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Gender Vulnerability to Climate Change Impacts Among Agro-pastoralists in Kondoa District, Tanzania

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Abstract
Climate change disproportionately affects both men and women in agro-pastoral communities worldwide. However, the levels of vulnerability across male- and female-headed agro-pastoral households remain debatable. This study collected data from 366 households in the Kondoa District using focus groups, interviews, and household surveys. The quantitative data were analysed using descriptive and inferential statistical methods. The IPCC Livelihood Vulnerability Index (LVI) and a two-sample t-test were employed to assess gender-based vulnerability levels. The qualitative data were analysed using content analysis. The findings indicate that female-headed households are more vulnerable to climate change (0.614 index score) than male-headed households (0.595 index score). The higher vulnerability is attributed to a higher sensitivity index (0.685) among female-headed households than among male-headed households (0.483). Additionally, female-headed households have a lower adaptive capacity index (0.543) than male-headed households (0.654). The study recommends that climate change stakeholders—including the Ministry of Agriculture, Kondoa District Council, and Tanzania Meteorological Authority—develop targeted mechanisms to increase awareness of climate information, extension services, and technology. Also, special attention should be given to supporting female-headed households to strengthen their capacity to respond and adapt to climate change impacts.

Keywords: *climate change, gender, agro-pastoral communities, vulnerability level.*

1. Introduction

Climate change is one of the most significant global concerns of the twenty-first century, endangering ecosystems, livelihoods, and human welfare worldwide (IPCC, 2022, 2023). According to Myeya (2021) and the Intergovernmental Panel on Climate Change (IPCC) (2022), the impacts of climate change are consistently manifested through elevated atmospheric temperatures and precipitation variability. Such changes in climate change elements have adverse effects on the environment and the livelihood of agro-pastoral communities (IPCC, 2022; Mung'ong'o, 2022; Tofu et al., 2025). According to Narbat (2024) and Tofu et al. (2025), agro-pastoral communities are among the most vulnerable to climate change because they depend on climate-sensitive livelihoods, and lack the requisite adaptation strategies.

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The impacts of climate change are widely documented, with negative consequences already evident, particularly in developing countries and among poor rural households (Gupta et al., 2019; Ogisi & Begho, 2023; Mwasha, 2024). Nnadi et al. (2019) and Onah et al. (2023) indicate that these impacts vary according to factors such as gender, location, and socio-economic status. Ayub et al. (2023) and Nagasha et al. (2019) further demonstrate that agro-pastoral men and women in developing countries experience climate change differently. Agro-pastoral women, especially those from female-headed households, are identified as among the most vulnerable groups (Gudi, 2023; Galwab, 2024). For instance, Chawene et al. (2026) and George (2025) report that women in semiarid regions face greater challenges accessing water and firewood due to prolonged droughts.

Various studies conducted elsewhere—including those by Galwab et al. (2024), Galwab (2024) and Nagasha et al. (2019)—have identified women in agro-pastoral communities as particularly vulnerable to climate change and variability. These studies primarily employ descriptive methodologies, which restrict the depth of analytical insight. In Tanzania, studies indicate that women from agro-pastoral communities are significantly affected by climate change (Mtupile & Liwenga, 2017; Kabote, 2018; Chawene, Msongaleli & Mwanyoka, 2026). However, these studies also remain largely descriptive and confirmatory; and lack comprehensive quantitative assessments of gender-specific vulnerability levels using indicators such as exposure, sensitivity, and adaptive capacity within the framework of the livelihood vulnerability index (LVI). Assessing gender-based vulnerability levels to climate change is essential for determining current household vulnerability and monitoring changes over time. This paper addresses this significant knowledge gap by investigating vulnerability levels among male- and female-headed households in terms of exposure, sensitivity, and adaptive capacity. The central research question is: What are the levels of vulnerability among male- and female-headed households in terms of exposure, sensitivity and adaptive capacity? This study advances existing knowledge by systematically measuring and comparing vulnerability levels among male- and female-headed households using the LVI. In addition, the study goes beyond descriptive evaluation by providing new insights into how exposure, sensitivity, and adaptive capacity interact to generate gender vulnerability levels in agro-pastoral communities.

2. Theoretical Framework

The feminist political ecology (FPE) was adopted in this study because it offers a comprehensive framework for analysing the interrelationships between gender, environment, and power dynamics within specific contexts (Elmhirst, 2015). The study uses the FPE since it views vulnerability as shaped by exposure, sensitivity, and adaptive capacity. From this perspective, the study uses the LVI to focus on indicators of exposure, sensitivity, and adaptive capacity (Rocheleau, 1995; IPCC, 2007). According to Rocheleau et al. (1996), the theory explains the importance of gender, and how power dynamics and inequality affect vulnerability to environmental change, i.e., climate change. Rocheleau et al. (1996), argue that the FPE views gender as a crucial factor in resource access and control; and hence it has been extensively used in research on environmental change in gendered rural environments (George, 2025). Besides, Rocheleau et al. (1996) argue that unequal power relations between genders in resource access and control shape differences in vulnerability. In this perspective, the FPE theory claims that variations in daily roles, mobility, and responsibilities cause men and women to experience environmental changes—such as droughts, land degradation and floods—differently. Hence, it provides a framework for understanding how power relations in agro-pastoral communities affect gender-based vulnerabilities through the dimensions of exposure, sensitivity, and adaptive capacity. Thus, it was deemed relevant to this study in elucidating the influence of gender roles and responsibilities on climate change vulnerability within agro-pastoral households.

3. Context and Methods

3.1 Description of the Study Area

The study was conducted in five villages in Kondoa District: Mtiryangwi, Mauno, Atta, Chubi, and Ihari. Kondoa District is situated in the northern part of Dodoma region, approximately 160km from the regional centre (Hamisi, 2019; Kondoa District Profile, 2020). The district is geographically positioned between latitudes 4°12" and 5°38" South of the Equator, and longitudes 35°6" and 36°2" East of Greenwich (Kondoa District Profile, 2020) (Figure 1).

According to the 2022 Tanzania national population census, Kondoa District had a population of approximately 244,854 people; comprising 124,379 males and 120,475 females (URT, 2022). The district is characterised by a semiarid ecological zone and a dry savannah climate; with a prolonged dry season and unimodal, erratic rainfall occurring from November to April ((Kondoa District Profile, 2020). The annual rainfall averages 500–1,000mm in the lowlands, and 800–1,500mm in the highlands. The mean annual temperature is approximately 21°C (ibid.).

Kondoa District was selected based on several criteria. To start with, it has a higher number of agro-pastoralists than other districts in Dodoma region, and it also exhibits considerable gender inequality in resource access (Swai, 2017; NBS, 2021). As well, it is characterised by frequent extreme droughts and significant soil erosion, both of which negatively impact agricultural productivity (Hamisi, 2019; Kondoa District Profile, 2020). Moreover, Ligonja and Shrestha (2015) report that Kondoa has experienced substantial soil erosion over several decades, with annual soil loss rates estimated at 14.7–23 tonnes per hectare; and up to 49% of the land is classified as having high to very high erosion severity. Five villages within the district were selected due to the pronounced impacts of climate change; in addition to having a high prevalence of agro-pastoralists (Kondoa District Profile, 2020; Kondoa District Council, 2022).

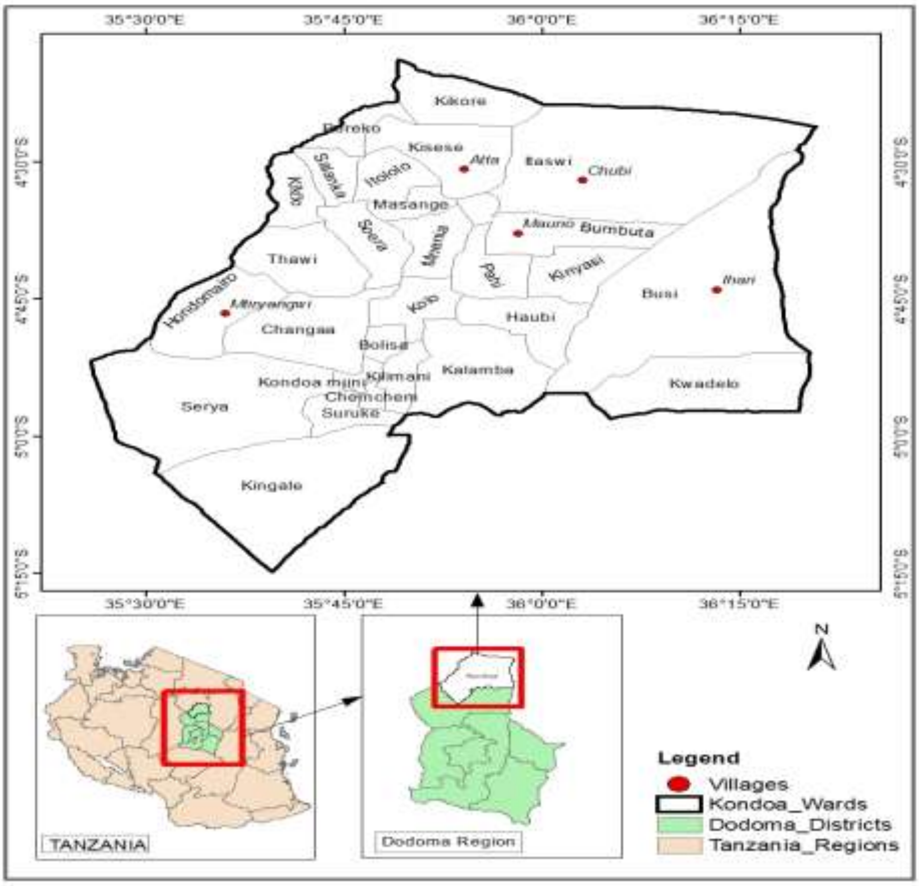

Figure 1: A Map of Kondoa District Showing the Location of the Study Villages.
Source: GIS Lab, UDOM (2023).

3.2 Sampling Procedures
3.2.1 Sampling Techniques
Probability and non-probability sampling techniques were employed to select respondents. Probability sampling ensured that every individual had an equal chance of being selected; whereas in the non-probability sampling, a purposive sampling technique was employed. Stratified and simple random sampling techniques were used to enhance representativeness and facilitate gender-based comparisons. Households in the selected villages were categorised by the sex of the household head into male- and female-headed groups. Within each stratum, households were selected using simple random sampling to maintain the probability of equal inclusion. Furthermore, purposive sampling was employed to select 20 key informants based on their knowledge and/or experiences relevant to the study; and also to pick out 70 participants for focus group discussions (FGDs).

3.2.2 Sample Size

Based on the 2023 village household registry, a total of 4263 households—consisting of 3314 male-headed and 949 female-headed households—were involved in agro-pastoral activities throughout all five selected villages (Kondoa District Council, 2022). The sample size of the study was 366; and this was obtained as per Yamane's (1967) formula:

$$n = \frac{N}{1 + N(e)^2}$$

Where: n = the sample size; N = the total number of households; and e = the level of precision. Hence:

$$n = \frac{4263}{1 + 4263(0.05)^2} = 366$$

The population and the sample size by gender are presented in Table 1.

Table 1: Population and Sample Size by Villages for Male and Female Headed Households

Village	Population			Sample		
	Males	Females	Total	Males	Female	Total
Mauno	605	193	798	52	17	69
Mtiryangwi	1,102	339	1,441	95	29	124
Ihari	409	102	511	35	9	44
Chubi	620	141	761	53	12	65
Atta	578	174	752	50	14	64
Total	**3,314**	**949**	**4,263**	**285**	**81**	**366**

Source: Field survey 2023.

3.3 Data Collection Methods.

The data for this study were collected through a household questionnaire survey, focus group discussions (FGDs), and key informant interviews (KIIs). The household survey gathered quantitative data using a structured questionnaire administered to respondents. In addition, 10 FGDs were conducted across 5 villages, with separate groups for males and females. Each group comprised 7 participants to ensure manageability and the collection of comprehensive information. The KIIs were conducted with the district and local government officials.

3.4 Data Analysis

The quantitative data were analysed using the Statistical Package for the Social Sciences (IBM SPSS, version 25). Descriptive statistics—including frequencies and percentages—were calculated for the three latent vulnerability variables defined in the IPCC framework: exposure, sensitivity, and adaptive capacity. Inferential statistics—and specifically the chi-square test—were applied to examine associations between the variables. The LVI was used to compute indices; and a two-sample t-test was conducted to compare indices between men- and women-headed households. The qualitative data were analysed through content analysis.

3.4.1 Analysis of the Livelihood Vulnerability Index (LVI)

The LVI—which included the IPCC's indicators for exposure, sensitivity, and adaptive capacity—was employed to generate indices. The LVI approach—which is mostly used in climate risk assessments—was used to select specific indicators for exposure, sensitivity, and adaptive capacity. The indicators were selected because they represented the agro-pastoral context, were accessible at the household level, and were supported by previous research. In addition, specific indicators were selected based on their alignment with the IPCC livelihood framework, and their relevance to the socio-economic and climatic conditions of agro-pastoral communities, particularly in Kondoa District. The LVI quantitatively evaluates vulnerability levels across household categories; while the FPE examines how differences in resource access, labour division, and decision-making power affect gender vulnerability to climate change. However, researchers can adopt or adjust the weighting scheme based on the nature of a study, and it can subsequently be updated by future users as needed.

The LVI was calculated using the method proposed by Hahn et al. (2009), which uses an average that is equally weighted. Although the number of sub-components may vary within each major component, the same balanced weighting method is consistently applied. The calculation process is outlined in a series of steps, from step 1 (expressed by equation 1) to step 6.

The method in step one (1) was used to compute the index for each sub-component of each major component.

$$Index_{sd^i} = \frac{S_d - S_{min}}{Smin_{max}} \dots\dots\dots\dots\dots\dots (1)$$

Where: S_d shows the original sub-component for each household category. S_{max} and S_{min} denote the maximum and minimum values of the sub-components, respectively.

According to Ochir et al. (2023) and UNDP(2007), the minimum and maximum values for standardised indices are 0 and 1, respectively; meaning that the indices range from 0 to 1.

Then, the standardised sub-components were averaged using the equation (2):

$$M_d = \frac{\sum_{i=1}^{n} Index_{sd^i}}{n} \dots\dots\dots\dots\dots (2)$$

Where: M_d = one of the five key gender-related factors [human resource capacity (HC), livelihood strategies (LS), technology (T), climate change effects (CCE), and food security (FS) as shown in Table 2; and $Index_{sd^i}$ = the sub-components, indexed by i, that make up each main component, and n is the total number of sub-components in each component.

The calculations are shown below:

$$ACindex = \frac{HRCiW_{HRc} + LSiW_{LS} + TEiW_{TE}}{\text{HRC} + \text{LS} + \text{TE}} \dots\dots\dots\dots\dots\dots (3)$$

Where: *AC* stands for adaptive capacity, *HRCW* is the weight for human resources capacity, *LSW* is the weight for livelihood strategy, *TEW* stands for the weight for technology, and *i* represents the number of subcomponents within the major component.

$$Expindex = \frac{TMW_{TM} + LDW_{LD} + FDW_{FD}}{\text{TM} + \text{LD} + \text{FD}} \dots\dots\dots\dots\dots\dots (4)$$

Where: *Exp* represents Exposure, *TMW* is the weight for temporary migration, *LDW* is the weight of livestock death, and *FDW* represents the weight of farm destruction. These are calculated based on the number of indicators under the major component.

$$Senindex = \frac{NFIW_{NFI} + CDW_{CD} + PW_{P}}{\text{NFI} + \text{CD} + \text{P}} \dots\dots\dots\dots\dots\dots (5)$$

Where: *Sen* represents sensitivity, *NFIW* is the weight of non-farm income, *CDW* is the weight of households practising crop diversification, and *PW* represents the weight for pests.

The calculations used to calculate the Livelihood Vulnerability Index (LVI) are:

LVI = [Exposure (E)- Adaptive capacity (AC)] x Sensitivity(S) .... (6).

4. Results

4.1 Gender Vulnerability to Climate Change Among Agro-pastoral Community

Table 2 presents the results showing the association between gender and indicators (subcomponents) of exposure, sensitivity, and adaptive capacity as functions of vulnerability, based on the IPCC (2007) criteria.

Table 2: Association Between Gender and Indicators of Adaptive Capacity, Sensitivity and Exposure

Adaptive Capacity Indicators (AC)		**Gender**			
Major components	***Sub -components (indicators)***	***Male-headed (n=285)***	***Female-headed (n=81)***	χ^2	**p-values**
Human resources capacity	Percent hiring farm labour	(50.2%)	(46.9%)	0.27	0.604
	Percent accessing weather information	(65.3%)	(22.2%)	47.36	<0.001
	Percent accessing agricultural extension services	(57.5%)	(32.1%)	16.36	<0.001
Livelihood strategy	Percent who engage in livelihoods diversification	(69.1%)	(34.6%)	31.80	<0.001
	Percent Owning big land size	(50.3%)	(9.9%)	72.92	<0.001
	Percent owning big number of livestock	(74.7%)	(18.5%)	84.87	<0.001
Technology used	Percent who use improved seeds	(59.7%)	(18.5%)	42.67	<0.001
	Percent using agricultural inputs(pesticides)	(16.1%)	(12.4%)	0.70	0.403
	Percent using ox plough-farming tool	(77.5%)	(43.2%)	13.77	<0.001
	Percent using improved farming tools (tractor)	(60.7%)	(18.5%)	44.93	<0.001
Sensitivity Indicators (S)					
Food security	Percent who engage in non-farm income	(60%)	(28.4%)	25.29	<0.001
	Percent practicing crops diversification	(76.1%)	(22.2%)	79.79	<0.001
	Percent reported pests	(58.9%)	(58.0%)	0.76	0.882
Exposure Indicators (E)					
Natural disaster i.e., droughts	Percent who Temporary migrate	(61.4%)	(4.9%)	80.48	<0.001
	Percent who reported livestock death	(53.3%)	(63.0%)	2.37	0.124
	Percent reported farm destruction	(86.3%)	(92.6%)	2.31	0.129

Source: Field Survey 2023.

4.1.1 Gender-based Adaptive Capacity to Climate Change

The results of the evaluation of three subcomponents (indicators) of human resources capacity, the major component of adaptive capacity, are displayed in Table 2. These indicators include households hiring farm labour, accessing weather information, and availing agricultural extension services. The results indicate that male-headed households accessed weather information more frequently (65.3%) than female-headed households (22.2%) (χ^2 = 47.36; p<0.001). This statistically significant difference suggests a correlation between gender and access to weather information.

Similarly, an FGD with women in Mtiryangwi indicated that limited mobility restricts their attendance at extension services meetings, consequently reducing their access to essential climate information, such as weather updates. The village executive officers (VEOs) further noted that many individuals in the agro-pastoralist community, particularly women, lack access to weather information because they do not participate in community meetings; and often lack mobile phones or radios, which are the primary sources of weather-related information.

The results on agricultural extension services accessibility reveal that a higher proportion of male-headed households (57.5%), than female-headed ones (32.1%), reported accessing these services. The data demonstrate a significant correlation between gender and access to agricultural extension services (χ^2 = 16.36; p < 0.001). Interviews with ward executive officers (WEOs) further supported these results: that men have greater access to extension services because institutional support programs reach men more frequently than they reach women.

The results in Table 2 further indicate that male-headed households performed better in all three indicators of the livelihood strategy, a major component of adaptive capacity. Specifically, 69.1% of the male-headed households reported engaging in livelihood diversification, compared to 34.6% of the female-headed households. This difference was statistically significant ($\chi 2$ = 31.80; p < 0.001), indicating a strong association between gender and livelihood diversification. The VEOs across all villages corroborated these findings; noting that male-headed households were able to diversify their livelihoods due to higher incomes and increased mobility.

Moreover, the results indicate that more male- (50.3%) than female-headed households (9.9%) reported owning large pieces of land (χ^2 = 72.92; p = 0.001), suggesting an association between gender and land size ownership. A similar finding was expressed in one FGD in Chubi village, where one male participant reported:

> *"In our communities, men tend to own larger landholdings. This is largely influenced by cultural norms and traditions that expect men to own and control household assets, particularly land and livestock."*

Also, the results in Table 2 show that 74.7% of male-headed households, compared to 18.5% of female-headed households, reported owning a big number of livestock. This difference is statistically significant (χ^2 = 84.87; p < 0.001), demonstrating a relationship between gender and livestock ownership. An FGD with women in Chubi village also revealed that women typically owned fewer livestock because prevailing norms and traditions often prevented them from inheriting or receiving a share of their ex-husbands' land or livestock, thereby restricting women's access to productive resources.

The results on technology use—a major component of adaptive capacity—were derived from an assessment of three indicators: the percentages of households using improved seed varieties, ox ploughs, and tractors in agricultural activities. Significant disparities were observed across all three indicators.

The findings show a significant disparity in the adoption of improved seed varieties; with 59.7% of male-headed households using them compared to only 18.5% of female-headed households. This difference was statistically significant ($\chi^2 = 42.67$; $p < 0.001$), indicating a relationship between gender and the use of improved seed varieties. FGDs in Mauno village further corroborated these findings, as women participants reported that male-headed households were more likely to use improved seed varieties due to greater access to technical information provided by agricultural extension officers.

The study results further show that 60.7% of male-headed households, compared with 18.5% of female-headed households, used tractors. These findings showed a statistically significant difference ($\chi^2 = 44.93$; $p < 0.001$), indicating a possible correlation between tractor use in cultivation and gender. The results also show significant differences in the use of ox ploughs between male- and female-headed households; with 77.5% of male-headed households using ox ploughs in farming, compared to 43.2% of female-headed households. Statistically, the results showed a significant difference ($\chi^2 = 13.77$; $p < 0.001$), suggesting a relationship between gender and the use of ox-plough. FGDs with women in Chubi village revealed similar findings. One participant stated:

> *"After my husband abandoned me, he took all the cows, which we were using for ox-ploughing, and I were left with only a few goats. I currently depend on a hand hoe in farming, which causes me to spend much time to manage cultivating just a small plot size."*

Moreover, the ward agricultural extension officers informed that the high cost of renting tractors and ox-ploughs has compelled many individuals, particularly those with low incomes, to rely on hand hoes for the entire farming process. Such a reliance has resulted in reduced crop yields and increased labour demands. During the time of the research that led to this paper, the cost of cultivation by a tractor was TZS50,000 per acre, and TZS30,000 per acre by an ox-plough; costs that only a few individuals with high incomes could manage.

4.1.2 Gender-based Sensitivity to Climate Change

This study considered three subcomponents of sensitivity: households engaged in non-farm activities, crop diversification, and reported pests. As shown in Table 2, a higher proportion of male-headed households (60.0%) participated in non-farm activities, than female-headed households (28.4%). These findings showed a statistically significant relationship between gender and participation in non-farm income activities ($\chi^2 = 25.29$; $p < 0.001$). Furthermore, insights from an FGD with women in Mtiryangwi village provided a context for these findings: participants reported limited engagement in non-farm activities, such as petty business, primarily due to constraints related to capital mobility and time.

Besides, the results show that a higher proportion of male-headed households (76.1%) than female-headed households (22.2%), reported diversifying crops on their farms ($\chi^2 = 79.79$; $p < 0.001$). This statistically significant difference indicates an association between crop diversification and the gender of a household head. FGDs with men in Mauno village revealed that male-headed households diversified crops mainly due to their owning of larger landholdings.

4.1.3 Gender-based Exposure to Climate Change

Moreover, the results in Table 2 identify three subcomponents of climate change exposure: temporary migration, livestock death, and farm destruction. Among these, temporary migration exhibited significant gender-based differences in exposure to climate change effects. Specifically, a higher proportion of male-headed households (61.4%) reported temporarily migrating with their livestock compared to female-headed households (4.9%). This difference was statistically significant ($\chi^2 = 80.48$; $p < 0.001$), indicating an association between temporary migration and gender.

4.2 Gender Vulnerability Levels to Climate Change

4.2.1 Adaptive Capacity Levels by Gender

Gendered adaptive capacity levels were calculated using the indicators listed in Table 2, and the results are summarised as indices in Table 3. Notably, the two-sample t-test results in Table 3 indicate that, on average, male-headed households exhibit a higher adaptive capacity (0.654 index value) than female-headed households (0.543 index value). This observed difference demonstrates a statistically significant relationship between gender and adaptive capacity level ($p < 0.001$).

Table 3: Two-sample T-test of Vulnerability Levels by Gender

Vulnerability Indicators	Mean Indices		T-statistic	P-values
	Male	*Female*		
Adaptive capacity	0.654	0.543	4.574	<0.001
Sensitivity	0.483	0.685	-4.041	<0.001
Exposure	0.629	0.605	1.172	0.081
Vulnerability index	0.595	0.614	3.052	0.001

4.2.2 Sensitivity Levels by Gender

Gender sensitivity levels were calculated using the indicators listed in Table 2, and the results are also presented as indices in Table 3. The two-sample t-test results (Table 3) indicate that female-headed households were more sensitive to climate change (index value of 0.685) than male-headed households (index value of 0.483). This difference in sensitivity levels between genders is statistically significant ($p < 0.001$).

4.2.3 Exposure Levels by Gender

The indicators in Table 2 were also utilised to calculate gendered exposure levels. While the statistical analyses (Table 3) reveal that the differences between the two household categories were not statistically significant ($p = 0.081$), the numerical results demonstrate that male-headed households exhibit a higher exposure level (0.629 index value) than female-headed households (0.605 index value).

4.2.4 Overall Vulnerability Levels by Gender

The LVI was calculated by summing the five major components, which generated different indicators (subcomponents) derived from the IPCC indicators on adaptive capacity, exposure, and sensitivity, as shown in Table 2. The two-sample t-test results (Table 3) indicate that, on average, female-headed households reported a higher level of vulnerability to climate change (0.614 index value) than male-headed households (0.595 index value). The significant differences in the means of the vulnerability indices ($t = 3.052$, p-value = 0.001) indicate that gender plays a major role in determining vulnerability levels.

5. Discussion

The study findings reveal that gender differences in access to weather information, which serves as an indicator of adaptive capacity, influence vulnerability. This disparity is often associated with women being the primary domestic caretakers of the family, something that restrict their participation in social networks, such as attending community meetings where information, including weather-related updates, is disseminated. Additionally, cultural norms restricting women's mobility further reduce their opportunities to participate in community meetings and training sessions, thereby also lessening their adaptive capacity to climate change. As noted at the outset, the feminist political ecology shows how limited access to resources, such as weather information, increases gender vulnerability to climate change (Rocheleau, 1995). Sundberg (2017) corroborates this reality by noting that feminist political ecologists argue that—across class, race, and other relevant axes of power—gender has a substantial impact on access to, and control over, resources. This is similar to what Balikoowa et al. (2019) and UN Women (2023) reported: that female-headed households have less access to weather information, which makes them less adaptive to the effects of climate change. These arguments accurately reflect the real situation of agro-pastoralists in Kondoa District, where men have greater access to, and control over, a variety of resources than women.

In this regard, previous analyses also report that male-headed households are more likely to access agricultural extension services because men typically have greater mobility, which allows them to attend extension services meetings, and possess stronger social networks that facilitate access to training opportunities. In contrast, women's participation in public activities is often constrained by time limitations imposed by household chores and reproductive responsibilities, making them less able to adapt to climate change. According to the feminist political ecology (Rocheleau et al., 1996), these variations reflect underlying power dynamics that influence resource accessibility. These differences are revealed in the Kondoa District's agro-pastoral community, where women have less access to weather information and extension services, which reduces their ability to adapt to climate change. Studies by Adebayo and Worth (2024), Onah et al. (2023), and Midamba and Ouko (2024) similarly demonstrate that female-headed households have a more restricted access to agricultural extension services compared to their male-headed counterparts.

Moreover, as pointed out previously, the capacity of male-headed households to diversify their livelihoods is partly attributable to their higher income earnings and greater access to capital. These factors have facilitated men to establish various non-farm activities, such as carpentry, food vending, charcoal production, and small-scale retail businesses. In contrast to the case of women, whose mobility is often restricted, men can also avail seasonal labour markets for agricultural and livestock products, and other income-generating opportunities, thereby enabling further diversification of income sources, and hence their adaptability. The lower participation of female-headed households in livelihood diversification is largely attributable to their significant involvement in household responsibilities, which restricts their time and capacity to pursue alternative income-generating activities, which in turn reduces their adaptive capacity.

This challenge of limited mobility, which constrains women's participation in activities beyond the home, is further compounded by the continuous demands of family responsibilities, such as caring for children, the elderly or sick family members, and managing young or sick livestock. From the FPE perspective, this dynamic illustrates how gendered divisions of labour shape unequal access to resources and opportunities. To make matters worse, the impacts of climate change exacerbates these pre-existing inequalities by increasing women's domestic and caregiving burdens, further constraining their adaptive capacity (Ayub et al., 2023). This is also substantiated by Eastin (2018), who argues that, outside the home, norms of gender discrimination and gender imbalances in socio-economic status restrict women from participating in formal labour markets.

The higher proportion of female-headed households owning smaller landholdings in the study area can be attributed to the limited control over, and ownership of, productive resources—such as land—by women in most rural areas in Tanzania. This limitation arises from prevailing cultural norms and social structures that restrict women's ownership and inheritance of land. According to the ethnic customs of the study area, it is sons—and not daughters—who typically inherit land and livestock (Mtupile & Liwenga, 2017). The FPE perspective (Rocheleau et al., 1996), attributes this to gendered power dynamics that restrict women's access to, and control over, land and other productive resources. This limitation reduces women's adaptive capacity, thereby increasing their vulnerability to the impacts of climate change. These findings are consistent with those reported by Galwab et al. (2024) and Awoke et al. (2025); all of whom observed that men predominantly own land.

Similarly, the predominance of males owning more livestock is attributable to cultural norms and traditional practices in many agro-pastoral communities that assign ownership of productive resources, such as land and livestock, to men. In addition, ethnic customs often grant inheritance rights of cattle to males rather than females. Besides, male-headed households are also more likely to acquire and maintain larger herds due to greater access to markets, veterinary services, and grazing areas; as well as greater mobility that enables migration with livestock in search of water and pasture, thereby enhancing their adaptability to climate change. This result aligns with Galwab et al. (2024) and Mtupile and Liwenga (2017), who found that male-headed households had significantly greater livestock holdings and bigger farmlands than female-headed households; which in turn contributed to their greater resilience and adaptability to climate change.

Also, the adoption of improved seed varieties was more common among male-headed households. The limited adoption among female-headed households can be attributed to insufficient information and restricted access to extension services: all of which constrain their awareness of available improved seeds. Female-headed households in the study areas reported limited access to improved seed varieties, indicating restricted mobility and inadequate information regarding agricultural inputs and extension services. Additionally, this was associated with the generally low incomes of female-headed households, which hinder their ability to purchase improved seeds. This finding is corroborated by Jaleta et al. (2023) and Dibakoane et al. (2022); all of whom observed a significant disparity in the adoption of improved seeds between male- and female-headed households, with the former predominantly adopting improved and recently introduced crop varieties.

Likewise, the limited use of tractors among female-headed households can be attributed to lower incomes that limit their capacity to rent tractors for agricultural activities. Household income plays a significant role in facilitating climate change adaptation by enabling the adoption of technologies, including tractors. The study found that female-headed households predominantly rely on hand hoes for land cultivation, which constrains the expansion of cultivated areas, thus diminishing agricultural productivity; and consequently resulting into low adaptive capacity to climate change. Mtupile and Liwenga (2017) also found that male-headed households were significantly more likely to employ tractors for farming than female-headed households.

Regarding ox-ploughs, the study found that a small number of female-headed households used them. The small proportion was due to the low-income of female-headed households to afford renting ox-ploughs. Additionally, such households lack draught animals (oxen) and experienced labour to 'operate' ox-ploughs. This is similar to what Mtupile and Liwenga (2017) found: that more males than females moved from hand hoe to ox-plough in farming. However, in contrast, Mwalyagile et al. (2023) observed that more women than men used ox-ploughs, although this difference was not statistically significant. These contradictory findings may be explained by variations in farming systems, such as differences in the size of cultivated land.

Also, the study findings indicate that a small proportion of female-headed households participated in non-farm activities. This was mainly due to limited capital, which restricted investment in non-farm activities; and also due to significant domestic workloads that reduced available time for such activities. Furthermore, constrained social networks reduced women's knowledge of available opportunities. Mobility limitations further restricted their ability to travel to access non-farm employment. These factors collectively limited participation in non-farm activities, making female-headed households more vulnerable to climate change impacts. These findings support those of Idiris (2021) and Ume et al. (2021), who also reported that limited involvement in non-farm activities increases the sensitivity of female-headed households to climate change impacts.

The results suggest that male-headed households' ability to diversify crops is influenced by their larger landholdings, which in turn facilitate the cultivation of a wider range of crops. Furthermore, this crop diversification is supported by stronger social networks that enhance men's skills and knowledge of effective farming methods. Hence, greater access to resources -- such as weather information, credit, and extension services -- directly supports crop diversification, which in turn helps decrease the sensitivity to climate change of male-headed households. Consistent with these findings, Suhiyini et al. (2018) also observed that male-headed households engage in greater crop diversification to enhance productivity than female-headed households.

The numerical values of exposure indicate that male-headed households were more affected by climate change, and can therefore be considered more exposed; although statistical analyses revealed that the disparities between the two household categories were not significant. Among the three indicators of exposure used in this study, only temporary migration demonstrated a significant difference. Gender division of labour and livestock control were more likely to have caused a temporary migration of males. These results are likely due to the nature of activities men undertake, such as searching for new grazing areas, and the long distances they walk because of climate change impacts, such as prolonged droughts in the study area.

The feminist political ecology (FPE**)** perspective asserts that differentiated exposure to climate risks is socially constructed rather than accidental. It highlights that gendered roles, responsibilities, and power relations determine vulnerability to climate change. In this context, roles traditionally assigned to men require increased mobility and interaction with degraded environments, which intensifies their exposure to climate-related stresses. These findings reinforce the FPE argument that the specific roles individuals undertake influence both the nature and extent of their vulnerability to climate change. Hence, males temporarily migrated to different areas in response to the impacts of climate change, particularly during prolonged droughts that reduced agricultural production, and led to livestock mortality. Males temporarily migrated to different regions with their livestock, suggesting that they were more likely to be exposed to the effects of climate change, particularly prolonged droughts. This is similar to what Balikoowa et al. (2019) and Mdemu (2021) found: that climate change effects, particularly droughts, have forced agro-pastoral men to migrate to other areas in search of pasture and water, thereby making male-headed households more exposed to climate change impacts than female-headed households. On the contrary, however, Idiris (2021) indicated that female-headed households have higher exposure levels to climate change than male-headed households. The possible reasons for these differing results may be due to location-specific differences in sample sizes; and/or due to social and economic factors.

Overall, as demonstrated earlier, the two-sample t-test results showed that female-headed households are more vulnerable to climate change than male-headed households. The greater vulnerability level of female-headed households is mainly due to their lower adaptive capacity and greater sensitivity to climate change. The results are mainly attributed to increased domestic responsibilities, mobility limitations, restrictions on access to productive resources, and lower decision-making power in women-headed households. The FPE accounts for these patterns by highlighting how disparities in decision-making power, resource access, and resource control contribute to differential vulnerability to environmental hazards, including those linked to climate change. This framework aligns with the observed agro-pastoralist context in Kondoa District, where women—particularly those in female-headed households—experience reduced access to, and control over, productive resources, thereby increasing their vulnerability to the impacts of climate change. These results align with those of previous studies by Idiris (2021), Basiru et al. (2022) and Balikoowa et al. (2019); all of which found that female-headed households are more vulnerable to the impacts of climate change than male-headed households.

6. Conclusion and Recommendations

It can be concluded that female-headed households are more vulnerable to climate change than male-headed households, primarily because of greater sensitivity and reduced adaptive capacity. Male-headed households demonstrate higher adaptive capacity, particularly in accessing weather information and extension services. The ability of men to diversify livelihoods, hold larger landholdings, and maintain more livestock; which in turn support the adoption of advanced technologies such as tractors, and afford improved seeds: all these making them more adaptive to climate change. On the contrary, female-headed households are more vulnerable to climate change due to limited participation in non-farm activities and crop diversification.

Consequently, it is recommended that the local government authorities should ensure equal access to productive resources for both men and women to reduce the high climate change vulnerability of female-headed households. Additionally, climate change stakeholders—including the Ministry of Agriculture, Kondoa District Council, and Tanzania Meteorological Authority—should develop mechanisms to increase climate information awareness, extension services, and technology use. These efforts should prioritise female-headed households to enhance their ability to respond and adapt to the impacts of climate change.

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