vulnerability contributors, the main conflict vulnerability components are categorized into exposure (climate/environmental factors and availabilities of natural resources and physical factors), adaptive capacity (socio-political network, socio-demographic and livelihood strategies) and sensitivity (governance of land, water and forest resources and farmer-herder relations) for policy recommendation. Thus, the livelihood vulnerability to farmer-herder conflict contributory factors (adaptive capacity, sensitivity and exposure), CCF_j are computed by averaging the main components constituting each contributory factor, using equation (7).

$$CCF_f = \frac{\sum_{f=1}^{n} MC_{hcw}}{N} \quad (7)$$

Where *N* is the number of main conflict vulnerability components under the conflict contributory factor *C*. The Kruskal-Wallis H test was used to test for differences in the computed indices for all conflict vulnerability indicators, seven main components, overall vulnerability index, and vulnerability contributors for the five occupational groups. Also, qualitative data from focused group discussions and key informant interviews were zanalyzed to complement the quantitative analysis using thematic and content analysis.

2.3.2 Tobit Regression Estimation of Factors Influencing Households' LVFHCI

The Tobit regression was used to model the factors influencing households' livelihood vulnerability to farmer-herder conflict because we need to censor zero observations (non-vulnerable households). According to Tobin (1958), the general specification of the Tobit model is given as:

$$y_i = x_i\beta_i + \varepsilon_i \quad (8)$$

Where y_i is a latent dependent variable, x_i denotes exogenous covariates, ε_i is the error term assumed to be normally distributed with zero means and constant variance and β_i is the associated parameter estimates. The latent dependent variable (y_i) is observed when $y^* > \tau$ as given in equation (9).

$$y_i = \begin{cases} y^* & if \;\; y^* > \tau \\ \tau & if \;\; y^* \leq \tau \end{cases} \quad (9)$$

In a classical Tobit regression model, $\tau = 0$ (Tobit, 1958). The observed variable (y^*) is the computed farmer-herder conflict vulnerability index (LVFHCI) and is a ratio ($0 \leq LVFHCI \leq 1$). This study adapted the classical Tobit model by censoring at y = 0. Thus, y_i is observed when $y^* > 0$. The empirical Tobit model is given by equation (10).

$$y^*(LVFHCI > 0) = \beta_0 + \beta_1 S + \beta_2 E + \beta_3 L + \beta_4 I + \varepsilon_i \quad (10)$$

Where β_0 denotes a constant term, *S* denotes socio-demographic characteristics of households, *E* denotes environmental factors, *L* denotes location factors, and *I* denotes institutional factors. β_1 to β_4 are parameters to be estimated from the model. Homoscedastiicity was ensured by using the robust Tobit regression and enabling the robust standard errors command in the STATA Software. Appendix B presents a description, measurement and a prior expectation of variables considered in the Tobit regression model.

3.0 Results

Before computing the LVFHCI, all the conflict indicators were correlated to avoid multi-collinearity in the computed vulnerability indices. Of the 43 conflict indicators, 10 were dropped for high correlation with other indicators. Thus, the LVFHCI was computed using 33 indicators. Also, there was a 100% response rate from sampled households, and the Fisher's Exact results on

missing data for a few survey questions showed no significant difference in missing data by districts and occupation. Therefore, there is no significant bias in the interpretation of computed indices.

3.1 Comparison of LVFHCI by Livelihood Strategy or Occupation

While households in the Asante Akim North Municipality are generally shown to be less vulnerable to farmer-herder conflict than households in the Sekyere Afram Plains district (Table 3), the Tobit regression results show that livelihood strategies (occupation) have a significant effect on households' livelihood vulnerability to farmer-herder conflict ($P<0.10$) with households in Asante Akim North Municipality being less vulnerable to farmer-herder conflict than households in the Sekyere Afram Plains district. In this section, we compare the main vulnerability components and vulnerability contributors accounting for the difference in households' livelihood vulnerability to farmer-herder conflicts among occupational groups (farmers, sedentary herders, transhumant, agro-pastoralists and other occupations). In each case, a comparison is made by the vulnerability main components and the vulnerability contributors (exposure, sensitivity and adaptive capacity) to farmer-herder conflicts. The weights, maximum and minimum values and computed indices of conflict vulnerability indicators are presented in appendix C.

Results of the Kruskal-Wallis test (Table 1) show that households' livelihood exposure to conflict ($X^2 = 20.906$, $P<0.01$), adaptive capacity ($X^2 = 49.408$, $P<0.01$) and livelihood sensitivity to the conflict ($X^2 = 8.664$, $P<0.10$) varies significantly among occupational groups. This is consistent with the Tobit regression results, which show a significant effect of occupation on households' livelihood vulnerability to farmer-herder conflict (Table 3). Results of the computed vulnerability contributory factors (Table 1) show that for all occupational groups, vulnerability to farmer-herder conflict is driven more significantly by conflict exposure (climate /environmental factors and availability of natural resources and physical factors) and conflict sensitivity factors (farmer-herder relations and governance of land, water, and forest resources) than adaptive capacity factors (livelihood strategies, socio-demographic factors, and socio-political network).
We computed indices for the seven main components of the LVFHCI and compared them across livelihood strategies/occupations. Results of the Kruska-Wallis test show no significant

difference in livelihood vulnerability to conflict among the different occupational groups regarding socio-demographic characteristics and livelihood strategies. On the other hand, the computed leading vulnerability indices (Table 1) show that transhumant herding households (0.75) are significantly most vulnerable in terms of climate change/environmental factors (X^2 = 40.65, P<0.01) than farming (0.73), sedentary herding (0.69), agro-pastoralists (0.60) and other occupations (0.68) households. The computed indices further show that sedentary herding households (0.55) are significantly most vulnerable than farming (0.47), agro-pastoralists (0.45), transhumant herding (0.45) and other occupations (0.30) households in terms of availability of natural resources and physical factors (X^2 = 12.54, P<0.05). The Kruskal Walis test results (X^2 = 30.221, P<0.01) also show a significant difference in livelihood vulnerability to conflict among livelihood strategies in terms of socio-political networks, and the computed vulnerability indices show that sedentary herding households (0.51) are significantly most vulnerable than agro-pastoralists (0.47), transhumant herding (0.32), farming (0.46), and other occupation (0.32) households. Results of the Kruska-Wallis test on the computed indices further show that the effect of farmer-herder relations on livelihood vulnerability differs significantly among occupation (X^2 = 68.40, P<0.01) and agro-pastoralist households (0.39) are the most vulnerable in terms of farmer-herder relations. Finally, the Kruskal Wallis results show a slightly significant difference (X^2 = 9.139, P<0.10) in the governance of land, water and forest resources main component among livelihood strategies or occupation with transhumant herding households (0.42) being the most vulnerable than farming (0.31), sedentary herding (0.31), agro-pastoralists (0.29) and other occupation (0.33) households. Table 1 presents the computed main component indices and Kruskal Wallis test results.

We also computed indices for the three vulnerability contributors (exposure, sensitivity, and adaptive capacity) and compared across the different livelihood strategy groups. The results of computed vulnerability contributors indices (Table 1) show that livelihoods of transhumant herding households (0.17) are significantly more sensitive to farmer-herder conflicts than farming (0.15), agro-pastoralists (0.13), sedentary herding (0.13), and other occupation (0.13) households. The Kruskal Wallis test results and computed vulnerability indicator indices show that the reason for livelihoods of transhumant herding households' higher sensitivity to farmer-herder conflict is because they are significantly more vulnerable than other households in terms

of conflict-induced migration (0.23), using dialogue to resolve farmer-herder conflicts (0.77), land tenure (0.49), access to land (0.60) and sharing of water with other natural resource users (0.90). This affects transhumant herding households' rapport with sedentary herders and farmers. In terms of exposure to farmer-herder conflict, the computed vulnerability indices reveal that livelihood of sedentary herding (0.19) and farming (0.19) households are significantly more exposed to farmer-herder conflicts than transhumant herding (0.18), agro-pastoralist (0.16) and other occupations (0.15) households. Results of conflict vulnerability indicator indices show that whereas farming households' exposure is due to the availability of fertile lands (0.85) and farm location (0.98), sedentary herding households' livelihood exposure to farmer-herder conflict is because they are significantly most affected when crops are destroyed or cattle are killed (0.79). Finally, farming (0.12) and agro-pastoralists (0.12) households are significantly more vulnerable in terms of adaptive capacity than sedentary herding (0.11), transhumant herding (0.10) and other occupation (0.09) households. Whereas farming households' low adaptive capacity can be attributed to trusting in traditional authority (0.42) and security (0.59), Konkomba ethnic group (0.13) and group farming (0.58); agro-pastoralist households' low adaptive capacity is because they do not trust the security services and hence do not report conflict cases to them for mediation (0.63) (appendix C).

Overall, livelihoods of transhumant herding (0.45) and farming (0.45) households are more vulnerable to farmer-herder conflicts than sedentary herding (0.43), agro-pastoralists (0.41) and other occupation (0.37) households. It was revealed in focus group discussions with herders and farmers, as well as key informant interviews, those transhumant herders migrate from other regions of Ghana to communities in Ashanti Akim North and Sekyere Afram Plains Districts from late November to early April each year in search of pasture and water for their cattle. These movements are often at the night and tend to cause crop destruction, a reason for transhumant herders' poor relationship with other natural resource users. Key informant interviews and focus group discussions show that sedentary herding households' livelihoods are more exposed because they are often victims of crop destruction and lose their cattle through reprisal attacks from farmers and interventions by the Ghana Police Service. On the other hand, transhumant herders have lost trust in the traditional authority and the Ghana Police Service because they often unduly extort money from them for crop destructions. This is why they do not want to dialogue in settling farmer-herder conflicts.

Table 1: Results of Computed Indices by Occupation and Kruskal-Wallis – test of Main component and Contributory Factors

FHCVI Main component/ Contributory factor	**Computed Main Component Index by Occupation**					**Kruskal-Wallis H Test**	
	Other Occupations	**Farmer**	**Sedentary Herders**	**Transhumant**	**Agro-Pastoralist**	**Chi^2 (4)**	**P-value**
LVFHCI Main Component							
Climate and environmental factors	0.68	0.73	0.69	0.75	0.60)	40.650***	0.000
Availability of natural resources and physical factors	0.30	0.47	0.55	0.45	0.45	12.540**	0.018
Farmer-herder relations	0.34	0.36	0.36	0.25	0.39	68.400***	0.000
Livelihood strategies	0.23	0.24	0.32	0.25	0.21	1.015	0.908
Socio-demographic characteristics	0.21	0.24	0.25	0.32	0.33	1.625	0.804
Socio-political network	0.32	0.46	0.51	0.32	0.47	30.221***	0.000
Governance of land, water, and forest resources	0.33	0.31	0.31	0.42	0.29	9.139*	0.063
LVFHCI Contributory Factors							
Exposure	0.15	0.19	0.19	0.18	0.16	20.906***	0.000
Sensitivity	0.13	0.15	0.13	0.17	0.13	8.664*	0.070
Adaptive Capacity	0.09	0.12	0.11	0.10	0.12	49.408***	0.000
Overall FHCVI	0.37	0.46	0.43	0.45	0.41	42.587***	0.000

Note:

***, ** and * denote statistically significant at 1%, 5% and 10% respectively

Source: Analysis of Field Data, 2022

3.2 Factors Influencing Households' Vulnerability to Farmer-Herder Conflict

The Tobit regression results show that the log-likelihood ratio Chi^2 (336.68) is highly significant ($P<0.01$), indicating that the error term is normally distributed and fits the data in modelling the factors influencing households' livelihood vulnerability to farmer-herder conflict. The results show that environmental factors significantly influence households' vulnerability to farmer-herder conflict. All three environmental factors (climate-induced population growth, dependence on natural water, and access to land) are highly significant ($P<0.01$) and increase livelihood vulnerability to farmer-herder conflict. The results show that 30.5% of households (Table 2) in Asante Akim North District perceived the influx of immigrants into their communities due to the effects of climate change; this compares to 20.3% of households in Sekyere Afram Plains District (Table 2). Also, whereas more households (88.0%) in the Ashanti Akim North District depend on natural water than in Sekyere Afram Plains (83.4%), more households in Sekyere Afram Plains (18.7%) reported availability of land for expansion of production than in Ashanti Akim North District (14.7%). Key informant interviews and focus group discussion results show that farmers rely on the River Afram, which passes through both districts and other water bodies, for dry-season farming. Similarly, herders, especially transhumant from the Eastern Region and other parts of the country, frequently bring their cattle to the study areas for pasture and water between November and April every year when there are not enough pasture and water for their cattle in the dry season.

The results further show that more households in the Sekyere Afram Plains district (25.7%) have their farms situated close to cattle grazing sites or cattle graze close to farm sites than in the Ashanti Akim North district (14.3%). The Tobit regression results (Table 3) show that the location of households and the farm or cattle grazing site significantly influence households' livelihood vulnerability to farmer-herder conflict. Farms along cattle movement routes or grazing sites are significantly more prone to destruction ($P<0.01$). Similarly, cattle grazing near farm sites are more likely to graze the crops. The results show that households in the Ashanti Akim North district ($P<0.10$) are less vulnerable to farmer-herder conflicts than those in Sekyere Afram Plains.

Between the two institutional factors, only households' reporting conflicts with other parties to authorities for dialogue has a significant effect ($P<0.01$) on reducing livelihood vulnerability to

farmer-herder conflicts. Thus, households who trust mediating institutions and use them to engage with disputing parties in settling conflict significantly reduce their vulnerability to the conflict. The results show that going forward, most households in both districts (77.2%) are willing to dialogue with conflicting parties to resolve farmer-herder conflicts rather than engage in violent conflicts. However, most households do not trust the mediating institutions, especially the Ghana Police Service and the traditional authorities. Participants of community-focused group discussions with farmers and herders expressed their willingness to rely on community-level dispute resolution committees to resolve farmer-herder conflicts rather than resorting to the security service and traditional authorities.

Finally, results on the socio-demographic characteristics revealed that both age and sex of household heads have no significant effects on households' vulnerability to farmer-herder conflicts. Membership with social groups (such as farmer-based associations, herders associations, and religious associations) is highly significant ($P<0.01$) and reduces households' livelihood vulnerability to farmer-herder conflicts. Focus group discussions with farmers reveals that farmers who belong to farmer associations often visit their farms in groups to avert any attacks from other parties and get assistance from group members to harvest their crops early to avoid crop destruction. Similarly, herders who move in groups have more control over their cattle to prevent straying cattle from crop destruction and assist in resolving issues for members when their cattle destroy farmers' crops. More households in the Sekyere Afram Plains district (62.2%) belong to social groups than in the Ashanti Akim North district (51.7%), which enhances their adaptive capacity. Though farmer-herder conflict does not discriminate based on households' origin, the results show that being an indigene has a slightly significant effect ($P<0.10$) in reducing households' livelihood vulnerability to farmer-herder conflict. The results show more indigene households in the Ashanti Akim North district (45.6%) than Sekyere Afram Plains district (13.7%). During a focus group discussion, it was mentioned that chiefs often pursue herders to pay compensation to farmer victims who are indigenes than migrants.

The results further show that the occupation of households has a significant effect on vulnerability to farmer-herder conflicts, with farmers and transhumant herders being more vulnerable ($P<0.05$). The results show that there are more farming (74.1%) and transhumant herding (12.4%) households in the Ashanti Akim North district than in the Sekyere Afram Plains

district (Table 2). The descriptive statistics of variables considered in the Tobit regression model are presented in Table 2, while Table 3 presents the Tobit regression results of factors influencing households' vulnerability to farmer-herder conflicts.

Table 2: Descriptive Statistics of Independent Variables for the Tobit Regression

Variable	Ashanti Akim North		Sekyere Afram Plains		Combined	
	№ of households	%	№ of households	%	№ of households	%
Number of households	259	51.8	241	48.2	500	100
Sex (Male)	156	60.2	183	75.9	339	67.8
Membership in Social group	134	51.7	150	62.2	284	56.8
Residence Status (Indigene)	118	45.6	33	13.7	151	30.2
Occupation:						
Farming	192	74.1	174	72.2	366	73.2
Sedentary herding	17	6.6	16	6.6	33	6.6
Transhumant herding	32	12.4	10	4.2	42	8.4
Agro-pastoralist	2	0.8	23	9.5	25	5.0
Others	16	6.2	18	7.5	34	6.8
Climate-induced population growth	79	30.5	49	20.3	128	25.6
Dependence on natural water	228	88.0	201	83.4	429	85.8
Land availability for expansion	38	14.7	45	18.7	83	19.0
Location of farm/kraal	37	14.3	62	25.7	99	19.8
Differences in political and economic opportunities	34	13.1	43	17.8	77	15.4
Willingness to dialogue on conflict	196	75.7	190	78.8	386	77.2
Trust in security	64	24.6	66	27.5	130	26.0
Trust in traditional authority	113	43.5	161	67.1	274	54.8

Source: Analysis of Field data, 2022

Table 3: Tobit Regression Results on Factors Influencing Households' Vulnerability to Conflict

Independent Variable	Coefficient	Std Err
Socio-Demographic Variables		
Age	0.003	0.003
Sex (Male)	-0.001	0.006
Membership in social group	-0.028***	0.006
Residence status (Indigene)	-0.006*	0.003
Occupation		
Farming	0.039**	0.013

Sedentary herding	0.019	0.027
Transhumant herding	0.090**	0.022
Agro-pastoralism	0.041	0.027
Environmental factors		
Climate-induced population growth	0.049***	0.007
Dependence on natural water	0.085***	0.009
Access to land	0.040**	0.002
Location factors		
Farm/kraal location	0.105***	0.008
District (Asante Akim North Municipality)	-0.014***	0.007
Institutional factors		
Differences in political & econ opportunities	-0.002	0.001
Willingness to dialogue on conflict	0.014***	0.002
Constant	0.530***	0.035
Model Diagnoses		
Number of observations	308	
LR Chi2 (15)	336.68	
Prob > Chi2	0.0000	
Pseudo R2	0.5633	
Log likelihood	-467.1718	

Note:

*, ** and *** denote statistically significant at 10%, 5% and 1% respectively

Source: Authors' Analysis of Field Data, 2022.

4.0 Discussion

4.1 Unearthing Livelihood Vulnerability in Conflict Situations

Our study re-categorizes the five livelihood assets (human, social, physical, natural and financial) into exposure, sensitivity and adaptive capacity as vulnerability contributors. This makes it easy to identify which livelihood assets should be targeted to reduce households' livelihood vulnerability to the conflict, which is missing in previous studies (Lin and Polsky, 2015). As much as the findings show that structural factors such as the availability of natural resources and climate and environmental factors contributes greatly to households' livelihoods vulnerability to the conflict, the dynamics of the process in accessing these resources such as natural resource governance, farmer-herder relations and socio-political networks are equally important contributors to vulnerability. Thus, unlike previous studies which relied on either structural approach (Abubakari & Longi, 2014; Benjaminsen & Ba, 2019; Benjaminsen et al., 2009; Bukari, 2022; Moritz, 2006; Mbih, 2020; Ntangti et al., 2019; Okoli & Atelha, 2014; Oyama, 2014; Scoones et al., 2019; Tonah, 2006; Walwa, 2020) or processual approach (Bukari,

2017; Hansen & Natland, 2017; Malthaner, 2017) to explore conflict vulnerability, our findings demonstrate the significant contributions of both structural and processual indicators to conflict vulnerability and therefore justify the need to combine both approaches in assessing households' livelihood vulnerability to the conflict as proposed by Moritz (2010).

Our findings further show that livelihood vulnerability is highly dynamic and varies among occupational groups. Also, the findings indicate that social relations among households who are dependent on natural resource and their quest for economic wellbeing through resource exploitation are the main indicators of livelihood vulnerability to conflict. This is consistent with Adger (2006) who showed that vulnerability is a dynamic phenomenon and that its measurement needs to consider the socio-economic processes and material outcomes across time and location. Unlike many livelihood vulnerability studies which are limited by the assumption of equal weights for vulnerability indicators in computing vulnerability indices (Alhassan et al., 2018, 2019; Carraro & Ferrone, 2023; Fletcher et al., 2013; Gerlitz et al., 2017; Hahn et al., 2009; and Okpara et al., 2017), the computed vulnerability indices in this paper, including weights, presents a more realistic view of the conflict situation at the community level.

4.2 Which Livelihood Strategy or Occupation is more Vulnerable to Farmer-Herder Conflict and Why?

Our findings reveal that households' exposure and sensitivity to conflict, adaptive capacity and overall vulnerability to farmer-herder conflict differ significantly between households with different main occupations. Overall, farming households are the most vulnerable to farmer-herder conflict while other occupations such as trading, formal employment, charcoal production, etc. are the least vulnerable. These findings have two implications: first, it suggests that households' vulnerability to the conflict differ by their main occupation. Secondly, the finding suggests that farms and grazing sites should not be located at close proximity or adjacent each other, but need to be separated to reduce households' exposure to crop destruction and cattle killing. Contrary to Diogo et al. (2021) who reported that agro-pastoralist livelihoods were most vulnerable to farmer-herder conflicts due to their inexperienced herding, this study reveals that whereas livelihoods of farming and sedentary herding households are vulnerable to farmer-herder conflict because of crop destruction, transhumant herding households' livelihoods are

vulnerable to farmer-herder conflicts because of climatic and environmental factors. The reason for transhumant herders' high vulnerability is that they continue to migrate in search of water and pasture for their herds. This finding is consistent with earlier studies such as Brottem (2016), Diogo et al. (2021) and Wafula et al. (2022), who relied on the environmental scarcity theory to show that farmer-herder conflicts in African countries stem from environmental factors which significantly drive pastoralists' migration during dry/drought seasons in search for water and pasture for their cattle in most agro-pastoral communities.

This study shows that farming and sedentary herding households' livelihoods are the most exposed to farmer-herder conflicts. In many cases, straying cattle destroy farms located on their routes, and once the affected farmers do not identify herders of such cattle, sedentary herding households are usually compelled to pay compensation. Furthermore, crops cultivated along water bodies in the dry season, such as the River Afram, are often exposed to destruction by cattle. This finding is consistent with earlier findings in Kenya, Nigeria, central Mali, and Northern Burkina Faso (Brottem, 2021; Dary et al., 2017; Tonah, 2006; Wafula et al., 2022; Yakubu et al., 2021).

This study also shows that transhumant herding households' livelihoods are the most sensitive to farmer-herder conflict; this emanates mainly from their poor relations with other natural resource users as well as issues relating to land governance and water resources. Transhumant herders are often unwilling to resort to dialogue in resolving crop destruction and the killing of cattle. They often think they will have to pay higher compensation fees for victims of crop destruction. As a consequence, they either migrate from communities when they envisage looming reprisal attacks on their cattle by farmers for crop destruction, or they revenge the killing of their cattle by attacking farmers in the hinterlands or allowing their cattle to graze on crop fields, especially when they are compelled to pay compensations to farmers for crop destruction. This confirms an earlier report by Kuusaana & Bukari (2015), who revealed that in the Asante Akim North District, vulnerability to farmer-herder conflicts results from the eroding trust in chiefs due to their corrupt deals and indiscriminate selling of land. Similar to Benjaminsen & Ba (2021), who reported that the Malian Government defeated the Fulani herder jihadists using the Dogon militia ethnic group in Central Mali, our findings indicate that transhumant herding households often avoid herding activities along Konkomba settled communities for fear of losing their cattle

through attacks by Konkomba farmers. This is consistent with Abroulaye et al. (2015), Adeniran (2020), Brottem (2021) and Napogbong et al. (2021) report of farmer-herder relations as the main vulnerability indicator of farmer-herder conflicts in Nigeria, Central Mali, Burkina Faso, and Upper West Region of Ghana.

We imply from our results that climatic and environmental factors heavily account for transhumant herding households' livelihood vulnerability to farmer-herder conflicts. These findings resonate with the environmental scarcity and eco-survivalism theories, which state that the increasing competition for diminishing scarce natural resources for survival among resource users and harsh climatic conditions are responsible for the worsening of farmer-herder relations in the Sahel region and most African countries (Blench, 1996; Okoli & Atelhe, 2014; Olaniyan, 2015; Tonah, 2000; Turner, 2003). In the Sahel and Eastern Africa, Hussein (1998) reported that herders' vulnerability to farmer-herder conflict depends on the availability of the burgu grass for cattle grazing in the region. The finding is also consistent with Napogbong et al. (2021), who reported that herders in the Kpongu community in the Wa Municipality of Ghana are most vulnerable to farmer-herder conflict due to scarcity of feed and fodder, water and high temperatures. Similar findings were reported by Wafula et al. (2022), who revealed that transhumant herders' migration in Kenya in search of pasture and water resources, especially during drought seasons, is the reason for their high vulnerability. Finally, we found that most migrant households, especially transhumant herders who do not own land, find it difficult to access land and have lower stake in the governance of natural and physical resources compared to indigenous farming and herding households. This finding is consistent with Bisson et al. (2021), who revealed that in Burkina Faso, natural resource governance characterized by exclusion and marginalization of pastoralists in access to land and water resources was the main contributory factor to pastoralist-farmer conflict vulnerability.

4.3 What Factors Contribute to Household Vulnerability to Farmer-Herder Conflict?

Households' livelihood vulnerability to farmer-herder conflicts is driven by the bimodal rainfall experienced in the study area, available fertile land for arable crop cultivation and pasture (especially the elephant grass, which is highly nutritious for cattle) which pulls factors attracting migrant farmers and herders from other parts of Ghana and West Africa to the study area. Farming households rely on the River Afram and other district water bodies for dry-season

farming. Similarly, herders, especially transhumant from the Eastern Region and other parts of the country, always bring their cattle to the study areas for pasture and water between November and April every year. These findings are consistent with earlier empirical findings from West and Central Africa, Gombe State of Nigeria and Rural Northern Ghana (Brottem, 2021; Napogbong et al., 2021; Yakubu et al., 2021).

Also, farms located along cattle movement routes or grazing sites are prone to destruction by cattle. Previous studies have been silent on farmers' encroachments on cattle movement routes. In this current study, we observed that in their poise to evade rent payments to landlords and chiefs, farming households sometimes squat in the hinterlands, which appear to be migration routes or grazing sites for herders and their cattle. This renders farming households more exposed to crop destruction. Similarly, cattle grazing near farm sites are more likely to graze on crops and therefore attract farmers' fury. The significant effects of farmers and herders' encroachment into each other's' territory on their vulnerability to crop destruction and the killing of cattle appears to be a common observation in many farmer-herder conflict studies in Nigeria, Northern Cameroon, and Ghana (Yakubu et al., 2021; Tellen et al., 2014; and Dary et al., 2017).

Unlike the Ashanti Akim North District, cattle grazing are officially accepted in the Sekyere Afram Plains District, needed for the celebration of the periodic traditional festivals. Also, as reported by GSS (2021), Sekyere Afram Plains has vast land (14.5% of the Asante Regional land area) and is the least populated district in the region (9.5 persons/km^2). These attract migrant farmers and herders to compete for the available land and water. Similar to Kuusaana & Bukari (2015) report, cattle owners and herders are perceived to have more wealth and can pay higher prices for land than farm owners and farming households. Hence, landlords reallocate pieces of land that farmers originally used to herders who offer higher prices. Hence, access to agricultural land is based on households' ability to afford the cost of land and there appears to be who are unable to pay the price of land. Thus, similar to Scoones et al. (2019), there appears to be economic scarcity of land but not physical land scarcity in the study districts.

The findings of this study indicate that going forward, dialogue between farmers and pastoralists supported by Government and traditional authorities could help reduce livelihood vulnerability to farmer-herder conflicts. However, the eroding trust in the Ghana Police also reported the traditional authorities as mediators of farmer-herder conflicts (as also reported by Kuusaana &

Bukari, 2015) is paving the way for the emergence of new institutions at the community level in resolving farmer-herder conflicts. The reason is consistent with Hyman et al. (2020), who revealed that there is weakening effectiveness of modern and traditional authorities' role in resolving disputes among farmers and pastoralists in most African countries. Chiefs often seek compensation payments from farmers or cattle owners who are indigenes than migrant victims. This finding differs from Kugbega & Aboagye (2021), who reported that indigene farmers in the Agogo Traditional Area were most vulnerable to farmer-herder conflict because of land tenure insecurity resulting from denial of their usufruct land use right by land owners who preferred to allocate more land to wealthy migrant pastoralists for economic gains. However, our findings are consistent with Kuusaana & Bukari (2015), who found that the farmer-herder conflict in the Ashanti Akim North district is formulated along ethnicity and migrant-indigene basis, with pastoralists and migrant farming households, often being discriminated against in terms of land allocation and administration of justice.

4.4 Limitations of the Study

The study is limited by its inability to measure livelihood vulnerability to farmer-herder conflicts using an absolute scale. It only compared livelihood vulnerability to farmer-herder conflict among the occupational group as vulnerability is measured using the same indicators and weights. This limitation, however, applies to most other vulnerability indices. Also, the study did not include females from herding households but interviewed both male and female farmers. Thus, the study's finding is without the views of females from herding households. Their exclusion was due to socio-cultural limitations where males of herding households in the study area speak for women in their households and do not allow 'strangers' to interact with them.

5.0 Conclusions and recommendations

The study shows that the livelihoods of farming and transhumant herding households are more vulnerable to farmer-herder conflicts than sedentary herding and agro-pastoralists households. However, whereas livelihoods of farming and sedentary herding households are most exposed to farmer-herder conflict than all other occupational groups due to crop destruction and cattle killing, transhumant herding households' livelihoods are the most sensitive to farmer-herder conflict due to their poor relationship with other natural resource users. Vulnerability to farmer-herder conflicts is significantly influenced by environmental and physical location factors such

as farming along cattle movement routes and competition for the same piece of land for pasture and crop cultivation. We further conclude that livelihood vulnerability to farmer-herder conflict is mainly driven by sensitivity and exposure factors, including farmer-herder relations and governance of land, water, and forest resources. These are more political ecology and processual factors than structural factors. Finally, we conclude that most households do not trust traditional authorities and the security service in mediating farmer-herder conflicts but are willing to dialogue with disputing parties in resolving farmer-herders conflicts.

Based on these conclusions, it is recommended that interventions into farmer-herder conflicts should be targeted at exposure and sensitivity factors. Thus, efforts should improve trust and farmer-herder relations to foster social cohesion through regular communicative engagements between farmers and herders. Also, local governments (the district assemblies) should facilitate the formation of committees at the community level (consisting of both farmers and herders) as mediation platforms charged with the responsibility of fairly listening, negotiating, and resolving farmer-herder conflicts. Since exposure is the major contributor to households' livelihood vulnerability to farmer-herder conflicts, the Government or traditional authorities should designate grazing reserves with buffer zones to prevent intermittent conflicts between farmers and herders arising from regular interactions of farming and herding activities.

Appendix A: Components and indicators of Livelihood Vulnerability to Farmer-Herder Conflict Index (LVFHCI)

Main component	Indicator	Explanation	Measurement Unit	Expected effect on FHCVI	Reference
Exposure					
Climate / environmental factors	Fertile land	Respondents' perception on available fertile lands for crop farming in the past 15 years	1 = available, 0 = otherwise	+	Appiah-Boateng and Kendie (2021), Ahmadu (2011)
	Available pasture	Respondents' perception of available pasture for cattle grazing in the past 15 years	1 = available, 0 = otherwise	+	Appiah-Boateng and Kendie (2021), Ahmadu (2011)
	Climatic factors	Respondents' perception of climatic conditions (rains & temperatures)	Dummy: 1 = favourable, 0 = otherwise	+	Abroulaye et al. (2015), Brottem (2021)
Availability of natural resources and physical factors	Farm destroyed / cattle killed	Size of farm destroyed by cattle (or number of cattle killed)	Acres (number of cattle)	+	Abroulaye et al. (2015), Adeoye (2017), Dary et al. (2017)
	Crops cultivated	Does the household cultivate crops preferred for cattle grazing? (Plantain, maize, yam, cassava)	Dummy: 1 = yes, 0 = otherwise	+	Authors (2022)
	Farm location characteristics	Do other farms completely surround farm?	Dummy: 1 = yes, 0 = otherwise	-	Authors (2022)
	Cattle movement corridors	Availability of cattle movement corridors (including water points, grazing reserves, campsites)	Dummy: 1 = Yes, 0 = otherwise	+	Adeoye (2017), Dary et al. (2017)
	Harvest of forest resources	Does the household harvest forest products	Dummy: 1 = Yes, 0 = otherwise	+	Authors (2022)
	Water contamination	Is natural water often contaminated by cattle or farming activities	Dummy: 1 = Yes, 0 = otherwise	+	Dary et al. (2017)

Main component	Indicator	Explanation	Measurement Unit	Expected effect on FHCVI	Reference
Adaptive Capacity					
Socio–political network	Visit farms or herd cattle in a group	Does the farmer (or herder) visit farms (or move around with cattle) with other household or community members in groups	Dummy: 1 = yes, 0 = otherwise	-	Yakubu et al. (2021)
	Local cooperation	Is there bilateral cooperation in the community for settling farmer-herder disputes?	Dummy: 1 = yes, 0 = otherwise	-	Adeniran (2020)
	Effectiveness of cooperation	Households' perceived effectiveness of local bilateral cooperation in settling conflicts	Scale: 1 (least effective) to 5 (most effective)	-	Adeniran (2020), Kos et al. (2023)
	Access to local/traditional leaders	Household's ease of accessing traditional authorities for their complains	Scale: 1 (least easy) to 5 (most east)	+	Brottem (2021)
	Access to modern political leaders	Household's ease at accessing political leaders for complains	Scale: 1 (least easy) to 5 (most east)	+	Brottem (2021), Frimpong et al. (2021)
	Trust in traditional authority	Households' trust in traditional authority in resolving farmer-herder conflict	Scale: 1 (no trust) to 5 (complete trust)	-	Frimpong et al. (2021), Mbih (2020), Kuusaana & Bukari (2015)
	Trust in security service	Household's trust in security services and authorities in handling farmer-herder disputes	Scale: 1 (no trust) to 5 (complete trust)	+	Benjaminsen et al. (2009)

Main component	Indicator	Explanation	Measurement Unit	Expected effect on FHCVI	Reference
Socio-demographic profile	Experience in farming/herding	Years of farming or herding	Years	-/+	Yakubu et al. (2021), Diogo et al. (2021)
	Level of education	Household head level of education	Years of education	-	Yakubu et al. (2021), Wafula et al. (2022)
	Years stay in the community	How long household has been in the community	Years	-	Tonah (2006)
	Presence of Konkomba ethnic groups in the community	Presence of the Konkomba ethnic group in the community	Dummy: 1 = yes, 0 = otherwise	-/+	Authors (2022)
Livelihood strategies	Number of economic activities engaged	Total number of economic activities engaged in by household for livelihood	Number	+	Authors (2022)
	Number of crops/ livestock	Total number of crops cultivated and/or different livestock reared by households	Number	+	Authors (2022)
	Remittance	Did the household receive any remittance during the year	Dummy: 1 = yes, 0 = otherwise	+	Hahn et al. (2009)

Main component	Indicator	Explanation	Measurement Unit	Expected effect on FHCVI	Reference
Sensitivity					
Farmer-herder relations	Conflict induced migration	Number of household members that fled out/into the community due to farmer-herder conflict	Number of persons	+	Abroulaye et al. (2015),
	Feeling of insecurity	Household's feeling of threat to violence	Scale: 1 (secured) to 5 (insecure)	+	Brottem (2021)
	Participation in or willingness to participate in farmer-herder conflicts dialogue	Has the respondent participated in any dialogue on farmers-herders dispute resolution	Dummy: 1 = participated, 0 = otherwise	-	Adeniran (2020)
	Conflict deaths	Household experience of farmer-herder-related deaths	Dummy: 1 = yes, 0 = otherwise	-	Abroulaye et al. (2015)
Governance of land, water, and forest resources	Land tenure	Household type of land ownership	Dummy: 1 = own land, 0 = otherwise	-	Kugbega & Aboagye (2021), Kuusaana & Bukari (2015)
	Access to land	Ease of getting land for production by household	Scale: 1 (very difficult) to 5 (very easy)	-	Kugbega & Aboagye (2021),
	Water and land-related conflict	Household engagement in dispute with other household members over land or water	Dummy: 1 = yes, 0 = otherwise	+	Moritz (2010), Oladele & Oladele (2011)
	Forest related conflict	Has any household member engaged in a dispute with other persons over forest products within the past 12 months	Dummy: 1 = Yes, 0 = otherwise	+	Bisson et al. (2021)
	Right to forest resources	Does the household has the right to harvest forest resources	Dummy: 1 = Yes, 0 = otherwise	-	Bisson et al. (2021)
	Sharing of water	Does the household share water with other households	Dummy: 1 = Yes, 0 = otherwise	+	Dary et al. (2017), Tonah (2002, 2006)

Appendix B: Description of Variables for the Tobit Regression Model

Variable	**Description**	**Measurement**	***A prior* expectation**	Reference
FHCVI	Farmer-herder Conflict Vulnerability Index	Fraction (0≤ FHCVI ≤1)	N/A	N/A
Socio-demographic Characteristics				
Age	Age of household head	Year	-/+	Yakubu et al. (2021)
Gender	Sex of household head	Dummy: male = 1, 0 = otherwise	-	Yakubu et al. (2021)
Group membership	Households belonging to a social group (e.g. farmer group, herder group, etc)	Dummy: 1 = yes, 0 = otherwise	-	Kugbega & Aboagye (2021),Kos et al. (2023)
Residence status	Is the household an indigene of the community	Dummy: 1 = yes, 0 = otherwise	-/+	Kugbega & Aboagye (2021), Kuusaana & Bukari (2015)
Occupation	Household main occupation	Categorical: 0 = others, 1 = farming, 2 = sedentary herding, 3 = transhumant, 4 = agro-pastoralism	-/+	Brottem (2016), Diogo et al. (2021) and Wafula et al. (2022)
Environmental Factors				
Availability of land	Availability of suitable land for farming/herding expansion	Dummy: yes = 1, 0 = otherwise	-	Brottem (2021)
Natural water	Depend on only natural water for farming/herding	Dummy: yes = 1, 0 = otherwise	+	Brottem (2021), Napogbong et al. (2021)
Perceived climate-induced population influx	Households' perception of the effect of climatic conditions as a pull factor for the influx of immigrants	Dummy 1 = increase population, 0 = otherwise	+	Yakubu et al. (2021), Napogbong et al. (2021)
Location Factors				
Farm/kraal site	Is the farm located on a cattle movement route (or cattle grazing around farm sites)	Dummy: 1 = farm located on cattle movement route (or cattle graze along farms), 0 = otherwise	+	Dary et al. (2017), Tellen et al. (2014)
District	District of household	Dummy: 1 = Agogo, 0 = otherwise	-/+	Kuusaana & Bukari (2015)
Institutional Factors				
Dialogue using institutions	Household use of dialogue on conflict using the institution managing the conflict	Dummy: 1 =yes, 0 = otherwise	-	Hyman et al. (2020),
Difference in opportunities	Discrimination in access to political & economic opportunities	Dummy: 1 =yes, 0 = otherwise	+	Hyman et al. (2020)

Appendix C: Results of Computed Indices of Main Components and Indicators of LVFHCI by Occupation

Main component	Sub – Component				Computed Indicator Index					Kruskal-Wallis H Test	
	Indicator	Measurement unit	Min	Max	Occupation					Chi^2 (4)	P-value
					Other	Farm	SenHe	Transh	AgroP		
Exposure											
Climate / environmental factors	Perceived available fertile land	1 = available, 0 = otherwise	0	1	0.69	0.85	0.76	0.77	0.58	10.098*	0.078
	Perceived available pasture	1 = available, 0 = otherwise	0	1	0.81	0.84	0.87	0.93	0.83	57.900***	0.000
	Perception of climate variables	Households' perception of weather (rain and temperature)	0	1	0.41	0.26	0.19	0.33	0.17	8.262*	0.093
Availability of natural resources and physical factors	Farm destroyed / cattle killed	Acres (number of cattle)	0	60	0.31	0.52	0.79	0.41	0.43	30.310***	0.000
	Cultivation of cattle-preferred crops for grazing	Dummy: 1 = yes, 0 = otherwise	0	1	0.41	0.91	0.88	0.83	0.83	0.344	0.921
	Farm location characteristics	Dummy: 1 = yes, 0 = otherwise	0	1	0.38	0.98	0.93	0.90	0.83	42.721***	0.000
	Availability of cattle movement corridors	Dummy: 1 = Yes, 0 = otherwise	0	1	0.16	0.15	0.21	0.25	0.27	13.183*	0.058
	Harvest of forest resources	Dummy: 1 = Yes, 0 = otherwise	0	1	0.28	0.34	0.25	0.33	0.25	1.557	0.817
	Water contamination	Dummy: 1 = Yes, 0 = otherwise	0	1	0.56	0.50	0.47	0.48	0.52	1.642	0.801

Main component	Sub – Component				Computed Indicator Index					Kruskal-Wallis H Test	
	Indicator	Measurement Unit	Min	Max	Occupation					Chi^2 (4)	P-value
					Other	Farm	SenHe	Transh	AgroP		
Adaptive Capacity											
Socio-political network	Moving in groups	Dummy: 1 = yes, 0 = otherwise	0	1	0.43	0.58	0.63	0.50	0.50	2.481	0.648
	Local committee	Dummy: 1 = yes, 0 = otherwise	0	1	0.41	0.38	0.63	0.33	0.33	45.008***	0.000
	Effectiveness of local committees	Scale: 1 (least effective) to 5 (most effective)	1	5	0.22	0.26	0.28	0.22	0.23	14.130**	0.042
	Access to local/traditional leaders	Scale: 1 (least easy) to 5 (most east)	0	1	0.39	0.49	0.57	0.49	0.50	4.730	0.316
	Access to modern political leaders	Scale: 1 (least easy) to 5 (most east)	1	5	0.27	0.30	0.26	0.25	0.33	1.037	0.904
	Trust in traditional authority	Scale: 1 (no trust) to 5 (complete trust)	1	5	0.38	0.42	0.47	0.42	0.44	9.008*	0.092
	Trust in security service	Scale: 1 (no trust) to 5 (complete trust)	1	5	0.22	0.59	0.60	0.20	0.63	22.242***	0.001
Socio-demographic profile	Farming/herding experience	Years	2	46	0.40	0.40	0.45	0.42	0.45	2.038	0.729
	Level of education	Years of education	0	16	0.25	0.22	0.22	0.21	0.31	1.857	0.762
	Years of stay in the community	Years	0	64	0.11	0.23	0.19	0.34	0.38	6.462	0.281
	Presence of Konkomba ethnic groups in the community	Dummy: 1 = yes, 0 = otherwise	0	1	0.10	0.13	0.13	0.25	0.17	12.120**	0.014
Livelihood strategies	Number of economic activities engaged	Number	1	3	0.14	0.18	0.34	0.22	0.17	5.455	0.243
	Number of crops/ livestock	Number	0	10	0.35	0.33	0.34	0.33	0.35	0.916	0.922
	Remittance	Dummy: 1 = yes, 0 = otherwise	0	1	0.25	0.26	0.30	0.23	0.17	0.601	0.963

Main component	Sub – Component				Computed Indicator Index					Kruskal-Wallis H Test	
	Indicator	Measurement unit	Min	Max	Occupation					Chi^2 (4)	P-value
					Other	Farm	SenHe	Transh	AgroP		
Sensitivity											
Farmer-herder relations	Conflict induced migration	Number of persons	0	5	0.01	0.13	0.02	0.23	0.00	14.335**	0.036
	Feeling of insecurity	Scale: 1 (secured) to 5 (insecure)	1	5	0.56	0.54	0.67	0.57	0.63	21.545***	0.003
	Participation or willingness to participate in farmer-herder conflicts dialogue	Dummy: 1 = participated, 0 = otherwise	0	1	0.49	0.51	0.47	0.77	0.58	15.494**	0.024
	Conflict deaths	Dummy: 1 = yes, 0 = otherwise	0	1	0.00	0.03	0.00	0.03	0.00	1.756	0.781
Governance of land, water, and forest resources	Land tenure type	Dummy: 1 = own land, 0 = otherwise	0	1	0.30	0.24	0.25	0.49	0.29	11.734*	0.078
	Access to land	Scale: 1 (very difficult) to 5 (very easy)	1	5	0.56	0.52	0.58	0.60	0.46	14.707**	0.048
	Water/land-related conflict	Dummy: 1 = yes, 0 = otherwise	0	1	0.15	0.09	0.06	0.17	0.00	4.835	0.305
	Forest related conflict	Dummy: 1 = Yes, 0 = otherwise	0	1	0.03	0.02	0.00	0.10	0.00	9.691	0.146
	Right to forest resources	Dummy: 1 = Yes, 0 = otherwise	0	1	0.06	0.07	0.00	0.10	0.08	1.701	0.791
	Sharing of water	Dummy: 1 = Yes, 0 = otherwise	0	1	0.63	0.78	0.69	0.90	0.83	9.890*	0.096

Note:

Max = Maximum value of indicator in combined data Min = Minimum value of indicator in combined data

Occupation: Farm = Farming SenHe = Sedentary Herders Transh = Transhumant AgroP = Agro-Pastoralism Other = other occupation

***, ** and * denotes statistically significant at 1%, 5% and 10% respectively

Source: Authors' Analysis of Field Data, 2022

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