

Social Capital and Climate Change Adaptation and Mitigation Among Pastoral and Agropastoral Livelihoods in the Borana Zone, Southern Ethiopia

Muleta Husein^{1*}, Terefe Tolessa², Chala Dechassa³

¹College of Development Studies, Oromia State University, P.O.Box 209, Batu, Ethiopia

²Ambo University, P.O. Box 19, Ambo, Ethiopia, Email: tertol2000@yahoo.com

³College of Development Studies Oromia State University, P.O.Box 209, Batu, Ethiopia, Email: cdechassa@gmail.com

*Corresponding author: muletaosu@gmail.com

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ABSTRACT:

Climate change is a serious issue in pastoral and agropastoral areas of Borana Zone, southern Ethiopia. Hence, this study aimed to explore how the social capital interrelated with climate change adaptation and mitigation in pastoral and agropastoral livelihood of Borana Zone, southern Ethiopia. A mixed methods approach was used to collect data from 365 households sample size through multistage stratified random sampling, while 40 key informant interviews and eight focus group discussions were employed by purposive sampling techniques. With this, Dilo and Moyale districts from pastoral, while Taltale and Elwaye districts from agropastoral livelihood system. Primary and secondary data were collected through structured questionnaires, key-informant interviews, focus group discussion, desk review, and personnel observation. These data were analyzed using descriptive statistics, multivariate regression, and chi-square tests across livelihood systems. The findings showed that in pastoral communities bonding social capital was dominant (77.3% in Yabelo and 82.4% in Moyale), whereas in agropastoral livelihood system linking and bridging social capital were stronger (linking: 78.4% in Yabelo; bridging: 83.6% in Dugda Dawa). Social capital in bonding, bridging, and linking showed significant difference in strengthening climate adaptation and mitigation efforts under regression analysis at $p < 0.05$. Likely, trust and collective action were more enhanced these interdependences. Thus, the interaction effects between bridging and linking showed that combined social capital dimensions amplified adaptation and mitigation outcomes. Therefore, strengthen bonding networks in pastoral area as well as bridging and linking social capital in agropastoral systems to enhance climate resilience as policy interventions.

Keywords: climate adaptation and mitigation, social capital, pastoral, agropastoral

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1. Introduction

Globally, climate change become one of the most livelihoods challenges results in hindering growth for community directly depends on natural resources (Yaméogo et al., 2018). In sub-Saharan Africa, pastoral and agropastoral livelihood systems influenced under climate change. In this area environmental degradation, climate variability, and recurrent droughts increasingly threaten income stability, food security, and social wellbeing (Carmen et al., 2022; Kebede et al., 2025). Pastoral and agropastoral communities have historically relied on indigenous knowledge systems, mobility, herd management, and communal resource governance to cope with climatic uncertainty (Carmen et al., 2022; Kebede et al., 2025; Worku et al., 2022; Yaméogo et al., 2018). However, the scale, frequency, and complexity of contemporary climate change increasingly exceed the buffering capacity of these traditional mechanisms alone (IFAD, 2015; Lv et al., 2024). As a result, adaptation and mitigation responses now depend not only on ecological and economic resources but also on social and institutional factors that shape collective action, access to information and engagement with external support systems (Cho et al., 2025). Of these, most of them act as a key influence by social capital which has found as a crucial determinant of climate change adaptation and mitigation specifically in livelihood-diverse and institutionally marginalized community (Lambebo et al., 2025). Social capital widely expressed by community norms, trust, networks, and social relationships that enable interaction and synergies for mutual benefit (Gören, 2026). Based on the determinantal thematization, social capital can be categorized into bonding, bridging, and linking aspects (Woolcock & Narayan, 2000). Bonding social capital is related to closely linkage between kin, family members, and neighbors, whereas bridging of social capital interconnects groups and individuals across ethnic, social, and livelihood boundaries. Likewise, linking in social capital related to vertical associations between communities and formal institutions like government, development programs, and NGO (Azad & Pritchard, 2023). These distinct yet

interrelated forms of social capital influence how communities perceive climate risks, mobilize resources, adopt innovations, and engage with governance structures. Community social capital in the form of mutual support, information sharing, and coordinated responses to environmental disaster can improve climate adaptation (Saptutyningsih et al., 2020). Strong bonding connection within the community like support by informal safety nets during droughts, whereas distribution of climate-smart techniques communities wide can accelerate bridging networks (Prayitno et al., 2025). Likewise, linking social capital sometimes connected with improved access to technical assistance, financial resources, and policy support (Azad & Pritchard, 2023). However, empirical findings stay combined, predominantly in pastoral and agropastoral community where presence of marginalization, mobility, and weak state hinder institutional and cross-sector engagement (Duguma et al., 2023). Additionally, most of the previous studies consider social capital as a homogeneous unit by underestimating the importance of its level of contribution across different livelihood systems on resources management (Caviedes et al., 2024). In Ethiopia, pastoral and agropastoral livelihoods systems are predominant in arid and semi-arid regions like Somali, Afar, Gambella, Borana, Guji, Karayu, and lowlands of Bale zone are highly vulnerable to climate change (Beyene et al., 2023). This is mostly happened because of these communities' high level of dependence on climate-sensitive natural resources (Bogale et al., 2025). In these areas, influence of rangeland degradation, recurrent droughts, and water scarcity are increasing. Although coexistence of pastoral and agropastoral communities differ substantially in market integration, settlement patterns, social organization, and institutional engagement (Gebremeskel et al., 2019; USAID, 2011). These differences indicate that how social capital determine adaptation and mitigation of climate change based on livelihood-specific issues. In the Borana Zone, resources utilization through community-based knowledge is common but

currently this approach is declined and varied under livelihood diversification to combat environmental shock. Resources availability and community interest in resources management is the main mismatches between climate interventions and local social realities. Programs based formal institutions is not effective in pastoral areas where customary governance is predominating the reverse also undermine agropastoral areas where external linkages are critical. This misalignment of intervention and community needs can contribute to low adoption and mitigation of climate change and ineffective outcome. Irrespective of increasing acknowledgment of social capital as a key factor of climate resilience, prior studies generally neglect to differentiate its roles among pastoral and agropastoral livelihoods, often assuming as a homogeneous options. Likewise, in the study area, its level of contribution in response to climate change impact remains underexplored among customary governance coexists with formal institutions setting. Moreover, this study addresses the limitation of empirical evidence across diverse livelihood systems regarding social capital significance to adapt and mitigate climate change through comparative analysis. Therefore, this study examines interconnection of social capital and climate change adaptation and mitigation in pastoral and agropastoral livelihood systems in the Borana zone, southern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

This study was carried out in Borana zone found in southern part of Ethiopia among the 21 administrative zones in the Oromia Regional State of Ethiopia (Figure 1). The zonal town of Borana zone far away about 575 km away from Addis Ababa (the capital city of Ethiopia) (Bekele et al., 2020). The zone encompasses 13 districts. The zone covers an area of approximately 95,000 km², with an overall population density of six inhabitants per square kilometer (Tofu et al., 2023). According to the National Meteorological Agency (NMA) of Ethiopia report, the area known for its mean annual temperature of 19 °C and with a mean maximum and minimum temperature of 24.6 °C and 12.96 °C, respectively. In general, the warmest period of the year ranges from March to May, while the lowest annual minimum temperatures occur between the months of November and January (NMA, 2007; Worku et al., 2022). In the study area semi-arid climatic conditions prevailed. So, the mean annual rainfall is highly variable from 500 to 900 mm per year (Nganga et al., 2016). Bimodal rainfall occurrence with long rains through March to June and short rains from August to October (Solomon and Coppock, 2004). Elevation of the study area between 1000 m to 1500 m in the highlands (Solomon et al., 2007).

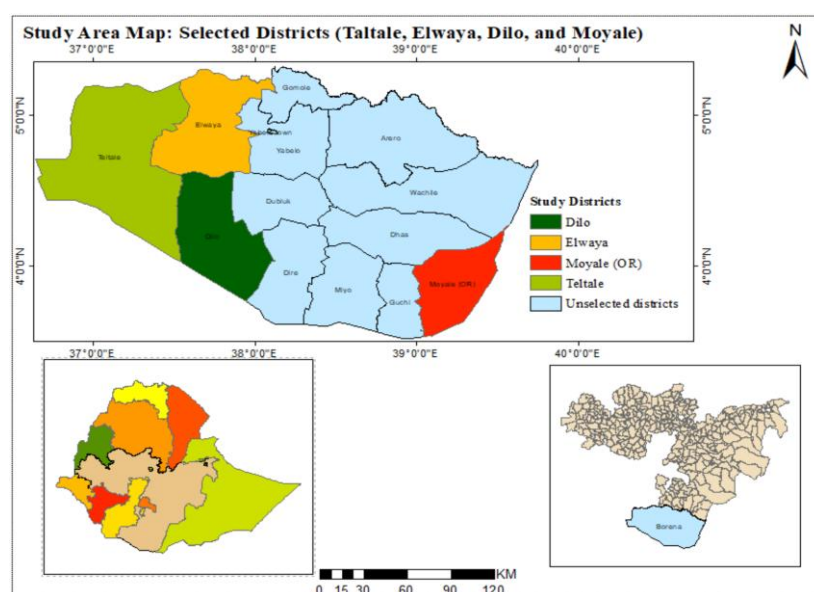


Figure 1. Map of the Study Area

2.2. Research Design and Philosophical Approach

This study employed a cross-sectional, mixed-methods research design situated within a pragmatist paradigm. The cross-sectional characteristics of the study was allowed to quantitative and qualitative data collection at a single point in time. The pragmatist paradigm was selected since it gives more attention to the research gap and values studies through utilization of multiple methods for better understanding the real-world phenomenon of community-based response to climate change (Creswell & Clark, 2017).

2.3. Target Population

The study was employed in four districts, comprising Dilo and Moyale districts from pastoralists districts, whereas Taltale and Elwaye from agropastoral. To capture heterogeneity in livelihood and institutional access across pastoral and agropastoral community these districts were purposively selected. The target population consisted of rural households whose livelihoods depend primarily on livestock production, with varying levels of crop integration.

2.4. Sampling Procedure and Sample Size

A multistage stratified sampling technique was used. First, districts were stratified by livelihood system (pastoral vs. agropastoral). Second, kebeles were randomly selected within each district. Finally, households were randomly sampled from updated household lists obtained from local administrations. A total of 365 households were surveyed: Dilo (110), Moyale (110), Taltale (80), and Elwaye (65). This sample size was adequate for district-level comparisons, chi-square tests, and multivariate regression analysis.

To account for finite population correction (since the total number of households in the selected kebeles 7,196), the adjusted sample size is calculated as:

$$n_1 = \frac{no}{(1 + no / N)}$$

Where;

n_1 = finite population correction factors (Cochran's formula, 1977) less than 10000

N = is total number of population (7196)

Therefore, sample size becomes 365 household for this study and for each kebele it was proportionally calculated.

To ensure representativeness, the sample of 365 households is distributed proportionally across the eight kebeles based on their household population sizes. The proportionally determination of sample for each Kebele from total sample size were minimized bias and ensures data accuracy are adequately represented. Then for each kebele, sample size was determined using the following equation:

$$n_i = \frac{N_i}{N} \cdot n$$

Where:

n_i = household sample size for kebele i

N_i = total number of households in kebele i

N = A number of total households in the study area, 7196

n = household sample size determined for the study area, 365

2.5. Data Collection Methods and Instruments

Primary data were collected between June to October 2025 using a structured household questionnaire administered through face-to-face interviews from households. Household questionnaire, checklist for key informant interview and focus group discussion were prepared to collect information on attributes, such as social capital aspect, community trust in indigenous and formal institutions as well as community cooperation and interconnectedness for climate adaptation and mitigation practices. Hence, household socio-demographic profile data were gathered to use in analysis as control variables. Three-point Likert-scale were also used to measure level of social capital, collective action, trust, and network density, whereas binary responses to measures adaptation and mitigation practices.

Additionally, qualitative data were used to triangulate household survey data through 40 key informant interviews and 8 focus group discussions or two FGD per district. The participants for these data collection methods were selected based on gender participation, elder, district agricultural officers, senior expert,

Gadaa leaders, and representatives from local NGOs. This triangulation of techniques enables detailed data compilation that used to collect both the statistical aspects and the role of social dynamics for the betterment of climate responses (Table 1).

2.6. Variable Measurement

Table 1. Variable type and measurement

Variable	Type	Measurement
Bonding Social Capital (BC)	Independent	From outer circle mutual aid group ties, neighborhood, and clan to inner circle (unit) called family
Bridging Social Capital (BR)	Independent	Inter connection among village to village, across ethnicity, and religion
Linking Social Capital (LC)	Independent	Connections to extension services, government, and NGOs
Collective Action Participation (CA)	Independent	Degree of participation in community-based projects
Trust in Customary Institutions (TC)	Independent	Through low or moderate or high
Trust in Formal Institutions (TF)	Independent	Through low or moderate or high
Network Density (ND)	Independent	Linkage at community-level
Adaptation Index (A)	Dependent	Rate of adaptation strategies adopted
Mitigation Index (M)	Dependent	Rate of mitigation strategies adopted
Climate Response Index (CR)	Dependent	Mitigation-Adaptation Synergies index
Household Controls (X)	Control	Age, education status, family size, gender

2.6. Descriptive and Comparative Analysis

Descriptive statistics were employed to outline the distribution of household characteristics toward response to climate variability, dimensions of social capital, collective action, trust, network density, and climate adaptation and mitigation practices. Similarly, frequency distributions and percentages were used to indicate ability of household response to climate change as of low, moderate, and high.

To examine livelihood- and district-level differences, cross-tabulations and chi-square (χ^2) tests were conducted. These tests assessed whether observed differences in social capital and climate response indicators across pastoral and agropastoral districts were statistically significant.

2.7. Conceptual Model

The study evaluates the effect of community trust, collective action, social capital, and network density of household to climate responses. With

this, social capital is classified into bonding bridging, and linking aspects. Along this, trust in customary and formal institutions and collective action performance as intermediating factors. Network density shows level of community interdependence. Climate response is a collection index of adaptation and mitigation strategies.

The conceptual framework is:

$$CR_i = f(BC_i + BR_i + LC_i + CA_i + TC_i + TF_i + ND_i + X_i) + \epsilon_i$$

Where:

CR_i = A combined HH climate response index for household i

BC_i = the scores of bonding, bridging, and linking social capital

CA_i = Participation in collective action

TC_i = Trust in customary and formal institutions

ND_i = Network density at community level

X_i = Household socio-demographic controls

ϵ_i = Error term

Regression Model

The multivariate regression model quantifies the effect of social capital on climate response:

$$CR_i = \beta_0 + \beta_1 BC_i + \beta_2 BR_i + \beta_3 LC_i + \beta_4 CA_i + \beta_5 TC_i + \beta_6 TF_i + \beta_7 ND_i + k \sum \gamma_k X_{ik} + \epsilon_i$$

Whereas:

β_0 = Intercept; $\beta_1 \dots \beta_7$ = Coefficients of main predictors; γ_k = Coefficients for control variables

Interaction Effects

To test the synergy between bridging and linking social capital:

$$CR_i = \beta_0 + \beta_1 BC_i + \beta_2 BR_i + \beta_3 LC_i + \beta_4 (BR_i \times LC_i) + \beta_5 CA_i + \beta_6 TC_i + \beta_7 TF_i + \beta_8 ND_i + k \sum \gamma_k X_{ik} + \epsilon_i$$

$BR_i \times LC_i$ = Interaction between bridging and linking social capital

β_4 = Incremental effect of combined horizontal and vertical networks

2.8. Climate Adaptation and Mitigation Indices

Adaptation Index (A_i)

$$CR_i = f(BC_i + BR_i + LC_i + CA_i + TC_i + TF_i + ND_i + X_i) + \epsilon_i$$

Adaptation practices included water harvesting, herd diversification, mobility planning, and fodder preservation.

Mitigation Index (M_i)

$$M_i = \frac{\sum_{j=1}^m m_{ij}}{m}; \quad m_{ij} = \begin{cases} 1 & \text{if practice } j \text{ used} \\ 0 & \text{otherwise} \end{cases}$$

Mitigation practices included tree planting, bush control, rangeland improvement, and irrigated livestock feed production.

Combined Climate Response Index (CR_i)

$$CR_i = \frac{A_i + M_i}{2}$$

CR index was used to classified household into low, moderate, and high response rate to climate change using percentage distributions.

Data analysis

Both quantitative and qualitative data were analyzed for result triangulation. Primary, quantitative analysis was done using descriptive statistics. In the next stage, Chi-square tests employed to determine level of associations between categorical variables across districts and livelihood systems. Thirdly, univariate regression models were employed to identify independent social capital networks and their specific components influence at individual level regarding response to climate using pastoralist and agropastoralist livelihood system as main strata. Then, multivariate regression models consider interaction effects for social capital aspects as well as between bridging and linking social capital to decide their synergistic interconnection effects.

To enrich quantitative methods of analysis, qualitative data undergo systematic thematic analysis. Hence, it was served as the essential aspects of triangulating quantitative findings

through which social networks and institutions influence climate action.

3. Result and Discussion

3.1. Drivers of Household Climate Adaptation and Mitigation

The study outcome showed that household social demographic and economic aspects of drivers to climate change adaptation and mitigation were significantly influenced. A livelihood strategy becomes a significant element in implementing adaptation measures, with 51.5% of pastoralist households slightly more active than 48.5% of agro-pastoralists ($\chi^2=6.25, p=0.012$). This finding aligns with regional and international evidence that show livelihood systems proportionally interacted by adaptive behavior (Beyene et al., 2023; Duguma et al., 2023). In contrast, this finding is in disagreement to study was carried out in Karamoja region in the East African drylands that reports income-diversified households better in employing climate adaptation and mitigation activities (Schumann et al., 2025).

Results revealed that male headed households were more engaged in climate change adaptation and mitigation adoption than female-headed households by 72.9% ($\chi^2=4.8, p=0.028$). It is similar to previous studies have shown female headed household significantly influenced by climate change (Deressa et al., 2009; Gemedu et al., 2023; Zeressa et al., 2021). Household education level significantly determined coping mechanisms, with 51.5%, 35.1%, and 13.4% of households having illiterate or informal, primary, and secondary education, respectively ($\chi^2=12.14, p=0.002$). It is common understanding as educated household has shown less vulnerable to climate change impact. This is in line to the study reports as household education proportionally influence climate change mitigation (Asefa et al., 2025; Galwab et al., 2025). Education can improve household know how regarding resilience to climate impact ((Beshir et al., 2021). Pastoralists and Agropastoralist household willingness to implement climate change adaptation strategy

show a positive correlation with household education ladder (Yegbemey et al., 2013).

Likewise, household age showed a significant influence on participation in adaptation measures ($\chi^2=7.62, p=0.022$). As household age increase the selection of climate change adaptation measures proportionally increases. A study conducted in southwestern Ethiopia on identification and evaluation of household-based climate change adaptation and determinants reported that as the age of household increase adoption of climate change adaptation alternative was increased (Gemedu et al., 2023). Higher household family size showed more active and significance differences in adaptation and mitigation than smaller family size households ($\chi^2=9.31, p=0.01$). This reflects that labor availability strengthening adaptation and mitigation of climate change. These findings are in line with Somali region at Siti zone research showing that higher household family size proportional to individual vulnerability to climate change (Gebremeskel et al., 2025; TAFERE, 2025).

Regarding household place of birth, those born within the study district are showing more participation in adaptation strategies than migrants' households ($\chi^2=5.47, p=0.019$). This reflecting that local origin has significant role in determining adaptive capacity. This could be happened due to native households have better knowledge regarding local grazing systems, climate patterns, water points, and indigenous coping alternatives that developed over generations. Residents for long period of time in the same area are more embedded in indigenous resources management systems and institutions, for instance, customary rangeland management systems, clan networks, and joint activities, which support access to labor, information, and resources required for adaptation (Duguma et al., 2023; Gebremeskel et al., 2019, 2025; USAID, 2011). Likewise, the cause of migration differently determined responses to climate change, with migrants due to drought or feed scarcity were being more highly engaged in the adoption of adaptation practices than those

primarily migrating for access to water ($\chi^2=8.07, p=0.005$).

Housing roof material is the function of household resilience, with the dominance of having flat or mixed roofs, while the lowest percentage observed was for corrugated iron sheets ($\chi^2=6.88, p=0.032$). Household obtained skill training was strongly associated with coping mechanism compared to households did not participate in any training ($\chi^2=10.25, p=0.001$).

This occasion reflects the importance of housing as a measurement of economic stability, long-term settlement, and livelihood security (Table 2). Flat and mixed roofs, that are classically built using locally available materials such as wood, earth, and thatch, offer improved thermal insulation which is resilient to extreme rainfall and heat, making them further appropriate for pastoral and agro-pastoral areas (UN-Habitat, 2020).

Table 2. Climate adaptation and mitigation determinants at household level

Characteristic	Category	n (%)	χ^2 (df)	p-value
Livelihood strategy	Pastoralist	188 (51.5)	6.25 (1)	0.012
	Agropastoralist	177 (48.5)		
Gender	Male	266 (72.9)	4.80 (1)	0.028
	Female	99 (27.1)		
Education status	Illiterate / Informal	188 (51.5)	12.14 (2)	0.002
	Primary	128 (35.1)		
	Secondary	49 (13.4)		
Age in years	1082-1100	49 (13.4)	7.62 (2)	0.022
	1082-1100	139 (38.1)		
	1082-1100	177 (48.5)		
Family size	1082-1100	49 (13.4)	9.31 (2)	0.010
	1082-1100	189 (51.8)		
	≥ 7	127 (34.8)		
Place of birth	Within district	276 (75.6)	5.47 (1)	0.019
	Outside district	89 (24.4)		
Migration drivers	Access to water	139 (38.1)	8.04 (1)	0.005
	Livestock feed resources	226 (61.9)		
Common roof materials for house building	Grass/Thatch	137 (37.5)	6.88 (2)	0.032
	Corrugated Iron Sheet	78 (21.4)		
	Flat / Mixed	150 (41.1)		
Exposure to skill training	Participate on training	276 (75.6)	10.25 (1)	0.001
	Not participate on training	89 (24.4)		

3.2. Social Capital and Household to Climate Responses

3.2.1. Social Capital Dimensions

In this study, bonding and bridging social capital by the households showed moderate by 46.3% and 44.1%, respectively. This shows that greatest households respondents continue with strong close relationship through kinship,

neighborhood, and clan ties, while bridging results suggests there is a limited interaction among various clans, social groups, and livelihood strategies in resources management. However, the predominance of moderate bonding social capital also states some unevenness or decline in traditional support system. With this, weaker connection through bridging may limit innovation diffusion,

information exchange, and cooperation that extend beyond immediate social circles. This arrangement is in agreement with several pastoral and agro-pastoral communities in Africa, where strong social capital through bonding sects offers immediate benefit during food shortages, droughts, and livestock losses, nevertheless often restrict collective action transect to wider social boundaries (Adger, 2003; Pretty & Ward, 2001). Comparable findings have been informed in pastoral areas of East Africa, where solidarity in clan-based strengthen survival but limits the sharing of new technologies, climate information, and market opportunities inter groups (Gannon et al., 2020). This finding has similar patterns in Ethiopia, particularly in Somali, Borana, and Afar, social institution is customarily built around lineage and clan systems that offer strong bonding capital but comparatively weak bridging ties (Pavanello, 2010; Gebru et al., 2019).

Additionally, out of the three aspects of social capital, 41.9% of households reporting linking is the weakest in responding to climate change. This implies that the limited vertical linkage between households and formal institutions which may reduce technical support, institutional integration, and access to climate finance for scaling up adaptation and mitigation strategies (Adger, 2003). Without strong institutional ties, local coping strategies remain small-scale, informal, and reactive rather than planned and transformative (Shukla et al., 2022). The finding is consistent with report from agropastoral and pastoral communities in Africa, where interference of state is weak, service delivery restricts households' ability to get climate-smart technologies, drought insurance, credit, and irrigation support (FAO, 2018; Pavanello & Levine, 2011). In Ethiopia, findings show that though pastoral and agropastoral communities have strong informal interconnection, weak social capital linkage restricts community participation in formal climate adaptation projects and programs (Deressa et al., 2009; Tesfahunegn & Gebru, 2021).

3.2.2. Collective Action, Trust, and Network Structure

38.3% high and 39.5% moderate participation. It indicates the availability of moderate to high collective action on communal resource management practices like customary meetings, rangeland management, and water point maintenance through strong social cohesion responses to climate variability. This is consistent with norms in agropastoral and pastoral livelihood systems in Africa, where collective action is crucial for sustaining and managing communal natural resources, including climate variability (Davies et al., 2012; Gören, 2026; Polko, 2024). Similarly, in Ethiopia, customary institutions like Gadaa system and local elders' associations show a fundamental role in modifying conflicts resolution, grazing pattern, and organizing communal labor for rangeland and water management (Deressa et al., 2009; Gebru et al., 2026; A. Worku et al., 2014). However, increasing socio-economic change and climate pressure have initiated to decline some of the traditional institutions (IPCC, 2022). Therefore, the moderate to high availability of collective action observance in this study show an important basis for climate resilience.

Institutional trust shows a significant difference for both customary and formal climate change adaptation and mitigation. This study revealed that 51.2% of households reported high trust in customary institutions, whereas 14.8% observed low trust. This confirms the strength of traditional governance systems in resolving conflicts and regulating resource use under Gadaa system and council of elders. In contrast, 39.7% of households reported low trust in formal institutions, with 23.3% showing high trust. Hence, the gap in trust by the community for formal institutions may limit the implementation of climate-related programs. Therefore, integration of local community indigenous customary governance systems into formal institutions has become mandatory for the success of the response to climate change. The results were in consistence to the report observed indigenous knowledge is the best option in for resources management.

Availability of network density at the community level moderately responds to climate by 48.8% of households, with 25.7% finding high density. This shows that while social networks are employed for mutual support and information sharing, this study indicates that the network is not dense enough to ensure rapid and uniform dissemination of climate-related innovations.

3.2.3. Adoption of Climate Adaptation and mitigation Practices

Adoption of climate change adaptation and mitigation strategies shows differences in adoption across specific practices. Herd diversification and mobility planning show proportionally higher adoption by 40.3% and 46.0% of households, respectively. These are significantly embedded in pastoral livelihood systems to provide immediate response to climate variability and drought. In contrast, fodder preservation and water harvesting show lower levels of resilience to climate change impact, at 24.4% and 25%, respectively. Hence, this low adoption rate suggests limitations connected to

study gaps, technical capacity, financial challenges, labor availability, and access to infrastructure.

In this study, in comparison to adaptation strategies, mitigation is less adopted than adaptation practices. Bush control shows relatively higher adoption by 35.9% of households observed to facilitate easy pasture regeneration. Rangeland improvement and tree planting primarily indicate moderate adoption. Livestock feed production through irrigation has gotten the lowest adoption by 18.7% of households, whereas only 26.6% show high adoption. This shows considerable limitations related to capital requirements, water availability, and technical knowledge. These are some of the challenges that make it less feasible for most households. The combination of adaptation and mitigation responses to climate shows that most of the households obtained in the ranges of low, moderate, and high response were 26.6%, 45.8%, and 27.6%, respectively (Table 3).

Table 3. Descriptive statistics for social capital types and climate response indicators

Variable		Likert Scale (Frequency Distribution in %)		
		Low	Moderate	High
Bonding Social Capital		18.6	46.3	35.1
Bridging Social Capital		27.4	44.1	28.5
Linking Social Capital		41.9	36.7	21.4
Collective Action Participation		22.2	39.5	38.3
Trust in Customary Institutions		14.8	34.0	51.2
Trust in Formal Institutions		39.7	37.0	23.3
Network Density (community-level)		25.5	48.8	25.7
Adoption of Adaptation Practices	Water harvesting	33.4	41.6	25.0
	Herd diversification	21.1	38.6	40.3
	Mobility planning	17.8	36.2	46.0
	Fodder preservation	35.6	40.0	24.4
Adoption of Mitigation Practices	Tree planting	29.0	42.5	28.5
	Bush Control	24.9	39.2	35.9
	Rangeland improvement	31.8	44.7	23.5
	Livestock feed by Irrigation	47.1	34.2	18.7
Adaptation & Mitigation Response Index		26.6	45.8	27.6

3.3. Social Capital and Climate Responses Across Districts

Across the district, social capital and climate response were observed differently. In pastoral districts bonding social capital is the highest in pastoral districts, with Dilo at 68.2% and Moyale at 82.4%. Whereas in the agropastoral districts, Elwaye at 55.4% and Taltale at 53.5% show moderate levels. This shows that resilience remains stronger due to better reliance on tight-knit family and clan networks.

In contrast, in agropastoral districts, bridging social capital is more predominant. This reveals that the higher rate, 46%, of the household reflects that bridging was mostly practiced as a means of response to climate under agropastoralists compared to pastoral districts by 12.1082-1100.2%. It happens because of greater cross-community interactions that facilitate

market integration and semi-sedentary lifestyles, which are difficult for mobile pastoralists. Likewise, linking social capital is considerably higher in agropastoral districts, from 39% to 41%, than in pastoral districts, 3.7% to 9.1%.

Trust patterns also show that betterment in informal institutions is high in all districts, ranging from 53.5% to 82.4%, whereas trust in formal institutions becomes low in pastoral districts and moderate in agropastoral districts (Table 4). Therefore, these differences show how livelihood strategies determine pastoral mobility and marginalization, which could restrict bridging and linking networks, whereas agropastoral communities benefit from semi-sedentary lifestyles, broader social networks, and institutional proximity to support climate adaptation.

Table 4. Distribution of key variables and statistical significance by livelihood zone and district

Variable	Category	Pastoralist Districts (%)		Agropastoral district (%)		Statistical Significance					
		Dilo (n=110)	Moyale (n=110)	Taltale (n=80)	Elwaye (n=65)	Livelihood		District (P)		District (A)	
						X ²	p-value	X ²	p-value	X ²	p-value
Bonding Social Capital	Low	6.8	2.9	14.0	5.4	10.24	0.006	8.15	0.017	1.82	0.403
	Mode rate	25.0	14.7	32.6	39.3						
	High	68.2	82.4	53.5	55.4						
Bridging Social Capital	Low	27.3	37.5	16.3	21.4	25.18	0.001	2.45	0.294	0.85	0.654
	Mode rate	54.5	50.0	37.2	32.1						
	High	18.2	12.5	46.5	46.4						
Linking Social Capital	Low	50.0	65.4	18.6	12.5	45.67	0.001	9.87	0.007	0.72	0.698
	Mode rate	40.9	30.9	42.6	46.4						
	High	9.1	3.7	38.8	41.1						
Adoption of Adaptation Practices	Low	12.5	18.4	8.5	12.5	3.85	0.146	8.92	0.012	1.45	0.484
	Mode rate	31.8	37.5	38.0	39.3						
	High	55.7	44.1	53.5	48.2						
	Low	20.5	25.0	12.4	16.1		0.01				0.341

Adoption of Mitigation Practices	Mode rate	44.3	46.3	36.4	39.3	13.28		3.89	0.143	2.15	
	High	35.2	28.7	51.2	44.6						
Trust In Formal Institutions	Low	40.9	50.0	34.9	32.1	11.45	0.022	3.25	0.197	0.68	0.712
	Mode rate	43.2	38.9	42.6	42.9						
	High	15.9	11.1	22.5	25.0						
Trust In Informal Institutions	Low	6.8	2.9	14.0	5.4	4.28	0.369	2.89	0.236	1.12	0.571
	Mode rate	25.0	14.7	32.6	39.3						
	High	68.2	82.4	53.5	55.4						

3.4. Effects of Social Capital on Climate Response across Livelihood Systems

Social capital significantly influences household response to climate under pastoralist and agropastoralist livelihood systems. Its effects employ numerous paths, internal cohesion (bonding), horizontal networks (bridging), institutional connections (linking), trust, collective action, network density, and adoption of climate adaptation and mitigation options. Hence, the livelihood system determines the relative significance of these pathways.

In this study, bonding social capital reports as the most important predictor of climate response in pastoral areas. With this, clan-based and kinship networks, herd diversification, and resource sharing facilitate mobility during climatic shocks for resilience. Accordingly, family cohesion, friends or neighbors, clan or sub-clan ties, and mutual aid groups are significantly influenced by pastoralists at $\beta=0.91$ and $p<0.001$, $\beta=0.61$ and $p=0.003$, $\beta=0.44$ and $p=0.016$, and $\beta=0.37$ and $p=0.032$, respectively. Additionally, in pastoral communities, trust in customary institutions, collective action, and network density show significant differences at $p<0.001$ and moderate associations at $\beta=0.41$, 0.37 , and 0.41 , respectively. Moreover, responses to climate enhanced by coordinated communal actions and adherence to indigenous governance systems illustrate that well-organized communities can more effectively mobilize resources during climate extremes.

However, coexistence between different ethnic and village ties in the study area shows moderate effects through bridging networks, while linking networks, extension services, government connection, NGOs, and trust in formal institutions are less influential. This shows there is a limited role of formal institutions in the pastoral community livelihood system. Adoption of adaptation and mitigation strategies to climate change shows a weaker to moderate association at $\beta = 0.39$ and $\beta = 0.22$ with a significant difference at $p < 0.001$ and $p = 0.018$ in the pastoral areas, respectively.

In the agropastoral area, the strongest predictors of climate response become linking and bridging social capital. Linking shows an association of government connections at $\beta = 0.267$, NGO partnerships at $\beta = 0.209$, and extension or advisory services at $\beta = 0.176$. The significant difference was also found to be significant for all linking categories at $p < 0.001$. Additionally, bridging networks' parameters shows significant differences at $p < 0.001$ for inter-ethnic and inter-village and positive associations enhance cross-community collaboration in agropastoral communities (Table 5).

In the agropastoralists, the comparison linking and bridging to bonding networks shows bonding to be less dominant in significance as of the pastoralist community. The high association between adaptation and mitigation to agropastoralist livelihood systems was found to improve the climate response, with a focus on mitigation practices showing a stronger effect under pastoral communities. This shows that

mitigation practices are feasible for long-term and land-based climate investments.

The synergy between bridging and linking social capital is significant in both pastoral ($\beta = 0.18$, $p = 0.032$) and agropastoral ($\beta = 0.23$, $p < 0.001$) households (Table 6). For pastoralists, this interaction suggests that even limited formal linkages can enhance the effect of horizontal networks, though the magnitude remains modest due to low institutional presence. Agropastoralists benefit substantially from the interaction, with combined horizontal and vertical networks facilitating access to climate information, innovation diffusion, and program uptake.

The model intercepts remain highly significant (0.94 for pastoralists, 0.96 for agropastoralists; $p < 0.001$), reflecting substantial baseline climate response independent of social capital interactions. The explanatory power of the interaction model is markedly improved: $R^2 = 0.61$ for pastoralists, suggesting that 61% of the variation in climate response is captured, and $R^2 = 0.72$ for agropastoralists, indicating that nearly

three-quarters of the variation is explained by the combined horizontal vertical social capital framework (Table 6). These values demonstrate that the model strongly accounts for the primary social determinants of community-level climate response.

This pattern aligns with the social capital synergy model (Woolcock & Narayan, 2000), which posits that the effectiveness of development interventions is maximized when bridging networks and linking capital reinforce each other. Empirical evidence from African drylands also corroborates this finding: climate adaptation success is highest when inter-community ties are coupled with institutional support, as observed in Ethiopia, Kenya, Niger, and Ghana (Adger, 2003; Partey et al., 2020; Simelton et al., 2021). Overall, these results underline the importance of integrated policy interventions that simultaneously strengthen horizontal networks and vertical institutional linkages to optimize climate resilience, particularly in livelihood-diverse contexts such as the Borana Zone.

Table 5: Multivariate Regression Results (Pastoral vs. Agropastoral Households)

Social Capital Dimension	Predictor	Pastoralists β (SE)	p-value	Agropastoralists β (SE)	p-value
Bonding	Family Ties	0.091 (0.022)	<0.001	0.067 (0.021)	0.002
	Friends / Neighbors	0.061 (0.020)	0.003	0.046 (0.019)	0.017
	Clan / Sub-Clan Ties	0.044 (0.018)	0.016	0.029 (0.017)	0.089
	Mutual Aid Groups	0.037 (0.017)	0.032	0.024 (0.016)	0.136
Bridging	Inter-Ethnic Networks	0.132 (0.036)	<0.001	0.178 (0.038)	<0.001
	Inter-Village Collaboration	0.098 (0.034)	0.005	0.133 (0.034)	<0.001
	Inter-Religious / Livelihood Ties	0.083 (0.033)	0.013	0.118 (0.033)	<0.001
Linking	Government Connections	0.211 (0.047)	<0.001	0.267 (0.047)	<0.001
	NGO Partnerships	0.163 (0.043)	<0.001	0.209 (0.043)	<0.001
	Extension / Advisory Services	0.138 (0.039)	<0.001	0.176 (0.039)	<0.001
Collective Action Participation		0.370 (0.055)	<0.001	0.300 (0.048)	<0.001
Trust in Customary Institutions		0.410 (0.058)	<0.001	0.250 (0.052)	0.008
Trust in Formal Institutions		0.080 (0.040)	0.210	0.150 (0.038)	0.086
Network Density		0.310 (0.052)	0.001	0.240 (0.048)	0.014

Adoption of Adaptation Practices	0.390 (0.056)	<0.001	0.340 (0.052)	<0.001
Adoption of Mitigation Practices	0.220 (0.045)	0.018	0.290 (0.048)	0.002

Table 6. Interaction Effect of Bridging × Linking Social Capital

Predictor	Pastoral β	p	Agropastoral β	p
Bridging × Linking	0.22	0.008	0.29	<0.001
Constant	0.94	<0.001	0.96	<0.001
R ²	0.61	-	0.72	-

3.5. Social Capital and Collective Action in Community Climate Response

3.2.1. The Primacy of Bonding Social Capital and Localized Trust

The most striking finding of this analysis is the overwhelming influence of bonding social capital and trust in customary institutions. Bonding social capital emerged as the strongest predictor ($\beta = 0.45$, $p < 0.001$), significantly outpacing all other forms of capital. This underscores a critical reality: in the face of climate-induced stressors, communities first turn inwards. Strong, trust-based ties among kin and close neighbors facilitate the rapid mobilization of support, the sharing of scarce resources (e.g., food, water, labor), and the dissemination of locally relevant knowledge and early warnings (Adger, 2003). This "thick" trust acts as a social safety net, enabling communities to buffer themselves against immediate shocks a function clearly reflected in its potent effect on adaptation practices ($\beta = 0.42$, $p < 0.001$) (Table 7).

Similarly, the powerful role of trust in customary institutions ($\beta = 0.41$, $p < 0.001$) reinforces the centrality of localized governance. Customary leaders and institutions often possess deep contextual knowledge of local ecosystems and hold a degree of moral authority and legitimacy that external actors lack. This legitimacy is crucial for enforcing rules, managing common-pool resources, and mobilizing collective action for long-term resilience strategies, such as soil conservation or community forest management (Ostrom, 1990). The synergy between bonding social capital and legitimate local institutions

creates a robust, endogenous system for climate response that operates largely independently of formal state apparatuses.

Social Capital's Hierarchy: Bonding, Bridging, and Marginal Linking

The results delineate a clear hierarchy in the utility of different social capital forms: Bonding > Bridging > Linking. While bonding capital was paramount, bridging social capital also demonstrated a significant, albeit more modest, positive relationship with climate response ($\beta = 0.20$, $p = 0.027$). Its slightly stronger association with mitigation ($\beta = 0.22$) than adaptation ($\beta = 0.18$) is telling. Mitigation practices, such as adopting new energy technologies or participating in carbon sequestration programs, often require novel information and connections beyond the local sphere (Table 7). Bridging ties provide this vital function, linking communities to new ideas, technologies, and practices from diverse external groups (Pelling & High, 2005).

In stark contrast, linking social capital and trust in formal institutions consistently failed to achieve statistical significance. This is a profound finding with major implications for climate policy. It suggests a significant disconnect between formal governance structures and grassroots action. Communities in this context appear to perceive formal institutions as either inaccessible, irrelevant, or untrustworthy in providing effective support for climate response. This finding challenges the prevailing top-down paradigm of many national climate adaptation and mitigation plans, indicating that without deliberate efforts to build genuine trust and

collaborative partnerships, formal policies may fail to resonate at the local level.

Collective Action as the Behavioral Manifestation of Social Capital

The analysis reveals that collective action participation is not just an outcome but a key mechanism ($\beta = 0.37, p < 0.001$). It serves as the active channel through which latent social capital is converted into tangible climate response (Table 7). A community may possess dense networks and high levels of trust, but without a culture and

practice of working together, this potential remains untapped. Participation in collective endeavors whether for irrigation, reforestation, or disaster preparedness builds shared identity, reinforces norms of reciprocity, and provides a ready-made organizational structure that can be swiftly reoriented towards climate-related challenges (Agrawal, 2001). This finding moves the discussion from simply having social capital to the critical importance of activating it through repeated collective endeavors.

Table 7: Regression and SEM Results for Social Capital and Climate Change Response

Predictor Variables	Adaptation Practices (β / p-value)	Mitigation Practices (β / p-value)	Climate Response (SEM Standardized Coefficient / p-value)
Bonding Social Capital	0.42 / <0.001	0.31 / 0.002	0.45 / <0.001
Bridging Social Capital	0.18 / 0.045	0.22 / 0.031	0.20 / 0.027
Linking Social Capital	0.12 / 0.120	0.15 / 0.086	0.14 / 0.091
Collective Action Participation	0.35 / <0.001	0.28 / 0.004	0.37 / <0.001
Trust in Customary Institutions	0.39 / <0.001	0.25 / 0.008	0.41 / <0.001
Trust in Formal Institutions	0.05 / 0.460	0.12 / 0.102	0.08 / 0.210
Network Density	0.28 / 0.002	0.22 / 0.015	0.31 / 0.001

3.5. Social Capital Interaction Patterns and Climate Response

Figure 2 shows that climate change adaptation and mitigation among pastoral and agropastoral livelihoods in the Borana Zone are shaped by institutionally embedded social capital pathways, with collective action serving as the central mediating mechanism. Trust in customary institutions strongly influences adaptation practices, mitigation practices, and collective action, highlighting the continued importance of indigenous governance systems in coordinating communal climate responses.

Adaptation and mitigation practices are closely interconnected, indicating that households implement these strategies as complementary components of an integrated climate response rather than as separate actions. Collective action

translates institutional trust into livelihood outcomes, underscoring the fundamentally social nature of climate adaptation in pastoral and agropastoral systems.

Distinct social capital pathways are evident across livelihood systems. Bonding social capital is more strongly associated with pastoral livelihoods, reflecting the role of kinship ties, clan-based reciprocity, and mutual support in sustaining mobility-based production systems under climatic stress. In contrast, linking and bridging social capital are more influential for agropastoral livelihoods. Trust in formal institutions strengthens linking social capital, which subsequently enhances bridging social capital and expands access to external resources, markets, and technical support.

The interaction between customary and formal institutions suggests a complementary relationship: customary institutions reinforce internal cohesion and collective action, while formal institutions facilitate vertical linkages and

network diversification. Together, these pathways enhance adaptive capacity and livelihood resilience, particularly in transitional agropastoral systems.

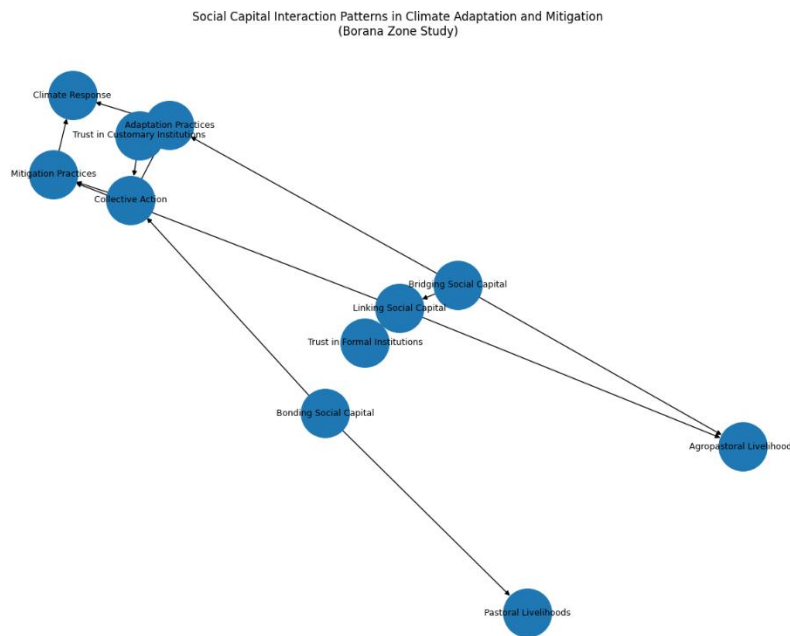


Figure 2. Social Capital Interaction Patterns and Climate Response

4. Conclusions

This study explores that social capital is a primarily basis of adaptation and mitigation to climate in the Borana Zone. Its effects strongly vary by livelihood systems. In both pastoral and agropastoral livelihood system trust in customary institutions and bonding social capital found as the most determinantal factors, providing a strong social safety net that enhance resource sharing, collective action, and rapid response to climate extremes. In pastoral systems linking and bridging of social capital become weaker whereas strong in agropastoral communities through strengthening connection by institutional support, external knowledge, and innovation necessary for long-term resilience.

In the hierarchical nature of social capital, the study found in sequence of bonding is greater than bridging still better than linking shows the dominance of local, kin-based networks, mostly in mobility dominated pastoral area, while in agropastoral area broader horizontal and vertical

connections benefit from semi-sedentary setting of the community. With this, collective action used as the primary approaches through which latent social capital interprets into practical response to climate. Significantly, the interaction between linking and bridging of social capital improve response to climate. This is focus on the embedding of community networks into formal institutional support to maximizes adaptive and mitigative results. With this, customary governance and strong social cohesion promote limitations in bridging and linking networks, and effective local responses determine access to external resources and scalability particularly in pastoral setting. Therefore, the following recommendation were based on the study results.

- Strengthen bonding networks and local governance in policies formulation for pastoral communities
- Enhance linking and bridging social capital in agropastoral setting

- Promote integration and participation of collective action for response to climate, programs formulation, and mobilize community assets for adaptation and mitigation change of climate.

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6. Ethics Declarations

Ethics approval and consent to participate
Ethical approval for this study was obtained from the Institutional Review Board of Oromia State University (Approval No: OSU/IRB/025/2025; Date: March 15, 2025). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki declaration and its later amendments.

Consent to Participate

Informed consent was obtained from all individual participants included in the study.

Verbal informed consent was obtained from household survey respondents and focus group participants, and written informed consent was obtained from key informants' participants, with consent formally recorded and witnessed.

Consent for publication

Consent for publication is not applicable to this article, as the study does not contain any identifiable images, personal data, or individual-level information.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

8. Author Declaration

We hereby declare that this study is our original work and have not been previously submitted for the purpose of undertaking the same or related studies. We also confirm that it has been prepared following plagiarism limits, and ethical clearances and integrity standards of International Journal of Special Education. Authors and all sources of material used for this manuscript have been duly acknowledged and the author declare no conflict of interest.

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