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Effect of farmer–herder conflict adaptation strategies on multidimensional poverty and subjective wellbeing in Ghana

Suhiyini I Alhassan*
West African Centre for Shea Innovation and Research, University for Development Studies, Tamale, Ghana / Department of Silviculture and Forest Management, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana / Global Development Section, Department of Food and Resource Economics, University of Copenhagen, Denmark. E-mail: issahsuhiyini@yahoo.com

Boateng Kyereh
Department of Silviculture and Forest Management, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. E-mail: kyerehb@gmail.com

Marième Pouliot
Global Development Section, Department of Food and Resource Economics, University of Copenhagen, Denmark. E-mail: mapo@ifro.ku.dk

Mercy AA Derkyi
Department of Forest Science, University of Energy and Natural Resources, Sunyani, Ghana. E-mail: mercy.derkyi@uenr.edu.gh

* Corresponding author

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Abstract

Farmer–herder conflicts deepen the incidence of poverty and worsen the wellbeing of both farming and herding households in Sub-Saharan Africa. In order to cope with the effects of conflict on their livelihoods, households adopt various adaptation strategies. This paper assesses the effects of adopting conflict adaptation strategies on the multidimensional poverty and subjective wellbeing of farmers and herders using primary data from 500 households (400 farming households and 100 herding households) from two farmer–herder conflict hotspot districts in Ghana. Specifically, the paper analyses the determinants of adopting adaptation strategies, and measures the effect of adopting these strategies on the multidimensional poverty and subjective wellbeing of households using multinomial endogenous switching regression to account for selectivity bias. We found that households' adoption of adaptation strategies is positively correlated with cattle killing, vulnerability to farmer–herder conflict, household size and labour size, access to land, nearness of farms to cattle grazing routes, access to extension services, and expectations of future occurrence of the conflict. On the other hand, households' adoption of adaptation strategies is negatively correlated with leisure time, incidences of crop destruction in the past, experience in farming/herding, and membership of farmer-based organisations. We also found that, although the adoption of both on-farm and non-farm

adaptation strategies by farming households, and herding and non-herding adaptation strategies by herding households, significantly reduce multidimensional poverty and increase subjective wellbeing. Households' multidimensional poverty levels are reduced to a greater extent and subjective wellbeing improved if farming households focus on adopting only on-farm adaptation strategies, and herding households focus on adopting only herding adaptation strategies. Hence, interventions aimed at mitigating the effect of farmer–herder conflict on households' poverty and wellbeing should focus on promoting on-farm and herding adaptation strategies for farming and herding households, respectively.

Key words: farmer–herder conflict, adaptation strategies, multidimensional poverty, subjective wellbeing, multinomial endogenous switching regression

1. Introduction

It has been established that most countries in Sub-Saharan Africa could not achieve the Millennium Development Goal of reducing poverty by 50% due to rural poverty (JICA 2013). One of the key factors accounting for this failure is natural resource conflicts, with farmer–herder conflicts being probably the most important (Igwe 2011; Okunlola & Okafor 2022). Studies have revealed that households' vulnerability to farmer–herder conflicts is underpinned by climate change, population growth and scarce resources, with Sub-Saharan Africa being the most vulnerable to the adverse effects of farmer–herder conflicts (Tonah 2006; Benjaminsen *et al*. 2009; Scoones *et al*. 2019; Bukari 2022). One reason why farmer–herder conflicts continue to be a significant challenge to poverty reduction and an improvement in the general wellbeing of rural people in Sub-Saharan Africa (SSA) is that they are associated with rampant crop destruction and cattle killing, but little adaptation strategies by the actors to avert the effects of the losses (Tonah 2006; Scoones *et al*. 2013; Kansanga *et al*. 2018; Krätli & Toulmin 2020; Kugbega & Aboagye 2021). Given that herders' livelihoods depend on cattle herding, and farmers depend on crop production for their livelihoods, there is a need for both farmers and herders to adopt strategies to adapt to the conflicts.

The causes of farmer–herder conflicts (Tonah 2006; Benjaminsen *et al*. 2009; Scoones *et al*. 2019) and their effects on livelihoods (Moritz 2010; Dimelu *et al*. 2017; Nnaji *et al*. 2022; Obasanmi & Enoma 2022), as well as households' adaptation strategies, are well documented in the literature (Majekodunmi *et al*. 2017; Soeters *et al*. 2017; Yekinni *et al*. 2017; Obaniyi *et al*. 2020; Brottem 2021; Turner *et al*. 2011; Twumasi *et al*. 2022). For example, Antwi (2018), Yakubu *et al*. (2021) and Nnaji *et al*. (2022) reported a significant negative effect of farmer–herder conflict on the food security of households in Nigeria and Ghana and recommended that households adopt adaptation measures to improve their wellbeing and reduce poverty. Some studies have revealed that farmers and herders in Ghana and Nigeria use a wide range of strategies, including on-farm and herding strategies. These include aspects such as the integration of crop and livestock production, early planting, early harvesting of crops, multiple farm plots and relocating farm sites, as well as off-farm and non-herding strategies. The latter include praying for peace and soliciting interventions from the police, NGOs and government in adapting to farmer–herder conflicts (Majekodunmi *et al*. 2017; Yekinni *et al*. 2017; Obaniyi *et al*. 2020; Nuvey *et al*. 2021). However, what is not clear in the farmer–herder conflict literature is the effect that adopting these adaptation strategies will have on poverty and wellbeing among farmers and herders involved in these conflicts. Only a few studies have focused on adaptation to natural resource conflict in Sub-Saharan Africa to assess the effects of households' adoption of farmer–herder conflict adaptation strategies on wellbeing and poverty. Also, unlike climate change adaptation strategies, there is no clarity in the literature on the determinants of households' adoption of conflict adaptation strategies. Therefore, the objectives of this paper were to determine the factors influencing households' adoption of conflict adaptation strategies, and the effect

of adopting adaptation strategies on the poverty and wellbeing of farmers and herders who compete for the same natural resources for their livelihoods.

Understanding households' strategies to adapt to socioeconomic turmoil such as farmer–herder conflict, is crucial to effectively address people's livelihood vulnerability to these unpredictable, yet common, vagaries. There have been calls by the international community to incorporate adaptation strategies into national development plans (IPCC 2007; Margulis & Narain 2010). However, in Sub-Saharan Africa, efforts to promote the adoption of adaptation measures in farmer–herder conflict hotspot areas as part of sustainable agricultural development policies (Amadi & Anokwuru 2017; Lipper & Zilberman 2018) are limited, with low adoption rates, leading to a high incidence of poverty and poor wellbeing (Arslan *et al*. 2015; Barnard *et al*. 2015; Amadi & Anokwuru 2017).

Farmer–herder conflict adaptation strategies are the measures practised by households to mitigate or minimise the effect of the conflict on their livelihood outcomes (poverty and wellbeing). Based on utility theory, households adopt and practise adaptation strategies that reduce their poverty and improve their wellbeing in farmer–herder conflict situations. As argued by Tol (2018), from an economic perspective, adaptation is widely considered part of essential measures to complement natural resource conflict mitigation due to its economic benefits for the adopters.

In this study, we classify farming households' adaptation strategies into on-farm and non-farm strategies, and herding households' adaptation strategies into herding and non-herding strategies. On-farm adaptation strategies consist of measures employed by farming households on their farm sites to avert or reduce vulnerability to conflict or exposure to crop destruction and its potential effects on their livelihoods (for example, the early harvesting of crops, fencing of the farm, staying late on the farm, reducing farm size, stopping the cultivation of cattle-preferred crops, etc.). Non-farm adaptation strategies are measures used by farming households outside the farm site to minimise vulnerability to conflict and its potential impact on their livelihoods. Examples of these strategies include engaging in other income-generating activities, such as charcoal production, petty trading, small livestock rearing, agro-processing and migration. Herding adaptation strategies include measures taken by herding households in their herding activities to avert or reduce their vulnerability to farmer–herder conflicts and their potential livelihood impact. Examples are night grazing, ranching, cattle feed reduction and integrated agriculture (cultivating crops and rearing animals simultaneously). Non-herding adaptation strategies include herding households' measures undertaken outside their herding activities to reduce or avert vulnerability to farmer–herder conflict and its potential livelihood impact. Examples include migration, engaging in farming and selling livestock.

In this paper, we first identify and analyse farming and herding households' strategies in adapting to the effect of farmer–herder conflicts. Secondly, we analyse the factors influencing households' adoption of adaptation strategies in relation to farmer–herder conflict. Finally, we determine the effects of adopting farmer–herder conflict adaptation strategies on the poverty and wellbeing of farming and herding households. We contribute to the empirical literature on natural resource conflict adaptation by using one of the modern impact assessment approaches, namely the multinomial endogenous switching regression model. The multinomial switching regression model has previously been used to assess the impact of households' adaptation strategies on their income, food security, multidimensional poverty and wellbeing in Ghana, Tanzania, Ethiopia, Kenya and Nigeria (Bourguignon *et al*. 2007; Teklewold *et al*. 2013; Kassie 2018; Biru *et al*. 2019; Issahaku & Abdulai 2019; Manda *et al*. 2021; Ogunleye *et al*. 2021). The multinomial endogenous switching regression approach can account for selectivity bias within multiple alternative situations. Therefore, the approach enables us to identify location-specific information on adoptable farmer–herder conflict adaptation strategies and the impacts of adoption on households' poverty and wellbeing.

We argue that households do not need to diversify their livelihoods by adopting non-farm (for farming households) and non-herding (for herding households) strategies to adapt effectively to the effect of farmer–herder conflicts. This argument is based on our findings that farming and herding households' multidimensional poverty and wellbeing improve more significantly when they focus on only on-farm and herding adaptation strategies than adopting both on-farm and non-farm adaptation strategies (farming households) and herding and non-herding adaptation strategies (for herding households).

Since farmer–herder conflict is not particular to Ghana, but a perennial problem affecting the development of many countries, especially in Africa, the findings from our study are relevant to the regional policy responses to manage pastoral movements in Africa, such as the Protocol on Free Movement of People and Goods among Member States of the Economic Community for West African States (ECOWAS) and the Policy Framework for Pastoralism in Africa of the African Union (AU). This study also contributes to the Government of Ghana's Flagship Programmes of Planting for Food and Jobs (P4FJ) and Rearing for Food and Jobs (R4FJ). The findings have policy implications for achieving several sustainable development goals in Sub-Saharan Africa, such as poverty reduction, improved wellbeing, food insecurity and hunger, and climate change adaptation (Vale 2016; Tol 2018).

After this introductory section, the rest of the paper is organised as follows. Section 2 presents the research methodology, including data sources and analysis methods. Sections 3 and 4 present the results of the data analysis and the discussions of the empirical findings, respectively, while Section 5 provides the main conclusions and policy implications derived from the study's findings.

2. Methodology

2.1 Description of the study area

This study was conducted in 18 communities in two farmer–herder conflict hotspot districts in Ghana (Sekyere Afram Plains District and Asante Akim North Municipality in the Ashanti Region). The main economic activities in the area are farming and herding. The major crops cultivated include plantain, yam, cassava, maize, rice and vegetables (Ghana Statistical Service [GSS] 2019). Since the early 2000s, Afram Plains has witnessed a rapid increase in migrants, mainly from Northern Ghana. Each migrant group has specialised in a particular economic activity that it controls and dominates, and with which it has become identified. The Ewes are mainly fishermen and fishmongers and live closer to the water, while most migrants from Northern Ghana are farmers. Cattle herding is the main occupation of the Fulani, often migrating from Burkina Faso, Nigeria, Mali and Niger (Tonah 2006; GSS 2011, 2019). The River Afram is a major water source for farming and herding activities, especially during the dry season. The primary vegetation in the two districts consists of open forests, closed forests and wooded savannah with abundant elephant grass (*Pennisetum purpureum*), which is very nutritious for cattle production and also conducive to crop cultivation. Livestock is mainly reared free-range and includes sheep, goats, pigs, poultry and cattle (GSS 2019). Figure 1 presents a map of the study area.

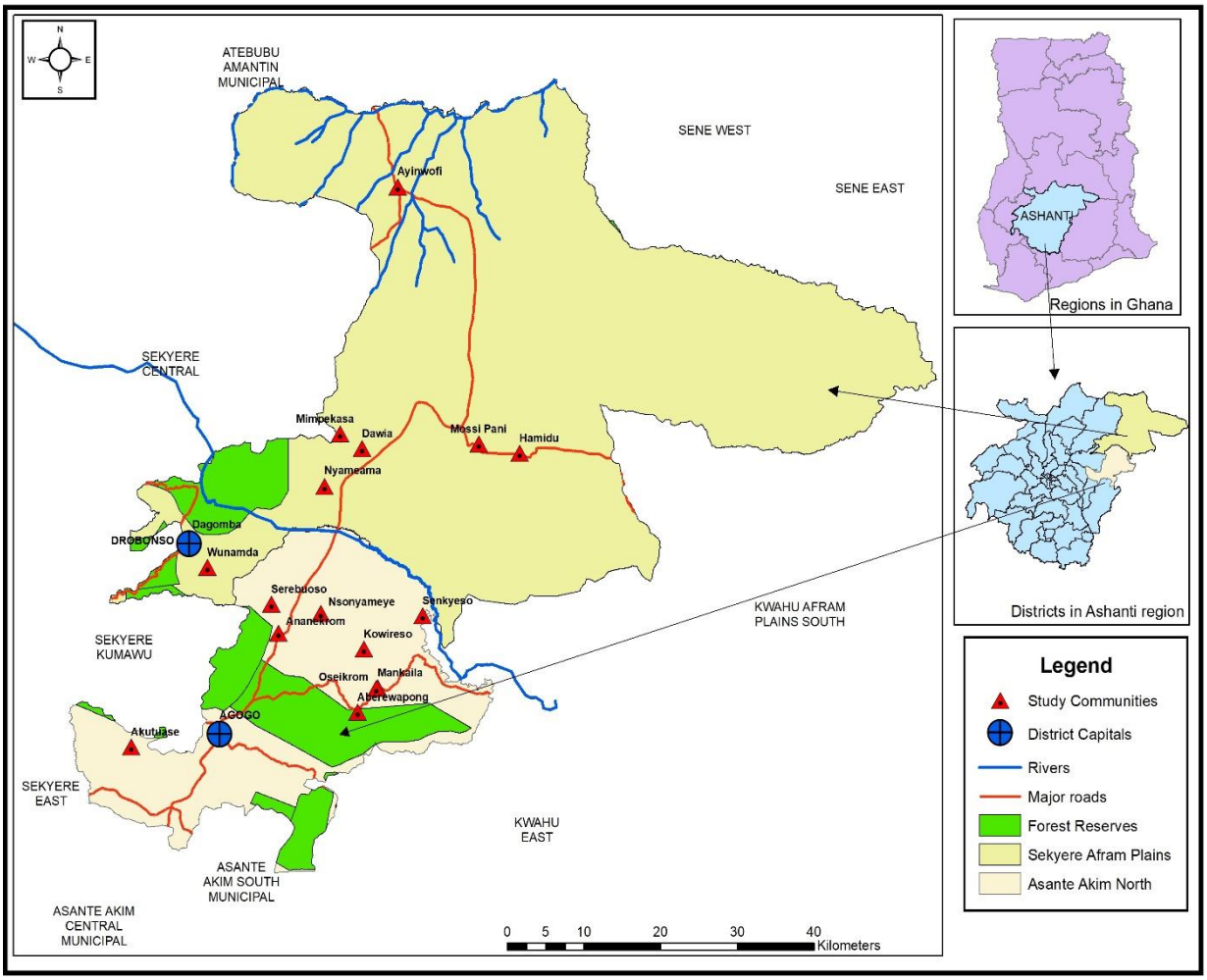

Figure 1: Map of Asante Akim North and Sekyere Afram Plains Districts in Ghana showing study communities

2.2 Data sources and sampling procedure

Data for this study came from a household survey sampled from 14 conflict-prone communities and four non-conflict-prone communities. We listed the households in each community to ascertain the total number and occupation of the household members. Households were stratified based on occupation to ensure that farming and herding households were included in the sample. Proportionate and simple random sampling were used to select the required number of households from each community to constitute the final sample. Sampled households were visited by the research team to explain the purpose of the study, to seek their consent, and later to administer a questionnaire to the household head or representative who was older than 18 years, had enough information about the household, and was willing to speak to the research team. A total of 500 households were sampled and interviewed. This consisted of 400 households with farming as their main occupation and 100 households with herding as their main occupation. However, some farming households were also engaged in herding and some herding households were also engaged in farming. These are the agro-pastoralist households. We had a 100% response rate for the household survey. Also, qualitative data was collected through focus group discussions and key informant interviews to complement the quantitative data from the household survey. A total of 38 focus group discussions were conducted, with both male and female farmers and sedentary and transhumant herders. We also conducted 24 key informant interviews with staff of the Ministry of Food and Agriculture, community chiefs, members of district/municipal assemblies, and leaders of herder and farmer groups.

2.3 Method of data analysis

2.3.1 Modelling determinants of households' adoption of conflict adaptation strategies

The specific adaptation strategies were identified from the literature a review with community members and other key informants during an initial field visit to ascertain the strategies applicable in the study area. During the main survey, households were asked to rank the effectiveness of these strategies in adapting to the conflict, using a scale from 1 (most effective) to 5 (least effective). Descriptive statistics (mean ranks) were computed for each strategy and ranked from the most effective to the least effective strategy based on the mean rank. The strategy with the lowest mean rank was ranked most effective, up to the strategy with the highest mean rank (least effective). Kendall's coefficient of concordance was then used to test for the degree of agreement among households on the ranking of strategies in adapting to the conflict.

In this paper, the treatment group constitutes households that adopted at least one adaptation strategy, while households that did not adopt any adaptation strategy constitute the control group. The selection variable is households' adoption of adaptation strategies, while multidimensional poverty and subjective wellbeing are the outcome variables. Following Bourguignon *et al*. (2007), Khonje *et al*. (2018), Issahaku and Abdulai (2019) and Manda *et al*. (2021), the determinants and effects of adopting farmer–herder conflict adaptation strategies were simultaneously modelled using the multinomial endogenous switching regression. The first stage modelled the determinants of adopting adaptation strategies, while the second stage modelled the determinants of poverty and wellbeing. Households' adoption of adaptation strategies was based on the random utility theory. Hence, a household's adoption of an adaptation strategy or a combination of adaptation strategies has the aim to maximise utility or benefits (U). Suppose the expected benefit from adopting the j adaptation strategy by households i is represented by U_{ij}. In that case, the expected benefits can be expressed as a function of observed characteristics (X_i) and unobserved factors (ε_{ij}), as given in Equation (1).

$$U_{ij} = X_{ij}\beta_j + \theta_j \bar{X}_{ij} + \varepsilon_{ij} \tag{1}$$

For the adoption decision, let U_i denote an index that indicates a household's observed adoption of a combination of adaptation strategies, given by Equation (2).

$$U_{ij} = \begin{cases} 1 \; if \; U_{i1} > \max_{k \neq 1} \left(U_{ik}^{*} \right) \; or \; \varepsilon_{i1} < 0 \\ \vdots \qquad \vdots \qquad \vdots \\ M \; if \; U_{iM}^{*} > \max_{k \neq j} \left(U_{ij}^{*} \right) \; or \; \varepsilon_{iM} < 0 \end{cases}, \tag{2}$$

where $\max_{k \neq j} \left(U_{ik}^{*} - U_{ij}^{*} \right) < 0$. From Equation (2), it can be seen that household i will adopt adaptation strategy j if the expected benefits are greater than adopting other adaptation strategies, or non-adoption ($k \neq j$). Thus, given that $\varepsilon_{ij} \max_{k \neq j} \left(U_{ik}^{*} - U_{ij}^{*} \right) < 0, \; \forall j, k \in M$.

In this paper, households had three options[1] (on-farm, non-farm and both on-farm and non-farm adaptation strategies for farming households; herding, non-herding and both herding and non-herding adaptation strategies for herding households), in addition to the base category of non-adoption. In Equation (1), we assumed that $\mathcal{E}_{ij}$ is independent and identified by Gumbel distribution. Based on the work of McFadden (1973), the probability that a household will adopt adaptation strategy *j* was modelled using the multinomial regression (Equation (3)).

$$P_{ij} = P\left(\varepsilon_{ij} < 0 \middle| X_i\right) = \frac{\exp\left(X_{ij}\beta_j + \bar{X}_{ij}\delta_j\right)}{\sum_{k\neq 1}^{M} \exp\left(X_{ij}\beta_k + \bar{X}_{ij}\delta_k\right)}, \quad (3)$$

where $\bar{X}_{ij}$ is a vector of characteristics associated with a specific adaptation strategy and δ_j are parameters to be estimated from the model. The adoption of the farmer–herder conflict adaptation strategy was modelled on the basis of the multinomial endogenous switching regression framework to establish a causal relationship between farmer–herder conflict adaptation strategies and the outcome variable (poverty and wellbeing), as done in previous studies (Bourguignon *et al*. 2007; Khonje *et al*. 2018; Issahaku & Abdulai 2019; Manda *et al*. 2021). The maximum likelihood approach was used to estimate the latent Equation (3).

2.3.2 Modelling the determinants of multidimensional poverty and subjective wellbeing (MESR second stage)

Bourguignon *et al*. (2007) espoused the multinomial endogenous switching regression (MESR) model for impact evaluation studies and it has since been employed in several empirical studies (e.g. Di Falco & Veronesi 2013; Teklewold *et al*. 2013; Ng'ombe *et al*. 2017; Khonje *et al*. 2018; Issahaku & Abdulai 2019; Manda *et al*. 2021). The second stage of the MESR for this paper modelled the determinants of households' multidimensional poverty and subjective wellbeing. Households face four adaptation strategies or regimes regarding adoption: farming households (non-adoption = 0, only on-farm = 1, only non-farm = 2, and both on-farm and non-farm adaptation strategies = 3); and herding households (non-adoption = 0, only herding = 1, only non-herding = 2, and both herding and non-herding adaptation strategies = 3). Non-adoption was the base category, denoted as *j* = 0. Equation (4) presents the outcome equation for each potential regime of households' adoption of the *j* adaptation strategy.

$$\begin{cases} \text{Regime 1: } y_{i0} = Z_{i0}\alpha_0 + \bar{Z}_{i0}\theta_j + \mu_{i0} \text{ if } U_i = 0 \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ \text{Regime N: } y_{ij} = Z_{ij}\alpha_j + \bar{Z}_{ij}\theta_j + \mu_{ij} \text{ if } U_i = J \end{cases}, \quad (4)$$

where y_{ij} denotes the outcome variable (multidimensional poverty or subjective wellbeing) of the i^{th} household in regime *A*, Z_i represents a set of exogenous observable explanatory variables, $\bar{Z}_j$ denotes the means of unobservable characteristics associated with the adoption of a specific adaptation strategy *j*, and the μ's represent the error terms associated with the model, with expected values of

[1] Agro-pastoralist households cultivate crops and also rear cattle, and thus had six options (only on-farm, only non-farm, both on-farm and non-farm, only herding, only non-herding, and both herding and non-herding adaptation strategies). Agro-pastoralists were captured in both the farming and herding households' models.

zero and constant variance, $Var\left(\mu_{ij}\left|X_i,Z_i\right.\right)=\sigma_j^2$. α_j and θ_j denote the vector of parameters to be estimated from the models in each regime. Thus, θ_j is essential to account for unobserved heterogeneity due to varying characteristics associated with the adoption of specific adaptation strategies, being correlated with other household-level variables influencing the adoption of specific adaptation strategies and the outcome variable (multidimensional poverty and wellbeing) (Mundlak 1978). To determine the relevance of the heterogeneity of a specific adaptation strategy in this paper, we conducted a Wald test for the null hypothesis that the vector θ_j is jointly equal to zero (Teklewold *et al*. 2013; Issahaku & Abdulai 2019).

Also, for α_j parameter estimates to be consistent and unbiased in Equation (4), we included selection correction terms derived from the multinomial selection process (Issahaku & Abdulai 2019). In doing this – following the works of Bourguinon *et al*. (2007) – we assumed the error terms $\mathcal{E}_{ij}$ (in Equation (1)) and μ_{ij} (in Equation (4)) to be linearly correlated for every j adaptation strategy adopted by households, so that the expected value of μ is stated as $E\left[\mu_1\left|\varepsilon_1,....\varepsilon_j\right.\right]=\sigma\sum_{j=1,...,N}\rho_j\varepsilon_j$, where ρ_j is the correlation between $\mathcal{E}_{ij}$ and μ_{ij}, and σ is the standard deviation of the error term μ_{ij}. According to Teklewold *et al*. (2013) and Issahaku and Abdulai (2019), having accounted for the bias in selecting adaptation strategies, Equation (5) can rightly be rewritten as:

$$\begin{cases} \text{Regime 1: } y_{i0}=Z_{i0}\alpha_0+\sigma_0\hat{\lambda}_{i0}+\bar{Z}_i\theta_j+\omega_{i0} \text{ if } U_i=0 \\ \qquad\qquad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ \text{Regime N: } y_{ij}=Z_{ij}\alpha_j+\sigma_j\hat{\lambda}_{ij}+\bar{Z}_{ij}\theta_N+\omega_{ij} \text{ if } U_i=J \end{cases}, \tag{5}$$

where $\lambda_{ij}=\sum_{k\neq j}^{N}\rho_j\left[\frac{P_{ik}\ln\left(\hat{P}_{ik}\right)}{1-P_{ik}}+ln\hat{P}_{ij}\right]$ refers to the inverse Mills ratios derived from the estimated probabilities of the multinomial logistic (MNL) regression in Equation (3), ρ_j is the correlation coefficient between the error terms μ_{ij} and $\mathcal{E}_{ij}$, ω_{ij} denotes the error terms with a zero mean, and $\hat{\rho}_{ij}$ denotes the estimated probability that household i adopts adaptation strategy j.

2.3.3 Econometric modelling of the effects of adaptation strategies on poverty and wellbeing

The paper's main interest was to estimate the effect of adopting farmer–herder conflict adaptation strategies on households' multidimensional poverty and wellbeing. Thus, the treatment was households' adoption of adaptation strategies. Following similar earlier studies (Di Falco & Veronesi 2013; Ng'ombe *et al*. 2017; Khonje *et al*. 2018; Issahaku & Abdulai 2019; Manda *et al*. 2021), we estimated the expected multidimensional poverty and wellbeing in both the actual and counterfactual scenarios. Specifically, we first estimated the expected multidimensional poverty and wellbeing of households that adopted at least one adaptation strategy (treatment group), which in this study denoted j = 1, 2 or 3 (j = 0 was the reference or base category, i.e. non-adoption). From Equation (5), the conditional expectations for each outcome variable-based adaptation strategy were chosen as follows:

Adopters with adoption (actual adoption observed in the sample):

$$E\left(y_{i1}\left|U_i=1\right.\right)=Z_{i1}\alpha_1+\sigma_1\hat{\lambda}_{i1}+\bar{Z}_i\theta_1 \tag{6a}$$

$$E\left(y_{iJ}\left|U_i=J\right.\right)=Z_{ij}\alpha_j+\sigma_j\hat{\lambda}_{ij}+\bar{Z}_i\theta_j \quad (6b)$$

The multidimensional poverty (or wellbeing) for the counterfactual scenario – that adopters did not adopt – is given by Equation (7):

$$E\left(y_{i0}\left|U_i=1\right.\right)=Z_{i1}\alpha_0+\sigma_0\hat{\lambda}_{ij}+\bar{Z}_i\theta_j \quad (7a)$$

$$E\left(y_{i0}\left|U_i=j\right.\right)=Z_{ij}\alpha_0+\sigma_0\hat{\lambda}_{ij}+\bar{Z}_i\theta_j \quad (7b)$$

The effect of adopting adaptation strategy *j* is denoted as the average treatment effect on the treated (ATT), which is calculated by subtracting Equation (6) from (7), to obtain Equation (8) as follows:

$$ATT=E\left(y_{i1}\left|U_i=1\right.\right)-E\left(y_{i0}\left|U_i=1\right.\right) \quad (8a)$$

$$ATT=Z_{i1}\left(\alpha_1-\alpha_0\right)+\bar{Z}_{i1}\left(\theta_1-\theta_0\right)+\hat{\lambda}_{i1}\left(\sigma_1-\sigma_0\right) \quad (8b)$$

The terms $\lambda_{ij}\left(.\right)$ and $\bar{Z}_{i1}$ (Mundlak parameter) account for selection bias and endogeneity emanating from unobserved heterogeneity.

The MESR approach produces consistent and efficient estimations. It accounts for selectivity bias in the outcome equations, even when the independence of irrelevant alternative (IIA) assumption is not met (Bourguignon *et al*. 2007). In this paper, the Hausman test for IIA did not reject the null hypothesis of no independence of irrelevant alternatives. Also, compared to other impact evaluation models, the MESR approach can evaluate the impact of both individual and a combination of farmer–herder conflict adaptation strategies on the outcome variable (Di Falco & Veronesi 2013). Another advantage of the MESR approach is its ability to relax Lee's (1983) restrictive assumptions of the single selectivity term model and provide a complete description of selectivity impacts on all alternative adaptation strategies adopted by households (Bourguignon *et al*. 2007; Issahaku & Abdulai 2019).

To ensure that our MESR model was identified correctly, as suggested by Bourguignon *et al*. (2007) we included some variables in vector X_i that are not included in vector Z_i. We used households' expectations for the future occurrence of farmer–herder conflict and access to extension as instruments. These variables intuitively influence farmers' decisions to adopt farmer–herder conflict adaptation strategies, but not multidimensional poverty and subjective wellbeing (Di Falco & Veronesi 2013; Issahaku & Abdulai 2019). A falsification test was used to confirm the validity or administrability of these instruments. The instrument validity test result showed that both instruments (households' expectations of future occurrence of farmer–herder conflict and number of extension contacts) had no significant effect on the outcome variables (multidimensional poverty and subject wellbeing) of households that did not adopt any adaptation strategy (Appendix 1), but had a significant effect on the selection variables (adoption of adaptation strategies) for farmers' and herders' selection equations. Hence, they were considered valid instruments (Di Falco & Veronesi 2013; Issahaku & Abdulai 2019). Following the works of Deb and Trivedi (2006), Khonje *et al*. (2018) and Issahaku and Abdulai (2019), a robustness check of our results was performed using multivariate treatment effects and multinomial endogenous treatment effect regressions, which account for unobservable factors in a multinomial choice and impact analysis framework. This paper envisaged potential endogeneity in non-farm and non-herding adaptation strategies. This was

addressed using the control function approach (Wooldridge 2005; Issahaku & Abdulai 2019). Finally, to deal with the problem of heteroscedasticity, the variance estimation was bootstrapped by 50 replications, as suggested by Bourguignon *et al*. (2007).

2.3.4 Measurement of outcome variables (poverty and wellbeing)

This study adopted the multidimensional poverty analysis index (MPAI) of the International Fund for Agricultural Development ([IFAD] 2014) to measure households' poverty. The MPAI is an easy, practical and rigorous tool for multidimensional poverty assessment. It provides insights into the underlying causes of poverty because it considers fundamental human needs, asset endowments, and social equality indicators (IFAD 2014). The MPAI consists of 10 components: food and nutrition security; domestic water supply; health and health care; sanitation and hygiene; housing, clothing and energy; education; farm assets; non-farm assets; exposure and resilience to shocks; and gender and social equality. Each of these 10 components consists of sub-components. The sub-components are derived from poverty indicators at the household and community level and are measured on different scales. The OECD (2008) standardisation formula was used to bring these indicators to a common scale and then weighted by multiplying the standardised values by their respective weights assigned by IFAD (2014). Next, we ascertained the value for each sub-component by summing the weighted indicators constituting the sub-component. After ascertaining the values for all sub-components of each component, the values were also weighted by multiplying the sub-component value by its respective weights. The value for the main components were obtained by summing the weighted sub-components constituting each main component. The main MPAI component values were also multiplied by their respective weights and summed to obtain the overall MPAI.

We followed the subjective approach used by Dolan *et al*. (2011), of measuring wellbeing based on households' perceived happiness, life satisfaction, anxiousness and leisure time. Households used a scale of 0 (lowest) to 5 (highest) to indicate their perceived level of happiness, life satisfaction, leisure time and anxiousness due to farmer–herder conflict. The procedure for computing subjective wellbeing was similar to how the MPAI was computed. Both the MPAI and wellbeing are indices between zero (0) and one (1). A higher MPAI depicts higher resource deprivation, hence higher multidimensional poverty and vice versa. On the other hand, a higher wellbeing index indicates higher wellbeing, and vice versa. We used equal weights for the wellbeing indicators because no previous weights are available in the literature.

Table 1: Description and measurement of variables in the MESR model

Variable	Description	Measurement	Mean (std dev.)
Outcome variables			
Poverty	Multidimensional poverty	Ratio: $0 \leq MPAI \leq 1$ (high ratio means higher poverty)	0.484 (0.077)
Wellbeing	Subjective wellbeing of household	Ratio: $0 \leq WI \leq 1$ (high ratio means high wellbeing)	0.470 (0.142)
Selection variable			
Farming households' adaptation strategies	Farming households' adoption of adaptation strategies	0 = non-adoption, 1 = only on-farm, 2 = only non-farm, and 3 = both on-farm and non-farm	1.368 (1.093)
Herding households' adaptation strategies	Herding households' adoption of herding adaptation strategies	0 = non-adoption, 1 = only herding, 2 = only non-herding, and 3 = both herding and non-herding	0.834 (1.023)

Variable	Description	Measurement	Mean (std dev.)
Independent variables			
Sex	Sex of household head	Dummy: 1 = male, 0 = otherwise	0.678 (0.234)
Age	Age of household head	Years	42.93 (12.96)
Dependency ratio	Number of dependants to number of active labour force in the household	Ratio	1.147 (0.960)
Access to market	Household's access to buyers of crops/ cattle	Scale: 0 (lowest) to 4 (highest)	0.602 (0.490)
Educational	Household head's years of education	Years	1.724 (1.150)
Conflict	Acres of crops lost to cattle destruction/ number of cattle killed due to farmer–herder conflict	Number of acres/number of cattle	8.06 (24.998)
Farming/herding experience	Number of years household has been farming or herding	Years	18.713 (10.662)
Remittance	Received cash from a family or friend in the past 12 months	Dummy: 1 = yes, 0 = otherwise	0.253 (0.436)
Membership of social group	Household belongs to a social group such as a herders' association, farmers' group, etc.	Dummy: 1 = yes, 0 = otherwise	0.570 (0.496)
Access to land	Ease of getting land for agricultural purposes	Dummy: 1 = yes, 0 = otherwise	0.368 (0.092)
Land ownership	Household's land tenure system	Dummy: 1 = own, 0 = otherwise	0.486 (0.242)
Extension	Households' access to extension services	Number of contacts with extension officers per annum	1.926 (1.772)
Site location	Farms and cattle movement routes are closely located	Dummy: 1 = yes, 0 = otherwise	0.198 (0.131)
Future conflict	Households' perceived expectation of likely outbreak of farmer–herder conflict in the next 12 months	Scale: 0 (less likely) to 4 (more likely)	2.136 (1.430)
Number of crops or herds	Total number of different crops cultivated or herds reared by household	Number of crops or herds	3.21 (2.72)
Labour adequacy	Availability of adequate labour for farming or herding activities	Dummy: 1 = adequate labour, 0 = otherwise	0.673 (0.512)
Leisure time	Households' perceived leisure time	1 = household members have enough leisure time, 0 = otherwise	0.572 (0.412)
Trust in traditional authorities	Respondents' trust in traditional authorities to handle farmer–herder conflict	Scale: 0 = not at all, 1 = rarely, 2 = sometimes, 3 = often, 4 = always	1.692 (1.290)
Trust in security service	Respondents' trust in security services to handle farmer–herder conflict	Scale: 0 = not at all, 1 = rarely, 2 = sometimes, 3 = often, 4 = always	1.078 (1.053)
Fertility of land	Respondents' perceptions of land fertility	Dummy: 1 = fertile, 0 = otherwise	0.702 (0.458)
District	Location of respondents	Dummy: 1 = SAPD, 0 = otherwise	0.482 (0.050)

3. Results

In the model, m0, m1, m2 and m3 denote the selectivity correction terms and capture the selectivity effects of not including unobservable variables such as cultural factors in the MESR model, which may also have a significant effect on poverty and wellbeing. The results show that the selectivity correction terms for non-adoption (m0), adoption of only on-farm (m1), only non-farm (m3) and both on-farm and non-farm (m4) adaptation strategies are significant (Appendix 2). Also, in the wellbeing model for farming households, the selectivity correction terms for adopting only non-farm (m1) and

both on-farm and non-farm adaptation strategies (m3) are significant (Appendix 3). The results further show that the selectivity correction term for adopting both herding and non-herding adaptation strategies (m3) is significant in the multidimensional poverty and wellbeing models (Appendix 3). This indicate the presence of sample selection bias, in which case estimating the determinants of farming and herding households' poverty and wellbeing using OLS will produce inconsistent and misleading results. This justifies our use of the MESR in modelling the determinants of households' poverty and wellbeing, because it accounted for selectivity effects.

Although the focus of this paper is not the determinants of households' multidimensional poverty and subjective wellbeing, the results of the MESR second stage (Equation (5)) show that farmer–herder conflict (operationalised as crop destruction for farming households and injuring or killing of cattle for herding households) significantly increases the multidimensional poverty of both farming and herding households (Appendix 2 and Appendix 3). Given these results, farming and herding households need to adopt some strategies to adapt to farmer–herder conflicts, as shown in the next section.

3.1 Households' strategies in adapting to farmer–herder conflict

Households' strategies to adapt to farmer–herder conflicts were assessed across three time periods: 2005 to 2011, 2012 to 2016, and 2017 to 2021. These periodical intervals are based on the history of farmer–herder conflicts in the study area. Between 2005 and 2011, although there were conflicts between farming and herding households, there was no official policy to expel herders in the study area. However, an assessment by a Kumasi High Court ruling on the eviction of cattle and herdsmen in Asante Akim North and its environs revealed that, on 26 January 2012, there was a court order to ban herding activities in the municipality. This had implications for herders' migration to Sekyereh Afram Plains and other adjourning districts. Households' consciousness in adapting to farmer–herder conflict was heightened when the Government of Ghana, through National Security, tried enforcing the 2012 court order by evicting herders and cattle from the jurisdiction of the Asante Akim North Municipality. This state intervention was known as "Operation Cow Leg" and was first carried out in February/March 2017. During the intervention, herders and their cattle were forcefully evicted from Asante Akim North Municipality which saw the killing of many cattle. Interviews with key informants revealed that, since 2017, it has become an annual event, with the military patrolling communities in the district to hunt down cattle and prevent them from destroying farms.

3.1.1 Farmers' adaptation strategies

Farming households adopted either on-farm or non-farm strategies, or both, to adapt to the conflict. The results show that 29.0% of households did not adopt any strategy to adapt to the effect of farmer–herder conflict, compared to 71% of farming households that adopted only on-farm, non-farm, or both on-farm and non-farm adaptation strategies (Table 2).

Table 2: Farming households' adoption of main adaptation strategies

Adaptation strategy	Number of households adopting strategy	Percentage
No adoption	145	29.00
Only on-farm strategies	121	24.2
Only non-farm strategies	139	27.8
Both on-farm and non-farm strategies	95	19.0
Total	500	100.00

Farmers adopted seven different on-farm strategies. Early harvesting of crops was the most popular on-farm adaptation strategy among farmers, with about 6.6% of farmers reporting to have adopted

this from 2005 to 2011. The number increased to 16.9% in the period 2012 to 2016, and further increased to 23.0% between 2017 and 2021. Another strategy adopted by farmers was staying in the field late to prevent crop destruction by cattle. Between 2005 and 2011, 7.1% of farmers adopted this strategy. This increased to 11.2% between 2012 and 2016 and 20.5% between 2017 and 2021. Reducing farm size was the third most popular strategy among farming households. The results show that, from 2005 to 2011 and 2012 to 2016, 9.8% and 12.8% of farming households respectively reported having reduced their farm sizes. The fourth most popular strategy was drying farm produce at home, for which the results show that, from 2005 to 2011 and 2012 to 2016, 9.3% and 11.8% of farming households respectively dried their produce at home to avoid crop destruction by cattle. This increased to 13.4% of farming households from 2017 to 2021.

Farming households also relocated their farms to different sites to avoid crop destruction by cattle, with 7.7% of households reporting to have done this between 2017 and 2021. This is an increase from 5.5% and 3.3% of households who reported to have relocated their farms from 2012 to 2016 and 2005 to 2011 respectively. The results show that, between 2017 and 2021, 4.4% of farmers reported using radio sets as an on-farm strategy to deter cattle from invading their farms in the night. Farmers disclosed that the sounds from the radios created the impression that the farmer was present on the farm, thus compelling herders to direct their cattle away from the farm. Finally, fencing to keep cattle out of farms was used as a strategy between 2017 and 2021 only, but fewer than 2.5% of farmers reported using it. Figure 2 presents farming households' on-farm conflict adaptation strategies from 2005 to 2021.

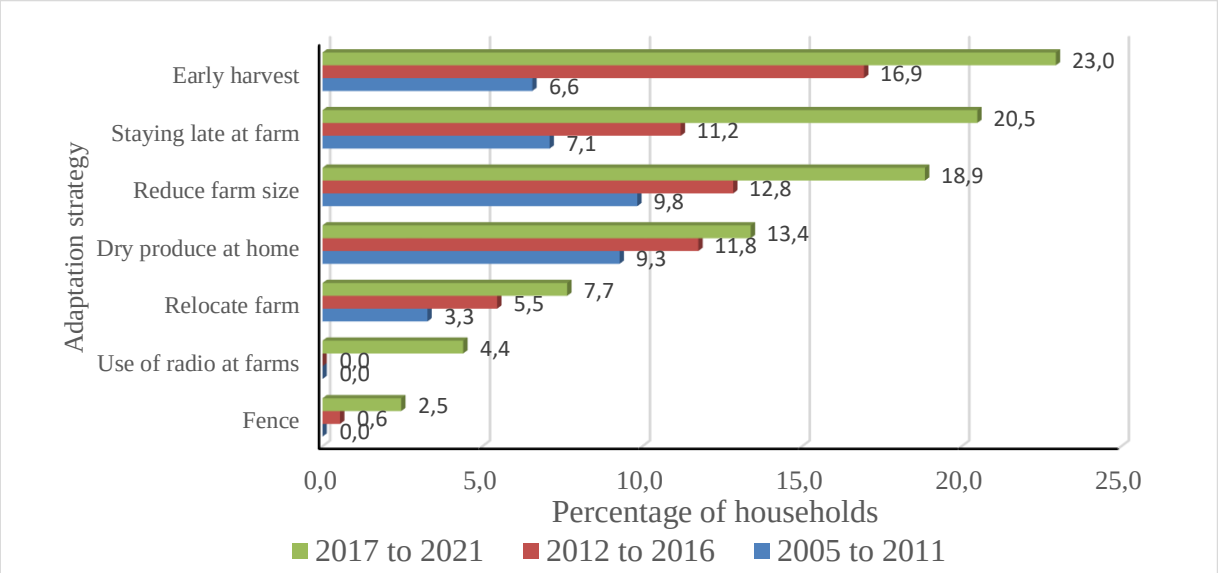

Figure 2: Farming households' on-farm conflict adaptation strategies from 2005 to 2021

In an interview with a key informant at the Sekyere Afram Plains District Department of Agriculture, it was revealed that:

> *Crop destruction could be avoided if farmers could fence their farms. However, farmers do not fence their farms. They rather prefer to stay at their farms even at night to prevent cattle straying into their farms*. (KI 04, 02/09/2022)

During a focus group discussion with farmers from the Hamidu community in the Sekyere Afram Plains District, a female participant explained why they were unable to fence their farms:

> *Our farms are not small. Therefore, fencing will cost us a lot of money and we do not have enough financial resources after spending our savings on land preparation, ploughing, and purchasing seeds and labour. This is why most farmers do not fence their farms. Instead, we stay late on the farm to prevent cattle from destroying our crops during their night grazing. Those who cannot stay on their farms at night use radio sets to scare away cattle when they are approaching the farm*. (FGD 04, 21/06/2021)

Farmers' used nine approaches to non-farm strategies to adapt to the effects of farmer–herder conflicts. The most common non-farm adaptation strategy was petty trading, with 8.2% and 12.3% of farmers adopting it from 2005 to 2011 and 2012 to 2016, respectively. Between 2017 and 2021, more farmers transited to petty trading, with 15.9% of them reporting to have engaged in it. Next to petty trading was charcoal production, which also increased – from 3.6% between 2005 and 2011 to 7.7% between 2012 and 2016 and 13.4% between 2017 and 2021 (Figure 3). During a focus group discussion with male farmers at Mankala in the Asante Akim North Municipality, a participant in support of why they engage in charcoal production stated that:

> *Cattle destroy crops, but not charcoal. So, we now produce more charcoal for additional income so that when cattle destroy our crops, we can still meet our basic needs*. (FGD 12, 08/07/2021)

The results further show that fishing and hunting and rearing of small ruminants were the next most common non-farm strategies adopted by farming households to adapt to the conflict, with 5.7% of households reporting to have adopted the two strategies from 2017 to 2021. Almost 4% of farming households were engaged in fishing, hunting and rearing of small ruminants between 2012 and 2016. The fifth most popular non-farm adaptation strategy was agro-processing, aggregation and sales of agricultural products. The results show that, from 2005 to 2011 and 2012 to 2016, only 0.5% and 3.0% of farming households were engaged in agro-processing, aggregation and sales of agricultural products respectively. This increased marginally, to 4.9%, from 2017 to 2021. Sale of livestock was another strategy adopted by farmers, while seeking assistance from friends/family, leasing out land and migration were other non-farm strategies adopted by farming households to adapt to the conflict. However, these strategies were not popular among households from 2005 to 2021, given that less than 4% of farming households reported ever adopting these strategies. Figure 3 presents farming households' non-farm conflict adaptation strategies from 2005 to 2021.

Furthermore, the results show that farming households ranked early harvesting of crops as the most effective on-farm strategy in adapting to the effects of the conflict. Although most households did not dry their farm harvests at home, this was ranked the second most effective on-farm adaptation strategy, followed by staying late on the farm. Among the non-farm adaptation strategies, aggregation of agricultural products and agro-processing were ranked as the most effective adaptation strategies, although most farming households did not adopt these. Participants in the focus group discussion revealed that the low adoption of aggregation of agricultural products and agro-processing were because these strategies required more financial capital, which most farmers cannot afford. Charcoal production and leasing out the land were ranked as the second and third most effective non-farm strategies respectively. The Kendall's concordance coefficients of 0.647 and 0.690 (Table 3) were both significant at 1%, which implies that there was 64.7% and 69.0% significant agreement among farming households in ranking on-farm and non-farm strategies respectively.

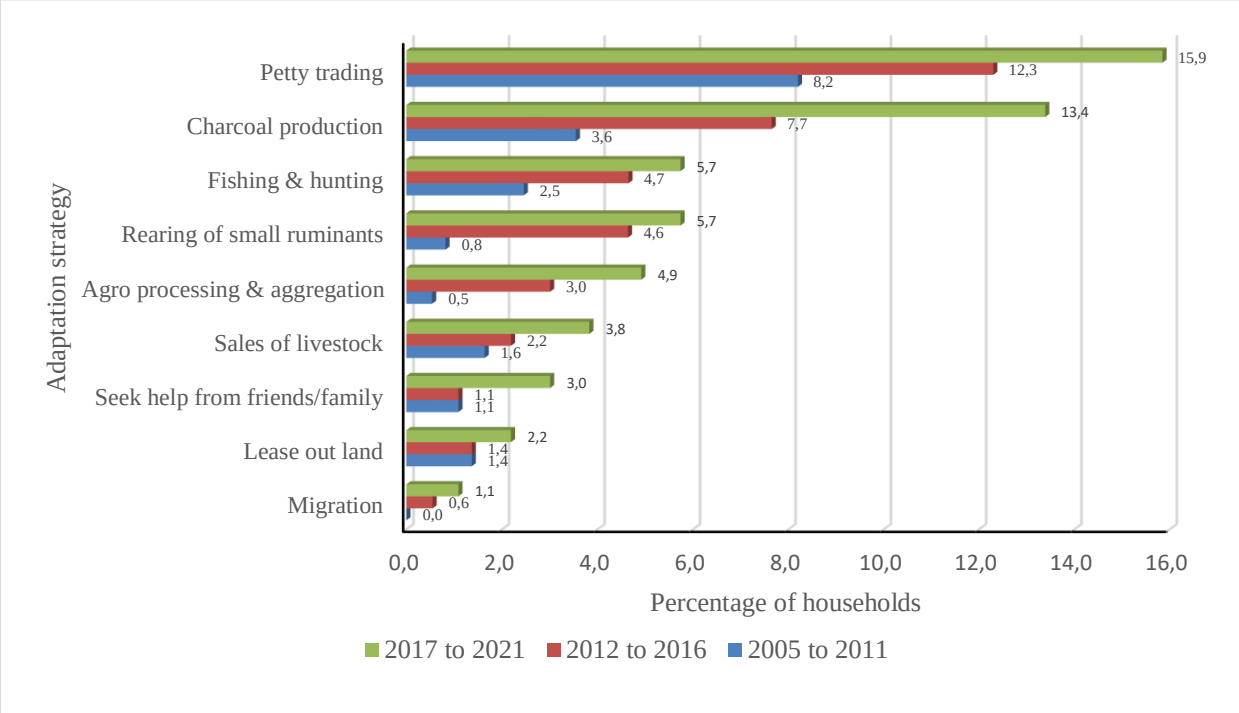

Figure 3: Farming households' non-farm strategies to adapt to conflict from 2005 to 2021

Table 3: Results of farming households' ranking of adaptation strategies

Adaptation strategies	Mean rank (standard deviation)	Rank of effectiveness
On-farm adaptation strategies		
Early harvest	1.52 (0.81)	1st
Dry farm harvest at home	1.60 (0.86)	2nd
Staying late on farm	1.68 (0.88)	3rd
Fencing of farms	1.78 (0.55)	4th
Use of radio on farm	1.81 (0.76)	5th
Reduce farm size	2.06 (1.18)	6th
Relocate farm	2.23 (1.10)	7th
Kendall's test statistics		
Kendall's W[a]	0.647	
Number of observations	218	
Chi-square	1 302.566	
Asymptotic significance	0.000	
Non-farm adaptation strategies		
Agro-processing and aggregation	1.30 (1.10)	1st
Charcoal production	1.43 (1.25)	2nd
Lease out land	1.89 (1.05)	3rd
Sales of livestock	1.95 (0.91)	4th
Migration	2.00 (1.19)	5th
Petty trading	2.15 (1.30)	6th
Seek help from friends/family	2.36 (1.36)	7th
Rearing of small ruminants	2.62 (1.25)	8th
Fishing and hunting	3.68 (1.21)	9th
Kendall's test statistics		
Kendall's W[a]	0.690	
Number of observations	164	
Chi-square	874.916	
Asymptotic significance	0.000	

3.1.2 Herders' adaptation strategies

Herding households adopted either herding or non-herding strategies, or both, to adapt to the farmer–herder conflict. The results show that 49.0% of households did not adopt any strategy to adapt to the effect of farmer–herder conflict, compared to 51% of households that adopted only herding, non-herding, or both herding and non-herding adaptation strategies (Table 4).

Table 4: Main adaptation strategies adopted by herding households

Adaptation strategy	Number of households adopting strategy	Percentage
No adoption	245	49.0
Only herding strategies	63	12.6
Only non-herding strategies	137	27.4
Both herding and non-herding strategies	55	11.0
Total	500	100.0

As presented in Figures 4 and 5, households adopted herding and non-herding strategies to adapt to farmer–herder conflicts. Four herding and three non-herding strategies were identified. Night grazing was the most common herding strategy, which increased from 5.2% between 2005 and 2011 to 16.0% between 2012 and 2016 and 28.5% between 2017 and 2021. Highlighting herders' night grazing as an adaptation strategy, a participant during a focus group discussion with herders stated that:

> *Cattle grazing has been banned in the Agogo area, and the police shoot our cattle when they see them grazing anywhere in the district. But we also have to find pasture and water for our cattle. Our cattle prefer the elephant grass, which is abundant in the Agogo area. So, we send our cattle for grazing at night because farmers would have gone home, and the police do not patrol at night. We return after 4:00 am*. (FGD 14, 15/07/2021)

The rearing of small ruminants such as sheep and goats was second most common after night grazing. Between 2005 and 2011, no herder reared small ruminants to adapt to the effect of the conflict, but 5% of herding households reported rearing small ruminants between 2012 and 2016. This increased to 7% between 2017 and 2021. In comparison to cattle, small animals do not destroy crops, and herding households often rely on these small animals when their cattle are killed for destroying crops. No herding household reduced feed for cattle as an adaptation strategy, while only 1% of herding households reported ranching their cattle as an adaptation strategy between 2017 and 2021. Figure 4 presents herding households' herding strategies in adapting to the effects of farmer–herder conflicts.

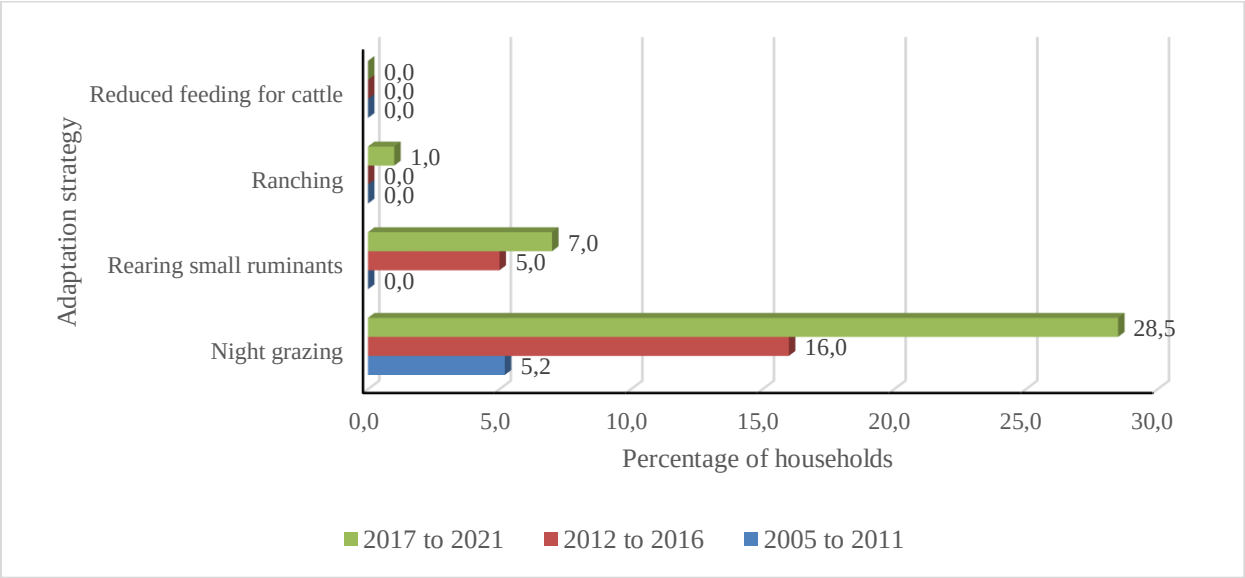

Figure 4: Herding households' herding conflict adaptation strategies from 2005 to 2021

Herders mentioned three non-herding adaptation strategies they adopted in the three periods to adapt to the effect of the farmer–herder conflicts. The results show that engaging in farming was the most common non-herding adaptation strategy among herding households. No herding household reported having engaged in farming between 2005 and 2011, but 10.0% of herding households adopted farming as a strategy to adapt to the effect of farmer–herder conflict between 2012 and 2016, which increased to 25.0% between 2017 and 2021. The second most popular non-herding adaptation strategy among herding households was migration. The results show that 21% of herding households migrated to other locations to adapt to the effect of the farmer–herder conflict between 2005 and 2011. This increased to 8.3% between 2012 and 2016, and 12.5% between 2017 and 2021. Sales of livestock was the next dominant non-herding adaptation strategy, with 3.1% of herding households adopting the strategy between 2005 and 2011. This increased to 4.2% between 2012 and 2016 and to 6.3% between 2017 and 2021. Figure 5 presents herders' non-herding adaptation strategies from 2005 to 2021.

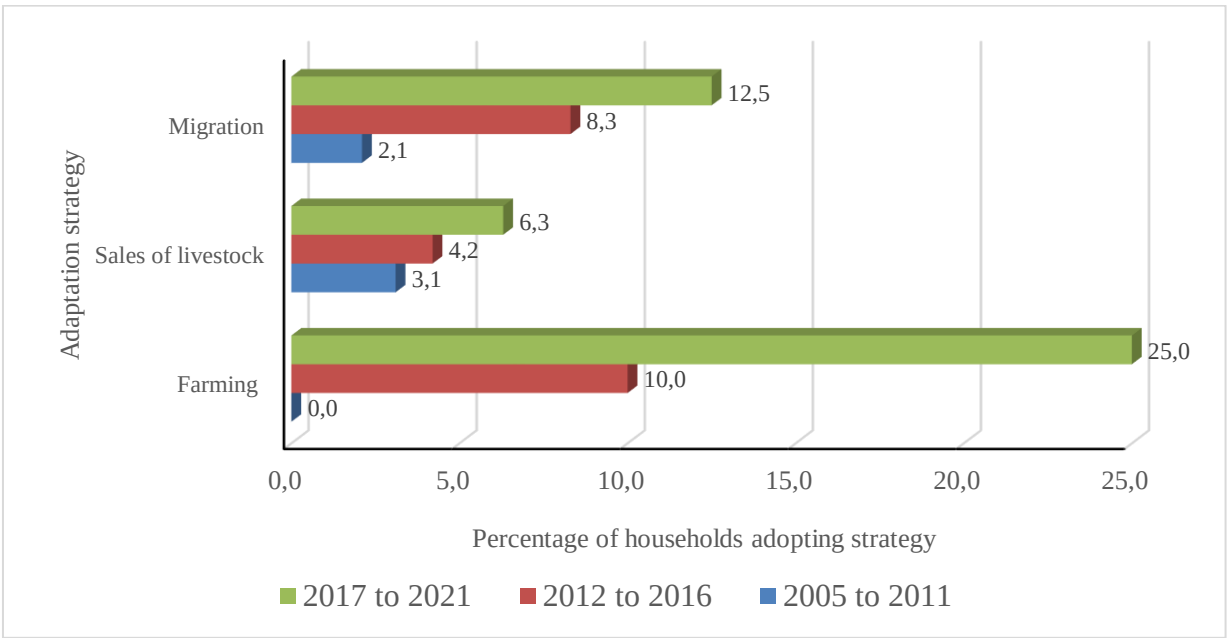

Figure 5: Herding households' non-herding conflict adaptation strategies from 2005 to 2021

The results further show that, whereas herders ranked night grazing and rearing of small ruminants as the first and second most effective herding strategies respectively, ranching was ranked as the least effective herding strategy. This is why most herders engage in night grazing but not in ranching. Among the non-herding adaptation strategies, farming was ranked the most effective, while migration was ranked the least effective. The Kendall's concordance coefficients of 0.575 and 0.615 (Table 5) were both significant at 1%, which implies that, among the herding households, there was 57.5% and 61.5% significant agreement among households in ranking herding and non-herding strategies, respectively. This suggests that the majority of herding households agreed in their ranking of the effectiveness of herding and non-herding adaptation strategies, as presented in Table 5.

Table 5: Results of herding households' ranking of adaptation strategies

Adaptation strategy	**Mean rank (standard deviation)**	**Rank of effectiveness**
Herding adaptation strategies		
Night grazing	2.62 (1.25)	1st
Rearing small ruminants	2.73 (1.40)	2nd
Ranching	3.00 (1.00)	3rd
Kendall's test statistics		
Kendall's W[a]	0.575	
Number of observations	76	
Chi-square	409.282	
Asymptotic significance	0.000	
Non-herding adaptation strategies		
Farming	1.57 (0.79)	1st
Sales of livestock	1.96 (0.91)	2nd
Migration	2.00 (1.19)	3rd
Kendall's test statistics		
Kendall's W[a]	0.615	
Number of observations	86	
Chi-square	1 153.315	
Asymptotic significance	0.000	

When herding households envisage impending attacks on them and their cattle in retaliation for crop destruction, they often migrate to locations perceived to be safe. When justifying why they migrate to adapt to farmer–herder conflict, a transhumant herder said, during a focus group discussion with transhumant herders at Sanchenso community in the Asante Akim North Municipality, that:

> *When we think farmers or the police will come to kill our cattle for crop destruction, we often move with our cattle to hide at locations where we think they will not find us. We do this to avoid killing of our cattle because the cattle are our wealth and source of income*. (FGD 29, 08/08/2021)

3.2 Factors influencing households' adoption of adaptation strategies

The first stage of the MESR model (Equation (3)) presents the multinomial logit regression results on the determinants of households' adoption of adaptation strategies. The results show that households' adoption of only on-farm adaptation strategies is negatively correlated with farm or crop losses due to destruction of farms by cattle, membership of a farmer-based organisation, and having enough leisure time, but positively corrected with vulnerability to farmer–herder conflict, farming along cattle movement routes, access to land, expectation of the future occurrence of farmer–herder conflicts, and access to agricultural extension services. The results also reveal that farming households' adoption of only non-farm adaptation strategies is negatively correlated with crop destruction, farming experience and access to adequate farm labour, but positively correlated with

vulnerability to farmer–herder conflict, household size and access to land. When it comes to households' adoption of both on-farm and non-farm adaptation strategies, the results show that it is negatively correlated with crop destruction, farming experience, membership of farmer-based organisations, leisure time, and access to adequate labour, but positively correlated with vulnerability to farmer–herder conflict, household size, access to land, expected likelihood of the occurrence of farmer–herder conflict and access to extension services.

Focus group discussions with farming households revealed that households that can afford the cost of labour can harvest their crops early, before the arrival of transhumant herders. But households that enjoy more leisure spend less time on both on-farm and non-farm activities and hence do not adopt measures to adapt to farmer–herder conflicts. Furthermore, households try to adopt on-farm measures such as staying late on the farm, relocating the farm, harvesting early and drying farm produce at home to avert crop destruction when they know their farms are located along cattle movement routes, have access to extension services, and when they think their crops are likely to be destroyed by cattle. Table 6 presents the MNL results on the determinants of farming households' adoption of farmer–herder conflict adaptation strategies.

Table 6: MNL results on determinants of farm households' adoption of adaptation strategies

Independent variable	**Adaptation strategies**		
	Only on-farm	**Only non-farm**	**Both on-farm & non-farm**
Sex of household head	-0.259 (0.339)	-0.417 (0.322)	-0.538 (0.393)
Farm/crop lost	-0.049*** (0.016)	-0.051*** (0.020)	-0.061*** (0.023)
Farming experience	-0.023 (0.016)	-0.040** (0.016)	-0.052*** (0.019)
FBO membership	-0.953*** (0.349)	-0.512 (0.335)	-0.752* (0.395)
Vulnerability	10.020*** (2.445)	5.723** (2.223)	15.685*** (2.860)
Leisure time	-0.534** (0.212)	-0.111 (0.212)	-0.751*** (0.240)
Number of crops cultivated	0.160 (0.134)	0.187 (0.128)	0.156 (0.143)
Household size	0.034 (0.045)	0.109*** (0.042)	0.110** (0.047)
Site location	1.377** (0.576)	-0.340 (0.533)	-0.497 (0.572)
Easy to access land	0.030** (0.015)	0.026* (0.015)	0.035** (0.015)
Land ownership	0.037 (0.095)	0.022 (0.0937)	0.213 (0.103)
Labour adequacy	-0.145 (0.147)	-0.394*** (0.138)	-0.391** (0.164)
Instrument:			
Access to extension	0.254*** (0.095)	0.098* (0.092)	0.259** (0.109)
Future occurrence of conflict expected	0.563*** (0.149)	0.048 (0.144)	0.387** (0.169)
Constant	-6.650*** (1.797)	0.121 (1.631)	-4.953** (1.989)
Wald test on instruments (χ^2)	44.12***	14.12*	16.49**
Model diagnosis			
Number of observations	412		
LR (42)	215.97		
Log likelihood	-457.80285		
Prob > Chi^2	0.0000		
Pseudo R^2	0.1909		

Note: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively
Figures in parentheses are standard errors; FBO = farmer-based organisations

The results show that herding households' adoption of only herding adaptation strategies was positively correlated with male household headship, losing cattle through killing, and vulnerability to farmer–herder conflict, but negatively correlated with access to extension services. However, herding households' adoption of only non-herding adaptation strategies was positively correlated with vulnerability to farmer–herder conflict and household size, while rearing different animals and perceived likelihood of experiencing farmer–herder conflict were negatively correlated with herding households' adoption of only non-herding adaptation strategies. Finally, herding households adoption of both herding and non-herding adaptation strategies was negatively correlated with herding

experience, enough leisure time, and rearing of different animals, but positively correlated with access to extension service and grazing close to farm sites. During the focus group discussions with transhumant herders, it was revealed that they often did not have access to extension services and treated their cattle themselves. Table 7 presents the MNL results on the factors influencing herding households' adoption of farmer–herder conflict adaptation strategies.

Table 7: MNL results on determinants of herding households' adoption of adaptation strategies

Independent variable	**Adaptation strategies**		
	Only herding	**Only non-herding**	**Both herding & non-herding**
Sex of household head	1.716** (0.779)	-0.057 (0.237)	-1.095 (0.694)
Herd lost	0.042*** (0.013)	-0.005 (0.013)	0.021 (0.015)
Herding experience	-0.012 (0.024)	-0.001 (0.012)	-0.080** (0.031)
Herders' association membership	0.281 (0.506)	-0.176 (0.235)	0.061 (0.522)
Vulnerability	6.199* (3.692)	4.260*** (1.578)	4.720 (3.849)
Leisure time	0.034 (0.277)	-0.003 (0.138)	-0.679** (0.321)
Number of different herds reared	0.211 (0.161)	-0.167* (0.090)	-0.313* (0.184)
Household size	0.031 (0.060)	0.060** (0.027)	0.055 (0.054)
Site location	0.585 (0.647)	-0.117 (0.348)	1.329* (0.705)
Land ownership	0.095 (0.129)	0.010 (0.065)	0.001 (0.157)
Easy to access land	-0.037 (0.023)	-0.003 (0.007)	0.002 (0.011)
Labour adequacy	-0.258 (0.196)	-0.097 (0.095)	-0.082 (0.210)
Instrumental variables			
Access to extension	-0.276* (0.235)	0.047 (0.062)	0.084** (0.171)
Expected future occurrence of conflict	0.070 (0.215)	-0.165* (0.098)	0.076 (0.242)
Constant	-1.665 (2.599)	-1.173 (1.154)	0.562 (2.696)
Wald test on instruments (χ^2)	13.11*	14.02*	16.35**
Model diagnosis			
Number of observations	412		
LR (42)	93.29		
Log likelihood	-355.7735		
Prob > Chi^2	0.0000		
Pseudo R^2	0.1159		

Note: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively
Figures in parentheses are standard errors

3.3 Effects of adopting conflict adaptation strategies on households' multidimensional poverty and subjective wellbeing

The results of the effects of adopting adaptation strategies on multidimensional poverty and subjective wellbeing of farming and herding households were disaggregated by only on-farm, only non-farm and both on-farm and non-farm adaptation strategies for farming households (and only herding, only non-herding and both herding and non-herding adaptation strategies for herding households). The reference category in each model was non-adoption. The results of the average treatment effect on the treatment group (ATT) show that the adoption of only on-farm, only non-farm and both on-farm and non-farm adaptation strategies significantly affect the multidimensional poverty and subjective wellbeing of farming households relative to non-adoption.

The multidimensional poverty of farming households that adopted only on-farm adaptation strategies reduced by 3.1%, while their subjective wellbeing increased by 11.0% compared to if they had not adopted any farmer–herder conflict adaptation strategy. However, the multidimensional poverty and subjective wellbeing of farming households that adopted only non-farm adaptation strategies increased by 2.5% and 3.4% respectively relative to non-adoption. Similarly, the multidimensional poverty and subjective wellbeing of farming households that adopted both on-farm and non-farm adaptation strategies reduced by 3.7% and 2.3%, respectively. Table 8 presents the predicted results

of the average treatment effects of farmer–herder conflict adaptation strategies on farming households' multidimensional poverty and subjective wellbeing.

The results of the focus group discussions on the effect of on-farm and non-farm adaptation strategies on farming households' multidimensional poverty and subjective wellbeing did not differ. A male participant in a focus group discussion with farmers at Serebuoso in the Asante Akim North Municipality indicated that:

> *We are the farms, and the farms are us. We depend heavily on plantain, cassava and maize cultivation for survival and all our needs. We only engage in charcoal production and other income-generation activities because cattle destroy our crops. We do not feel happy when cattle destroy our crops and we have to find money by engaging in other activities aside from farming*. (FGD 11, 12/07/2021)

The herding households that adopted only herding, only non-herding and both herding and non-herding adaptation strategies experienced significant differences in their multidimensional poverty and subjective wellbeing compared to if they had not adopted any strategy. The results of the ATT show that the multidimensional poverty of herding households' that adopted only herding adaptation strategies reduced significantly, by 3.2%, while their wellbeing increased by 8.9% compared to if they had not adopted any adaptation strategy. However, the multidimensional poverty and wellbeing of herding households that adopted only non-herding adaptation strategies increased by 2.1% and 1.0% respectively, compared to if they had not adopted any adaptation strategy. Finally, the multidimensional poverty and wellbeing of herding households that adopted herding and non-herding adaptation strategies reduced by 10.9% and 1.1% respectively, relative to non-adoption. The results of the ATT of farmer–herder conflict adaptation strategies on multidimensional poverty and subjective wellbeing of farming and herding households are presented in Tables 8 and 9, respectively. In these tables, estimates from equations (6) and (7) are presented in columns 2 and 3 respectively, while estimates from Equation (8) are presented in column 4.

In an interview with herders in Asante Akim North Municipality, one of their leaders indicated that herding households are better off when they adapt by protecting their herds than diversifying into other non-herding activities. He stated that:

> *Cattle herding is part of our culture, and we cannot do without it since that will mean abandoning our culture. We would rather do what we can to prevent cattle killing than abandon herding. Even when a herder engages in farming or other occupation for income, he must still herd animals to be self-satisfied because that makes us happy and brings us more income*. (KI 09, 08/09/2021)

Table 8: Average treatment effects of adopting conflict adaptation strategies on farming households' multidimensional poverty and subjective wellbeing

Adaptation strategy	Households' adoption decisions		Net effect of adaptation strategy on livelihood outcome (ATT)	
	If adopters had adopted strategy (C)	If adopters had not adopted strategy (N)	ATT = C – N	% Change = (ATT/N)*100
Multidimensional poverty				
Only on-farm strategies	1.607 (0.005)	1.660 (0.015)	-0.052*** (0.017)	3.1
Only non-farm strategies	1.701 (0.011)	1.660 (0.015)	0.041*** (0.014)	2.5
Both on-farm and non-farm strategies	1.599 (0.005)	1.660 (0.015)	-0.061*** (0.017)	3.7
Subjective wellbeing				
Only on-farm strategies	1.817 (0.045)	1.633 (0.009)	0.183*** (0.048)	11.0
Only non-farm strategies	1.578 (0.011)	1.633 (0.009)	-0.056*** (0.007)	3.4
Both on-farm and non-farm strategies	1.594 (0.015)	1.633 (0.009)	-0.039*** (0.013)	2.3
Number of observations	412		412	

Notes: *** denotes statistical significance at 1%; figures in parentheses are standard errors.

Table 9: Average treatment effects of adopting conflict adaptation strategies on herding households' multidimensional poverty and subjective wellbeing

Adaptation strategy	Households' adoption decisions		Net effect of adaptation strategy on livelihood outcome (ATT)	
	If adopters had adopted strategy (A)	If adopters had not adopted strategy (N)	ATT = A – N	% change = (ATT/N)*100
Multidimensional poverty				
Only herding strategies	1.576 (0.003)	1.628 (0.004)	-0.052*** (0.005)	3.2
Only non-herding	1.662 (0.004)	1.628 (0.004)	0.034*** (0.003)	2.1
Both herding and non-herding strategies	1.450 (0.010)	1.628 (0.004)	-0.178*** (0.011)	10.9
Subjective wellbeing				
Only herding strategies	1.456 (0.101)	1.599 (0.007)	-0.143*** (0.009)	8.9
Only non-herding strategies	1.615 (0.009)	1.599 (0.007)	0.016*** (0.005)	1.0
Both herding and non-herding strategies	1.581 (0.013)	1.599 (0.007)	-0.018*** (0.104)	1.1
Number of observations	412		412	

Notes: *** denotes statistical significance at 1%; figures in parentheses are standard errors.

4. Discussion

4.1 Households' strategies in adapting to farmer–herder conflict

The findings of this study reveal that the poverty of both farming and herding households increases, while their wellbeing decreases, when they experience farmer–herder conflict in the form of crop destruction by cattle and the killing of cattle. The situation is worse among households that do not adopt any adaptation strategy, or cannot adapt well. Such findings have also been reported from other African countries, such as Nigeria (Adebisi *et al*. 2020), Benin (Diogo *et al*. 2021) and Cameroon (Kongnso *et al*. 2021). Our results regarding adaptation strategies suggest that households are concentrating on a few, trusted strategies, rather than trying all manner of possibilities in adapting to the conflict. However, our results show that the strategies adopted by households have grown over the years in response to the worsening of the conflict.

Knowing that transhumant herders and their cattle migrate to the study area from November to April every year, farming households harvest their crops early. This was previously reported in Nigeria as

a strategy among farmers to cope with pastoralists' destruction of their crops (Yekinni *et al*. 2017; Obaniyi *et al*. 2020). Furthermore, rather than drying harvested crops on the farms, as practised before the seasonal migration of herders, some farming households now dry harvested crops at home to avoid their destruction by cattle. Apart from avoiding losses from cattle consumption, these practices may help farmers reduce their postharvest losses from insects and other biological sources. They may also play a dual role by allowing herding on or in the vicinity of farms without any destruction to crops. However, they may exert undue pressure on farmers and reduce their leisure time, and for farmers who hate to see cattle on their lands, these practices may send wrong the signal to herders that the field is now open for them to graze their animals freely. Although the use of radio sets to prevent farm destruction by cattle was low, it is a new strategy that has not been reported in the literature before. Whilst being innovative and effective at this stage, its effectiveness might deteriorate as herders become aware of the strategy. Farmers have been transitioning from farming to non-farm activities, with charcoal production and petty trading being the predominant non-farming activities. According to the farmers, charcoal production is not prone to cattle destruction, and also is profitable because production costs are generally low. This resonates with earlier research in Kenya, where charcoal production as a conflict adaptation strategy was the second most used contributor to the livelihood income of farmers during conflict with pastoralists (Akall 2021). Although it is often criticised for its negative environmental impact, charcoal production is noted for its valuable role as a safety net in times of livelihood crises in rural areas (Brobbey *et al*. 2019).

Night grazing was the most popular and perceived to be the most effective herding adaptation strategy among herding households. In Asante Akim North Municipality, security personnel often patrol the communities and shoot to kill cattle found grazing around farming communities. To avoid cattle killing, herders send their cattle for grazing at night. Unfortunately for farmers, crops are often destroyed by cattle during night grazing. This implies that night grazing is not a sustainable adaptation strategy, since it exacerbates the conflict. Unlike herders in the Sahel Region of Africa, where cattle graze at night to complement day grazing because of insufficient fodder in the dry season (Ayantunde *et al*. 2002), our findings show that herders can avoid payment of compensation to victims of crop destruction when they send their cattle for night grazing. In Kenya, herders use night grazing to avoid the payment of fees to landowners and fines for crop destruction (Pas & Cavanagh 2022). Thus, the poverty of herding households reduces when they adopt herding strategies.

Similar to previous findings in Kenya (Akall 2021) and Namibia (Inman *et al*. 2020), our findings show that farming is the predominant and most effective non-herding adaptation strategy among sedentary herders. Besides providing them with food and a cash crop, farming allows herders to produce residues to feed their livestock (Young & Ismail 2019). Another popular adaptation strategy among herders is migration. Transhumant herders migrate from one location to another when they expect reprisal attacks on them and their cattle. This is similar to reports by Idrissou *et al*. (2020) and Napogbong *et al*. (2020), who observed mobility to be the most important coping strategy among pastoralists in Benin and North-Western Ghana, respectively. Herders' destination of migration is influenced by the availability of water and pasture, especially elephant grass. In contrast to the expectations of the Ghana government's ranching policy, herders did not mention ranching as an adaptation practice. The perceived reasons accounting for non-use of ranches among herders were inadequate feed for cattle, poor veterinary services – leading to high cattle mortality, the unwillingness of herders to stay far away from the cattle, cattle breeds not coping with confined conditions – as in the case of the current form of ranching, and poor management practices at the ranch. In addition to these, Ahmed and Kusaanaa (2021) mention land dispossession and the unwillingness of chiefs to allocate land to herders as some of the reasons why ranching is not able to play its expected role in the farmer–herder conflicts in Ghana.

4.2 Factors that influence households' adoption of conflict adaptation strategies

The adoption of conflict adaptation strategies is influenced by several determinants. Farming households do not see the benefit of adopting on-farm adaptation strategies when cattle have already destroyed their crops. Also, households that prioritise leisure to a greater extent have little time to continue working on stay on their farms late to avert crop destruction or engage in other non-farm activities. We realised that herding households headed by males are likely to adopt herding adaptation strategies such as night grazing. Yet herding households whose livelihoods are more vulnerable to the impact of farmer–herder conflict are likely to adopt either herding or non-herding adaptation strategies, but not both. The reason is that households receive higher returns from their investments when they focus on herding activities alone, rather than splitting their investments into herding and non-herding activities. This is consistent with the utility theory, which postulates that farmers/herders will rather adopt more strategies with higher benefits/returns (Balew *et al*. 2014; Thinda *et al*. 2020; Wens *et al*. 2021).

Meanwhile, larger households are likely to engage in other non-herding activities besides their primary herding occupation to adapt to farmer–herder conflict. An interesting finding of this study is that households with higher herding experience are less likely to adopt both herding and non-herding adaptation strategies. The reason is that experienced herders claim they know the grazing routes that will not destroy crops to ensure they do not experience any conflict with farmers. Also, they are acquainted with information on security patrols and danger zones to prevent cattle-killing. Hence, experienced herders feel they can cope without adopting any strategy. These findings are consistent with other findings on the determinants of herders' adoption of adaptation strategies in Benin, Pakistan and Ghana (Idrissou *et al*. 2020; Faisal *et al*. 2021; Twumasi *et al*. 2022).

4.3 The effect of adopting conflict adaptation strategies on households' multidimensional poverty and subjective wellbeing

Farmers and herders adopt adaptation strategies to ameliorate the effects of farmer–herder conflict on their multidimensional poverty and subjective wellbeing. However, only sustainable adaptation strategies should be promoted for adoption by households. Although on-farm adaptation strategies such as fencing farms and using radio sets to scare cattle from farms increased the cost of production for farming households, they prevented crop destruction by cattle. Hence, farming households feel happy and satisfied that their farms are not destroyed and that they receive good returns from their investment, since they perceive crop farming as their cultural occupation and feel fulfilled engaging in it.

From the farmers' perspectives, crop cultivation, especially of plantain, is more profitable than non-farm economic activities, such as petty trading and charcoal production, due to the availability of fertile land that does not require fertilisers for good crop yields. Our findings also show that farming households splitting their limited resources to enter into other ventures does not maximise returns on their investments. In line with the utility theory, most farmers adopt on-farm strategies rather than off-farm strategies to avoid crop destruction because the former reduce their multidimensional poverty and improve their subjective wellbeing. Thus, they feel better off adopting measures that prevent crop destruction than diversifying their livelihood into other, non-farm economic activities. This explains why some farmers adopt risky measures, such as staying late on the farm to chase cattle away. The higher effects of on-farm adaptation strategies on the subjective wellbeing of farming households have also been shown in Zimbabwe, Ethiopia and Morocco (Mujeyi *et al*. 2021; Alary *et al*. 2022; Yitbarek & Tesfaye 2022).

Fulani herders, in particular, see herding as their traditional occupation. Thus, herders' subjective wellbeing declines when they resort to non-herding activities to adapt to farmer–herder conflict. The findings of this study are consistent with those of Inman *et al*. (2020), who found that, although herders engaged in farming to cope with resource conflict in Namibia, it was ineffective because of climate change.

4.4 Policy implications of farmers' and herders' adaptation strategies

Although the most common non-farm adaptation strategies among farming households are petty trading and charcoal production, charcoal production may be a threat to the achievement of the United Nations Sustainable Development Goal of transitioning to clean energy (United Nations 2020). In addition, this strategy may not be sustainable because the continuous depletion of the forests without reforestation will result in deforestation. The sustainability of charcoal production could be ensured by establishing woodlots, as enshrined in Ghana's Forest and Wildlife Policy (Ministry of Lands and Natural Resources [MLNR] 2012) and the Draft Bioenergy Policy (Energy Commission 2010). Furthermore, night grazing is the most popular and perceived as the most effective herding adaptation strategy among herding households, yet it is contrary to the regulations guiding transhumance movements as contained in the ECOWAS (1998) Protocol on Transhumance and the African Union (2010) Policy Framework for Pastoralism in Africa. The reason is that crops are often destroyed during night grazing, which fuels farmer–herder conflicts. Finally, the non-use or low patronage of the ranches among herders has huge implications for the success of ranching policies in Africa, such as the Ghana Ranching Policy, to curb farmer–herder conflict. Hence, herders require more sensitisation on the use of ranches to ensure the success of the ranching policy, which is a more sustainable solution and adaptation strategy.

5. Conclusions and recommendations

Farming households adapt to farmer–herder conflicts by harvesting their crop early, staying late on their farms and reducing their farm size as on-farm strategies, or engaging in non-farm livelihood activities such as charcoal production and petty trading. On the other hand, herding households graze at night to prevent the killing of their cattle, engage in farming, or move to non-conflict-prone communities. We conclude that, if farmers and herders would adopt adaptation strategies to deal with crop destruction by cattle and the killing of cattle by farmers or security forces, it would lead to a significant reduction in the conflict actors' poverty and an improvement in their wellbeing compared to the situation of non-adoption of strategies. Even though farming households' adoption of both on-farm and non-farm adaptation strategies reduces their poverty and increases their wellbeing, they are better off focusing on only on-farm adaptation strategies than adopting both on-farm and non-farm strategies. Similarly, herding households' adoption of only herding adaptation strategies reduces their poverty and improves their wellbeing more than if they adopted only non-herding adaptation strategies or both herding and non-herding adaptation strategies. Thus, the wellbeing and poverty status of both farming and herding households will improve if they focus only on on-farm and herding strategies to adapt to farmer–herder conflict, rather than adopting other non-farm and non-herding adaptation strategies. However, to promote households' adoption of adaptation strategies, there should be increased access to extension services and land for households.

Based on these findings, we recommend that interventions aimed at mitigating or minimising the effect of farmer–herder conflict on the poverty and wellbeing of households should focus on on-farm adaptation strategies only for farming households, and herding adaptation strategies only for herding households. Also, given that a loss of crops through cattle invasion and the killing of cattle for crop destruction significantly increases households' poverty and reduces their wellbeing, it is

recommended that the district assemblies, in collaboration with the traditional authorities or landlords, should explore the possibility of promoting more sustainable adaptation strategies. These could include designating grazing corridors for cattle to avoid crop destruction. When there is limited interaction between farming and herding activities, poverty will be reduced for both farming and herding households, and their wellbeing will be improved. Finally, we recommend that further studies should focus on the effect of individual adaptation strategies on poverty and wellbeing. This will help expose the effects of specific adaptation strategies on poverty and wellbeing to guide the formulation of policies on which strategies should be promoted and which should not.

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Appendix 1: Test of the validity of instruments in multidimensional poverty (pool sample)

Variable	Multidimensional poverty	Subjective wellbeing
Sex	0.002 (0.007)	-0.004 (0.016)
Age	0.006** (0.003)	0.002* (0.006)
Dependency ratio	0.001 (0.001)	0.002 (0.002)
Years of education	0.001 (0.007)	0.001 (0.002)
Farmer–herder conflict	0.134*** (0.039)	0.012* (0.008)
Received compensation	-0.080** (0.003)	0.018 (0.007)
Adaptation strategies		
Only on-farm	-0.061*** (0.011)	0.038*** (0.024)
Only non-farm	0.020** (0.001)	-0.047*** (0.025)
Both on-farm and non-farm	-0.019** (0.014)	-0.065*** (0.030)
Only herding	-0. 138 (0.017)	-0.080*** (0.037)
Only non-herding	0.017** (0.010)	0.017* (0.002)
Both herding and non-herding	-0.035** (0.022)	-0.090** (0.048)
Vulnerability to conflict	0.097** (0.0.063)	-0.020* (0.013)
Number of crops cultivated/different herds	0.048*** (0.002)	0.003 (0.005)
Farming close to cattle movement site	0.021* (0.012)	0.070*** (0.026)
Trust in traditional authorities	0.009 (0.003)	0.010 (0.008)
Trust in security services	-0.008* (0.004)	-0.022** (0.0.010)
Fertility of land	-0.040*** (0.009)	0.017 (0.020)
District (SAPD)	-0.033*** (0.0.008)	-0.055*** (0.017)
Instruments		
Access to extension	-0.002 (0.003)	0.005 (0.006)
Future farmer–herder conflict	0.001 (0.003)	-0.001 (0.008)
Constant	0.494*** (0.041)	0.473*** (0.089)
Wald test on instruments		
F (2, 412)	0.400	0.520
Prob > F	0.6694	0.5932
Number of observations	412	412
Prob > F	0.000	0.000
Adjusted R^2	0.3514	0.1790

Appendix 2: MESR second stage results on determinants of farming households multidimensional poverty and wellbeing

Independent variable	Multidimensional poverty				Wellbeing			
	Non-adoption	OFAS	NFAS	OnNAS	Non-adopter	OFAS	NFAS	OnNAS
Sex	-0.001 (0.015)	-0.017 (0.007)	0.023 (0.015)	-0.017 (0.022)	0.043** (0.018)	-0.002 (0.022)	0.008 (0.024)	0.018 (0.036)
Age	0.002*** (0.000)	0.001 (0.001)	0.002*** (0.000)	-0.001 (0.001)	0.002*** (0.000)	0.001 (0.001)	-0.001 (0.001)	-0.002 (0.002)
Dependency ratio	0.014 (0.011)	0.004 (0.007)	0.005 (0.004)	-0.007 (0.010)	0.003 (0.012)	0.001 (0.129)	0.001 (0.015)	0.010 (0.025)
Market access	-0.039 (0.034)	-0.004 (0.062)	0.026 (0.032)	-0.056 (0.051)	0.010 (0.053)	-0.001 (0.213)	0.065 (0.054)	-0.130 (0.129)
Educational level	0.020*** (0.006)	0.015 (0.005)	0.016** (0.006)	0.006 (0.005)	0.003 (0.009)	-0.004 (0.013)	0.004 (0.006)	0.008 (0.008)
Loss of crops	-0.003* (0.002)	0.005 (0.001)	0.001 (0.001)	0.003** (0.001)	0.002 (0.004)	-0.005 (0.003)	-0.001 (0.001)	-0.001 (0.002)
Farming experience	-0.001* (0.001)	0.001 (0.001)	-0.002* (0.001)	0.001 (0.001)	-0.002* (0.001)	-0.003** (0.002)	0.002 (0.001)	0.000 (0.002)
Remittance	-0.006 (0.018)	-0.006 (0.012)	0.010 (0.010)	-0.020 (0.014)	-0.014 (0.014)	-0.005 (0.170)	-0.008 (0.023)	-0.034 (0.031)
Farm size	-0.003 (0.006)	0.005 (0.009)	-0.023** (0.010)	0.012* (0.008)	-0.004 (0.016)	0.012 (0.023)	0.009 (0.017)	-0.023 (0.034)
Access to land	0.044 (0.042)	0.156** (0.072)	-0.164** (0.069)	0.160 (0.147)	-0.120 (0.131)	-0.128 (0.190)	-0.082 (0.122)	-0.279* (0.166)
Instruments								
Access to extension	0.124 (0.423)	0.016 (0.173)	0.022 (0.202)	0.029 (0.030)	0.036 (0.042)	0.142 (0.213)	0.062 (0.171)	0.082 (0.291)
Future conflict	0.036 (0.105)	0.011 (0.021)	0.044 (0.142)	0.027 (0.125)	0.001 (0.011)	0.032 (0.013)	0.021 (0.032)	0.001 (0.011)
Constant	0.293 (0.047)	0.228 (0.140)	0.340 (0.117)	0.428 (0.121)	0.300*** (0.094)	1.453 (0.856)	0.668 (0.278)	0.463 (0.302)
Selectivity terms								
m0	-0.105* (0.060)	-0.290 (0.355)	0.431** (0.178)	-0.050 (0.106)	-0.080 (0.156)	1.578 (0.999)	-0.462 (0.505)	0.905 (0.597)
m1	-0.141 (0.089)	-0.124 (0.180)	-0.290* (0.180)	-0.127 (0.151)	-0.164 (0.157)	0.400 (0.276)	-0.313 (0.482)	0.163 (0.467)
m2	-0.241 (0.153)	-0.386 (0.309)	-0.261*** (0.074)	0.020 (0.138)	-0.523 (0.211)	0.726 (0.780)	-0.443** (0.183)	-0.024** (0.609)
m3	-0.204 (0.132)	-0.274 (0.378)	-0.412*** (0.153)	-0.002 (0.055)	0.184 (0.560)	2.041** (1.032)	0.242 (0.505)	0.434 (0.212)

Note: OFAS denotes adopters of only on-farm adaptation strategies; NFAS denotes adopters of only non-farm adaptation strategies; OnNAS denotes adopters of both on-farm and non-farm adaptation strategies. Figures in parentheses are standard errors; ***, ** and * denote statistical significance at 1%, 5% and 10% respectively.

Appendix 3: MESR second stage results on determinants of herding households' multidimensional poverty and wellbeing

Determinant	Multidimensional poverty				Wellbeing			
	Non-adoption	OHAS	ONHAS	HnNAS	Non-adoption	OHAS	ONHAS	HnNAS
Sex	-0.012* (0.007)	0.018 (0.050)	0.030*** (0.007)	-0.005 (0.204)	0.019* (0.010)	-0.025 (0.065)	0.012 (0.022)	-0.086 (0.335)
Age	0.002*** (0.001)	0.002 (0.019)	0.002*** (0.001)	-0.002 (0.011)	0.002* (0.001)	-0.001 (0.004)	-0.000 (0.002)	0.002 (0.011)
Dependency ratio	0.007 (0.005)	0.004 (0.021)	-0.005 (0.008)	-0.012 (0.073)	0.010** (0.004)	-0.119 (0.131)	-0.004 (0.018)	0.031 (0.107)
Market access	-0.032 (0.027)	-0.005 (0.099)	-0.033 (0.044)	0.271 (0.668)	0.058 (0.085)	-0.119 (0.131)	-0.096 (0.095)	0.446 (1.863)
Educational level	0.014*** (0.003)	0.016 (0.014)	0.010 (0.005)	0.026 (0.150)	0.003 (0.009)	0.006 (0.023)	0.003 (0.009)	0.009 (0.129)
Cattle loss	-0.003 (0.001)	-0.006 (0.006)	-0.008** (0.001)	0.002 (0.006)	-0.002 (0.001)	0.002 (0.002)	0.002 (0.002)	0.002 (0.009)
Herding experience	-0.002 (0.009)	-0.001 (0.003)	-0.002** (0.001)	-0.004 (0.036)	-0.001* (0.001)	0.003 (0.004)	-0.003 (0.002)	0.003 (0.036)
Remittance	-0.009 (0.006)	-0.027 (0.041)	-0.010 (0.012)	0.100 (0.276)	-0.013 (0.018)	-0.120** (0.047)	-0.044*** (0.014)	0.022 (0.333)
Herd size	0.011 (0.007)	-0.003 (0.020)	-0.029*** (0.007)	-0.003 (0.269)	0.001 (0.013)	-0.003 (0.054)	0.017 (0.021)	0.011 (0.474)
Access to land	-0.059* (0.033)	0.209 (0.310)	-0.095 (0.0.070)	0.652 (0.727)	-0.319*** (0.104)	-0.284 (0.587)	-0.217 (0.184)	-0.268 (0.812)
Instruments								
Extension	0.088 (0.091)	0.111 (0.203)	0.024 (0.109)	0.085 (0.216)	0.100 (0.192)	0.054 (0.131)	0.031 (0.082)	0.022 (0.052)
Future conflict	0.036 (0.122)	0.104 (0.210)	0.012(0.161)	0.037 (0.126)	0.003 (0.011)	0.120 (0.216)	0.032 (0.064)	0.009 (0.052)
Constant	0.349 (0.112)	-0.036 (0.226)	0.410 (0.152)	-0.484 (0.197)	0.454 (0.037)	0.760 (0.400)	0.876*** (0.299)	-1.131 (7.133)
Selectivity terms								
m0	-0.240 (0.155)	-0.650 (0.355)	-0.170 (0.253)	0.543 (0.571)	0.205 (0.317)	-0.091 (0.746)	0.630 (0.737)	0.662 (2.432)
m1	-0.265 (0.272)	-0.121 (0.172)	-0.048 (0.162)	-0.806 (0.658)	-0.030 (0.770)	-0.131 (0.218)	1.479 (1,078)	-1.611 (5.115)
m2	-0.392 (0.269)	-0.408 (0.732)	-0.029 (0.051)	-1.636 (7.183)	-0.036 (0.732)	-0.200 (0.820)	0.448 (0.412)	-2.169 (11.438)
m3	-0.2232 (0.201)	0.456* (0.267)	-0.068 (0.195)	0.107 (0.334)	1.201** (0.490)	0.668 (0.817)	1.076* (0.650)	0.336 (1.081)

Note: OHAS denotes adopters of only herding adaptation strategies; ONHAS denotes adopters of only non-herding adaptation strategies; HnNAS denotes adopters of both herding and non-herding adaptation strategies. Figures in parentheses are standard errors. ***, ** and * denote statistical significance at 1%, 5% and 10% respectively.