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Full Length Research Paper

Social Capital, Indigenous Knowledge, and Institutional Integration for Climate Change Adaptation among Pastoral and Agropastoral Communities in Borana Zone, Southern Ethiopia

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Abstract

This study evaluates the role of indigenous knowledge, institutional integration, and social capital in climate change adaptation by pastoral and agropastoral livelihoods in the Borana zone. A multistage sampling method was employed to select the respondents within the study zone. Borana zone was purposively selected and then the zone was stratified into pastoral and agropastoral livelihoods. From these categories, two districts per livelihood activities were selected. Within the districts households were randomly selected. A mixed-methods that integrated household surveys, focus group discussions, key informant interviews, and social network analysis was used to address the objectives set. Data was collected through a household survey on 365 households. The collected data was analyzed using descriptive statistics, structural equation modelling, Tobit regression, and social network analysis. The findings revealed that social capital was the main factor for participating in indigenous institutions (97.5% of households). Similarly, herd mobility was the most widely adopted climate change adaptation strategy by 87.7% of the households. These were followed by indigenous weather forecasting (83.6%) and herd diversification (77.8%). Livestock ownership, household size, wealth status, and education positively influenced the Social Capital Index, whereas these factors negatively affected pastoralism. Structural equation modelling showed that indigenous knowledge significantly improved adaptation to climate change through both direct and indirect pathways along social capital and institutional integration. Social networks are shown by high clustering and high density of 0.74 and 0.68, respectively. Therefore, the result showed that incorporating indigenous knowledge in social networks needs partnerships, and institutional collaboration between formal governance systems and customary law that can strengthen resilience and adaptation to climate change.

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1. Introduction

Nowadays, climate change is the most serious environmental challenge in developing nations. This is enhanced by extreme weather events, rainfall variability, rising temperatures, and prolonged droughts, which are influencing pastoral and agropastoral communities whose livelihood systems mainly depend on natural resources (Feyissa et al., 2025; Shibru et al., 2023). East Africa is mostly vulnerable due to poverty, limited adaptive capacity, reliance on rain-fed agriculture, and weak institutions. These impacts are severe in pastoral and agropastoral community along with climate variability directly affects water availability, pasture land, productivity of the livestock, and food security (Tofu et al., 2023).

Ethiopia is more exposed to climate risks such as erratic rainfall, recurrent droughts, and rising temperatures. The finding shows in southern Ethiopia, the prolonged droughts have caused significant livestock losses and increased food insecurity (Shibru et al., 2023; Feyissa et al., 2025). Despite national adaptation efforts, agropastoral and pastoral communities remain more vulnerable to climate-sensitive production and fragile rangeland systems. Hence, the study area, Borana Zone, has these challenges despite pastoral and agropastoral communities having 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). The communities experienced repeated droughts that led to rangeland degradation, livestock mortality, water scarcity, and growing livelihood insecurity (Tofu et al., 2023; Shibru et al., 2023). Recent droughts have weakened traditional coping systems and increased household vulnerability (Feyissa et al., 2025).

Indigenous knowledge strengthens climate adaptation through livestock diversification, climate forecasting, mobility strategies, and communal resource management (Tushura et al., 2022; Shibru et al., 2023). But it relies on social relationships and institutions that allow knowledge sharing and collective action. Social capital is therefore vital for adaptive capacity. It consists of networks, trust and norms that facilitate cooperation, and is often classified into bonding, bridging and linking types. Bonding is strengthening internal cohesion, bridging is strengthening intergroup exchange, and linking is connecting communities to external institutions (Feyissa et al., 2025). These, in combination, determine access to resources, information, and institutional support. Evidence illustrates that social capital enhances adaptation by strengthening information flow, collective action, and reducing transaction costs. However, reliance mostly on bonding ties can impact innovation. So, it should be complemented with bridging and linking social capital inter- and intra-connections (Tofu et al., 2023; Feyissa et al., 2025).

Consequently, social capital and indigenous knowledge are extensively studied, but few information and research studied about their interaction for determining climate adaptation results. Therefore, this study addresses these gaps through integration of climate adaptation with institutional systems, indigenous knowledge, and social capital within a single framework. Therefore, this study evaluates indigenous knowledge, institutional integration, and social capital in climate change adaptation by pastoral and agropastoral livelihoods in the Borana zone, southeastern Ethiopia.

2. Materials and Methods

2.1.Description of the Study Area

This study was carried out in the Borana zone, found in the southern part of Ethiopia among the 21 administrative zones in the Oromia Regional State of Ethiopia (Figure 1). The zonal town of Borana zone is 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 km^2, 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 is known for its mean annual temperature of 19 °C, 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 from March to June and short rains from August to October (Solomon and Coppock, 2004). Elevation of the study area is between 1000 m to 1500 m in the highlands (Solomon et al., 2007).

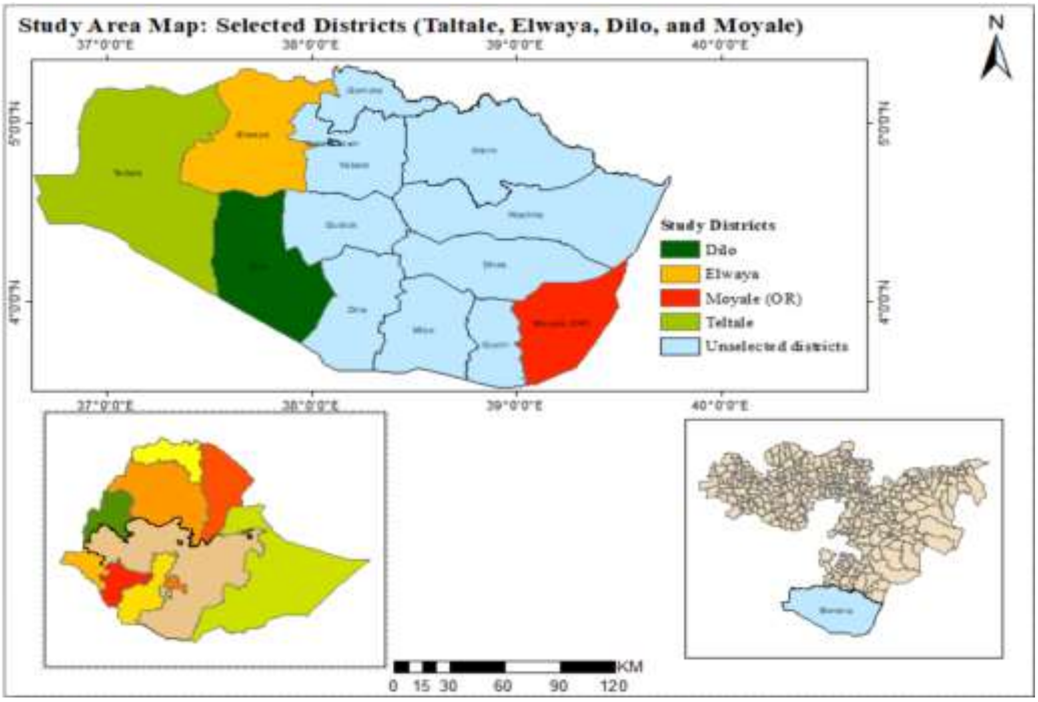

Figure 1. Map of the Study Area

2.2.Research Design, Sampling Procedure and Sample Size

This study used a cross-sectional and mixed-methods approaches. A multistage stratified sampling technique was used. Firstly, districts were stratified by livelihood system (pastoral vs. agropastoral). Secondly, 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 selected: Dilo (110) and Moyale (110) from Pastoralist, while Taltale (80) and Elwaye (65) from Agropastoralist livelihood systems (Ethiopia Agro-ecology classification report, 2020). 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 than10000

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 simple size were minimized bias and ensures data accuracy are adequately represented. Then for each kebele, sample size was determined using the following equation:

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

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

2.3.Sources of data and Collection Methods

Structured questionnaires were prepared through KoboToolbox that administered through face-to-face interviews were used as a primary data. To supplement household survey data key informant interviews were employed with Gadaa leaders, district experts, development agents, and community elders. Similarly, focus group discussions (FGD) one FGD that consists eight participants per four districts were done. Inclusion criteria to the FGD was elders, Abba Gada members, Abba

Dheeda, Abba Eela, district experts, and development agents.

2.4. Measurement of Variables

Three-dimensional framework was used to conceptualize social capital in accordance with bonding, bridging, and linking. Measurement of bonding social capital was done through determination of level of household participation in Gadaa System, Buusaa Gonofa, Iddir, and Equb. Likewise, bridging social capital determined from participant relationships with members of neighboring communities' and other clans. In the meantime, linking social capital examined connections between household participants and formal institutions. Formal institution includes, extension services, government agencies, and non-governmental organizations (NGOs).

The result obtained from these indicators were standardized and combined to formulate a composite Social Capital Index (SCI). Finally, it was used in the Tobit regression analysis as dependent variable.

Participation of the household in the Indigenous Institutions that responsible for social protection, governance, financial cooperation, natural resource management, and mutual assistance was recorded through binary responses (if participate 1, if not 0). Likewise, climate adaptation strategies by the household were determined based on six major adaptation practices, indigenous weather forecasting, herd mobility, herd diversification, fodder conservation, water harvesting, and livelihood diversification. Since households can adopted more strategies at the same time, multiple responses were allowed.

Explanatory variables in the Tobit model were used household information and socioeconomic characteristics likely influence social capital such as household wealth status, education level, household size, livestock ownership in Tropical Livestock Units, and livelihood type.

2.5. Data Analysis

Frequencies and percentages from descriptive statistics were used to express participation of household in practicing climate adaptation strategies and indigenous institutions as well as in the distribution of bonding, bridging, and linking social capital. Data was analyzed using SPSS version 31, while Structural Equation Modeling was employed AMOS 26. UCINET 6 and network visualization software were used to analyses social network analysis.

A Tobit regression model was used to identify issues influencing the Social Capital Index. The Tobit model is represented as:

$$SCI_i = \mathrm{X_i}\beta + \varepsilon_\mathrm{i}$$

where

$\mathrm{SCI_i}$ is the latent Social Capital Index, Xi represents the vector of explanatory variables, β denotes regression coefficients, and εi is the normally distributed error term. Parameter estimates were considered statistically significant was checked at the 1%, 5%, and 10% significance levels.

3. Result and Discussions

3.1. Socioeconomic Characteristics and adaptive capacity

The findings revealed that 51.5% (n = 188) were pastoralists and 48.5% (n = 177) agropastoralists (Table 1). With this study, the slightly higher share of pastoralist shows livestock-based livelihoods dominance in the study area. Conversely, a number of agropastoral proportion reflects an ongoing livelihood diversification by the household in response to climate change. In connection to household head the share of female-headed households higher when compared to earlier studies.

Household low levels of education, with 51.5% (n = 188) illiterate was observed. It is aligning with previous studies by Doyo et al 2018, reported in pastoral areas schooling is constrained by limited infrastructure and mobility. The average household size was obtained as 6.8 ± 2.4 persons. It also consistent with Eneyew (2013 but it is above the national average. Using Tropical Livestock Units (TLU) household's livestock ownership 18.7 ± 11.3 on average. This shows substantial variation for livestock wealth.

Table 1. Socioeconomic Characteristics of Households (N = 365)

Variable	Category	Frequency	Percentage (%)
Livelihood strategy	Pastoralist	188	51.5
	Agropastoralist	177	48.5
Sex of household head	Male	266	72.9

	Female	99	27.1
Education level	Illiterate	188	51.5
	Primary education	128	35.1
	Secondary and above	49	13.4
Mean household size		6.8 ± 2.4	
Mean livestock ownership (TLU)		18.7 ± 11.3	

3.2. Livestock Ownership, Social Networks, and Resilience

This study revealed that 37.8% of the household owned 10 to 20 TLU, 25.2% of households owned less than 10 TLU, 23.8% owned 20 to 30 TLU, and only 13.2% possessed more than 30 TLU. With this the concentration of households between 10 to 20 TLU reflects that most households owned moderate livestock assets, while maintenance of large herds shows relatively small proportion. The size of livestock ownership is the main indicator of household economic status in pastoral and agropastoral communities since it determines income, access to food, resilience during climatic shocks, and social influence. Hence, households with higher herds size have greater adaptability to drought through livestock sales, herd mobility, and herd recovery mechanisms. The result is consistent with previous studies conducted by James et al 2013. This could be due to rangeland degradation, recurrent droughts, and changing socioeconomic conditions.

In the Table below 92.1% of households participate in indigenous institutions whereas the left 7.9% did not participate. This finding shows the level of importance of traditional institutions, customary councils, clan networks, Gadaa system, and resource-sharing in in the study area. This plays great role in facilitating mutual support, resolving conflicts, access to pasture and water, and disseminating information. The finding is consistent with previous studies that found indigenous institutions as the major determinant of collective action and social organization in the study area (Bassi, 2005; Tache and Oba, 2009; Watson, 2003). Similar findings have illustrated that indigenous institutions play a great role significantly in climate change adaptation through coordination of responses to resource scarcity and drought (Oba, 2014; Megersa et al., 2014; IPCC, 2022).

The study shows strong institutional and social and capacity among households. Household membership in indigenous social related organizations was stated by 87.9% of respondents. This showing greater levels of social capital can support collective action and mutual assistance. Similarly, Access to climate information (70.7%) and extension services (67.4%) of the household states better dissemination of climate-related and agricultural and knowledge. Likewise, 59.7% of the household diversified their livelihoods to minimize the impacts of climate-related risks, while 87.7% of the household practiced herd mobility as the primary pastoral adaptation strategy. 79.2% of the household were participated in collective resource management to ensure contribution of indigenous institutions in managing communal resources.

Table 2. Distribution of Households According to Livestock Ownership and Associated Socioeconomic and Adaptive Characteristics

Variable	Category	Frequency	Percentage (%)
Livestock ownership (TLU)	<10 TLU	92	25.2
	10–20 TLU	138	37.8
	20–30 TLU	87	23.8
	>30 TLU	48	13.2
Participation in indigenous institutions	Yes	336	92.1
	No	29	7.9
Membership in social organizations (Iddir, Equb, Buusaa Gonofa)	Yes	321	87.9
	No	44	12.1
Access to extension services	Yes	246	67.4

	No	119	32.6
Access to climate information	Yes	258	70.7
	No	107	29.3
Livelihood diversification	Yes	218	59.7
	No	147	40.3
Use of herd mobility as an adaptation strategy	Yes	320	87.7
	No	45	12.3
Participation in collective resource management	Yes	289	79.2
	No	76	20.8

3.3.Distribution of Social Capital Typologies

In this study, the bonding social capital through Gadaa system, Iddir, Equb, and Buusaa Gonofa was the most prevalent by 97.5%. Concurrently, bridging social capital by 71.8% of households showing substantial inter-community and inter-clan interconnection. Lately, linking social capital was the least prevalent by 62.7% which reflects households had weaker interactions with extension services, government structures, and NGOs. The prevalence of bonding social capital shows the key role of these institutions in improving collective action, reciprocity, trust, and mutual support for household resilience to recurrent droughts. It is consistent with previous studies by (Bassi, 2005; Tache & Oba, 2009; Watson, 2003). Even though the relatively greater prevalence of bridging social capital enables collaboration inter communities regarding resource sharing, grazing management, and climate information exchange, lower level of the bridging of social capital associated with bonding showed social connections continue mostly localized. Likely, lower level of linking social capital showed restricted access to formal services, such as climate information, extension support, and development programs (Megersa et al., 2014).

Table 3. Distribution of Social Capital Types

Social Capital Type	Operational Definition	Prevalence (%)
Bonding Capital	Membership in Gadaa, Iddir, Equb, Buusaa Gonofa	97.5
Bridging Capital	Relationships with other clans and communities	71.8
Linking Capital	Contacts with government agencies and NGOs	62.7

3.4.Social Capital Index (SCI)

The study observes that 52.88% of the households had a high level of SCI greater or equal to 0.70, 36.71% of households had a moderate level of SCI between 0.40 and 0.69), and 10.41% of households show low level of SCI less than 0.40. with the 0.72 mean of SCI and 0.14 SD, showing that the households owned strong social capital. The high mean of SCI response to indigenous institutions shows the significant influence of Jarsa Dheedaa, Gadaa system, and Jaarsa Eela in nurturing cooperation, reciprocity, trust, and collective action in the study area. The indicated indigenous institutions enable household resilience to climate through conflict resolution, livestock redistribution, reciprocal labor exchange, and collective management of grazing and water resources. The study is aligning with Social Capital Theory, which reflects adaptive capacity and collective action strengthen by social networks and trust (Bassi, 2005; Watson, 2003; Tache & Oba, 2009). However, 10.41% of the households shows low social capital mean remain weakly connected to social and institutional networks to obtain development services, access to climate information, and mutual support.

Table 4. Distribution of the Social Capital Index (SCI) among Households (N = 365)

Social Capital Index Category	SCI Range	Frequency (n)	Percentage (%)
Low Social Capital	< 0.40	38	10.41
Moderate Social Capital	0.40–0.69	134	36.71
High Social Capital	≥ 0.70	193	52.88
Mean SCI	0.72 ± 0.14	365	100.00

3.5 Indigenous Institutions and Their Roles in Climate Adaptation

All of the household touched by this study participated in Gada system. Hence, it shows Gada system play great role in social organization and customary governance. High prevalence of the household participation observed for Jarsa Dheeda and Jaarsa Eela Institution by 94.52% 89.86%, respectively. This shows that in pastoral and agropastoral livelihood system grazing and water management needed continued indigenous systems. In Buusaa Gonofa, Iddir, and Equb 57.81%, 18.36%. and 3.29% of households were participated, respectively.

The prevalent participation in the indigenous institution shows the continuing significance in strengthening climate resilience under conflict resolution, collective decision-making, and the sustainable management of natural resources. These results are consistent with previous studies in East African pastoral systems, which identify customary institutions as the basis for resource governance, social organization, and adaptation to environmental shock (Bassi, 2005; Watson, 2003; Tache & Oba, 2009).

Table 5. Indigenous Institutions and Their Roles in Climate Adaptation

Indigenous Institution	Function	Respondents (n)	Percentage (%)
Gadaa System	Governance and conflict resolution	365	100
Iddir	Social protection and social solidarity	67	18.36
Buusaa Gonofa	Mutual support and redistribution	211	57.81
Dedha Institution	Grazing management	345	94.52
Jaarsa Eela	Water management	328	89.86
Equb	Financial support and savings	12	3.29

3.6 Climate Adaptation Strategies

The study observed that herd mobility was the most widely adopted strategy by87.7% of the household, followed by 83.6% of the household adopted indigenous weather forecasting, whereas 77.8% of the household adopted herd diversification to cope with climate variability and recurrent drought. Water harvesting and fodder conservation were used as resource management strategies adopted by 70.1% and 63.8%, respectively. In comparisons livelihood diversification was the least adopted by 59.7%.

The high prevalence of herd mobility shows its significantly important in enabling access to water resources and pasture as well as minimizing livestock losses during droughts. This result agrees with works by Barbara Tache and Gufu Oba (2009) and Gufu Oba (2014), which reported the impacts of climate change and variability on community livelihoods and cattle production in southern Ethiopia. Thus, livestock mobility was identified as the most effective indigenous climate change and variability adaptation strategy in pastoral systems of Ethiopian. Likewise, the prevalent use of weather forecasting through indigenous knowledge supports study by the Intergovernmental Panel on Climate Change (2022) and Gufu Oba (2014), which identify this knowledge as a valued match to scientific climate information service. reported that combining livestock management with natural resource conservation enhances resilience in dryland systems.

However, the continued domination of herd mobility as climate change adoption in disagreement with findings showing livestock mobility decline due to agricultural expansion, settlement, rangeland fragmentation, and restrictions on communal grazing lands (Galvin, 2009; Little et al., 2001). Similarly, the level of livelihood diversification is lower than (Ellis, 2000; Intergovernmental Panel on Climate Change, 2022). respectively.

Table 6. Major Climate Adaptation Strategies Practiced by Households

Adaptation Strategy	Frequency	Percentage (%)
Herd mobility	320	87.7
Indigenous weather forecasting	305	83.6
Herd diversification	284	77.8
Water harvesting	256	70.1
Fodder conservation	233	63.8
Livelihood diversification	218	59.7

3.7 Determinants of Social Capital Index: Tobit Regression Analysis

This study observed that Tobit regression model used to identify Social Capital Index (SCI) determinants of the households in the study area. The results revealed that the overall model output was statistically significant with the Pseudo R^2 of 0.31 which shows moderate explanatory power and Likelihood Ratio $\chi^2 = 93.47$, $p < 0.001$.

The findings reflect that Social Capital Index was positively and significantly influenced by household size, education level, livestock ownership and wealth status. In contrast, presence as pure pastoralist had showed a significant negative effect with $\beta = -0.294$, $p = 0.006$. It showing that mobile pastoral and agropastoral households practice relatively weaker institutional relationships in spite of continuing strong indigenous social networks.

The positive effects of livestock ownership, education, and wealth show that households with better economic and human and capital are best suited to found and tolerate diverse institutional and social networks. These results are in agreement with findings, education and household assets that strengthen participation in improve access to extension, customary institutions, and development services (Megersa et al., 2014; Tache & Oba, 2009; Watson, 2003). Similar findings have been stated in the Bale eco-region, where livelihood assets and education highly influence farmers' participation in climate adaptation initiatives and community organizations (Deressa et al., 2009). Also, studies undertaken in the Somali Region observed that richer households with a number of livestock holdings had consists greater adaptive capacity and stronger institutional linkages than not wealthy households (Aklilu & Catley, 2010). On the other hand, the negative consequence of pure pastoralism align with suggestion from the Afar Region, where remoteness, pastoral mobility, and limited infrastructure inhibited access to formal institutions (Yirga et al., 2017).

Table 7. Tobit Regression Results for the Determinants of the Social Capital Index

Explanatory Variables	Coefficient	Std. Error	p-value
Household size	0.103	0.034	0.003**
Education level	0.176	0.058	0.002**
Livestock ownership (TLU)	0.048	0.019	0.015*
Wealth status	0.122	0.051	0.019*
Pure pastoralist (1 = Yes)	-0.294	0.108	0.006**
Constant	1.063	0.237	<0.001***

Model statistics: Number of observations = 365; Log likelihood = −248.16; Likelihood Ratio χ^2 (5) = 93.47* ($p < 0.001$); Pseudo $R^2 = 0.31$; Significance levels: ***$p < 0.001$; **$p < 0.01$; $p < 0.05$.

3.8 Association Between Social Capital and Institutional Integration

The study revealed that significant associations between institutional integration and social capital dimensions. With this, the strongest association was obtained between institutional integration and linking social capital by $\chi^2 = 32.58$, $p < 0.001$. This shows that households owned stronger associations with extension services, government structures, and NGOs have enhanced possibilities to access technologies, climate information, and development programs.

It is consistent with Pelling and High (2005), who reported that linking social capital strengthening climate adaptive capacity by linking local communities with political resources and external institutions.

Table 8. Association Between Social Capital and Institutional Integration

Associated Tested	χ^2	p-value
Bonding capital with Institutional integration	14.27	0.001
Bridging capital with Institutional integration	18.64	<0.001
Linking capital with Institutional integration	32.58	<0.001

3.9 Structural Equation Modeling

Results

This study results from structural equation modeling reports that indigenous knowledge highly enables social capital $\beta = 0.62$, $p < 0.001$, which in turn social capital strongly improves institutional integration by $\beta = 0.71$, $p < 0.001$. Followingly, institutional integration positively influences climate adaptation consequences by $\beta = 0.68$, $p < 0.001$. This result is consistent with studies of the role of linked social with institutional systems for climate change resilience building (Adger, 2003; Pretty, 2003). Similarly, indigenous knowledge shows a when assisted by strong institutional collaboration and social networks. The findings in agreement with Resilience Theory and Social Capital Theory, which give attention to direct effect and stronger indirect effect on adaptation by $\beta = 0.29$ and $\beta = 0.44$), respectively. With this, 0.73 is the total effect suggesting social and institutional pathways mediation.

Institutional integration strength adaptation through combining scientific and indigenous knowledge to interconnected multi-level governance system, which is mostly used as tool for adaptive capacity (Folke et al., 2005; IPCC, 2014). The greater indirect effect shows that indigenous knowledge is the most effective adaptive capacity happened from interactions between institutions, knowledge systems, and social relations (Adger, 2003; Folke, 2006).

Table 9. Direct, Indirect and Total Effects

Path	Direct Effect	Indirect Effect	Total Effect
Indigenous Knowledge → Social Capital	0.62***	-	0.62
Social Capital → Institutional Integration	0.71***	-	0.71
Institutional Integration → Adaptation Outcomes	0.68***	-	0.68
Indigenous Knowledge → Adaptation Outcomes	0.29***	0.44***	0.73

***p < 0.001.

3.10 Social Network Characteristics

The study revealed that the network density of 0.68 shows a highly interacted system where greatest potential bonds are existing. This indicates strong information exchange and interaction among stakeholders (Wasserman & Faust, 1994). Similarly, the average degree of 5.9 illustrate that each stakeholder is allied to nearly six others. Since that it provides multiple networks for accessing to resources, information, and support. Also, 0.74 of high clustering coefficient indicates strong local cohesion. This also showed that households form strongly interconnected groups that enable cooperation, trust, and rapid dissemination of indigenous knowledge. On the other hand, it may also restrict exposure to external input if bridging bonds are weak (Granovetter, 1973;

Bodin & Crona, 2009).

The betweenness centrality of 0.41 shows the existence of key bridging actors who join if not disconnected groups and play a critical role in resource flows, coordinating communication, and climate-related information exchange (Freeman, 1977).

Table 10. Social Network Indicators

Network Indicator	Value
Network Density	0.68
Average Degree	5.9
Clustering Coefficient	0.74
Betweenness Centrality	0.41

4 Conclusion and Recommendations

The integrated results observed that climate adaptation in the study area is determined by the interaction of social capital, strong indigenous institutions, and institutional linkages. Households are predominantly with moderate livestock holdings and high social cohesion with mean of SCI 0.72. Bonding social capital is dominant by 97.5%) compared to bridging 71.8%, and linking 62.7% forms. Adaptation is significantly determined by indigenous strategies such as indigenous forecasting and herd mobility, while structural equation modeling results showed that indigenous knowledge influences adaptation of the household both directly and indirectly through institutional and social capital integration. Social network indicates a dense and cohesive structure found to support strong collective action and information flow. Therefore, enhancing linking social capital and institutional collaboration along government and development actors is recommended to improve long-term climate resilience.

Author Contributions

Muleta Husein: Conceptualization, methodology, investigation, data curation, formal analysis, visualization, writing original draft, and manuscript revision.

Terefe Tolessa: Conceptualization, methodology, supervision, validation, project administration, writing review and editing, and critical revision of the manuscript.

Chala Dechassa: methodology, supervision, validation, writing-review and editing, and critical revision of the manuscript.

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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.

Competing interests

The authors declare no competing interests.

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