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Livelihood Resilience Capacity and Adaptation Strategies of Rural Farm Households to Climate Variability-Induced Shocks in Damot Woyde District, Southern Ethiopia

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Abstract
Small-holder farmers' livelihoods in developing countries are expected to be more vulnerable to climatic shocks. Building livelihood resilience needs lowering exposure and sensitivity to shock while enhancing adaptive capacity. The purpose of this study is to assess rural livelihood resilience to climate-induced shocks and to investigate the factors that influence household resilience and adaptation strategy selection in Damot Woyde, Southern Ethiopia. The study's data were gathered through a survey of 346 households, 6 focus group discussions, 27 key informant interviews, and personal observations. The livelihood resilience index was used to assess rural farm households' resilience to climatic shocks, and linear and binary logistic regressions were used to determine factors of livelihood resilience and adaptation strategy decisions, respectively. The findings revealed that social capital (0.801) from absorptive capacity and socio-demographic (0.550) from adaptive capacity contributed more to livelihood resilience. Whereas the score of farmland locations and soil fertility (0.154) from absorptive capacity, assets (0.216) and livelihood strategy (0.293) from adaptive capacity, and formal safety nets (0.263) from transformative capacity reveals the main causes of poor resilience capacity. Thus, the cumulative livelihood resilience score is only 0.356 (35.6%). Both Linear and logistic regression analysis revealed that literacy, income, food security, livelihood diversification, land size, soil fertility, extension and social services, and shock events are significant drivers of livelihood resilience and adaptation strategy choices. Therefore, it is recommended that relevant stakeholders, policymakers, and institutions enhance the access of farmers to these vital services in order to improve their adaptation and thus livelihood resilience to climate hazards.
Keywords: Livelihood Resilience; Adaptation Strategies; Climate-induced Shocks; Damot Woyde
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1. Introduction

Climate-related impacts disproportionately affect the poorest citizens' livelihood systems, destroying their capacity to build sustainable livelihoods and raising their vulnerability (UNDRR, 2019; Serdeczny et al., 2017; Tanner et al., 2015). Climate-related hazards such as droughts, floods, and rising temperatures pose a serious threat to the poor's livelihoods in Ethiopia (Bekele et al., 2020). Enhanced resilience to climatic impacts attained as a result of adaptation action is not only a protective measure for handling acute onset shocks (like floods, disease outbreaks, food price increases, etc.) and slow onset shocks (like as drought, environmental degradation, etc.), it is also a driver of social and economic development (Dicker et al., 2021).

The concept of resilience is complicated and multi-interpretable, with disputed explanations and relevance (Jordan, 2009). However, resilience is gaining traction in sectors related to development and vulnerability reduction, such as social protection, disaster risk reduction, and climate change adaptation (Béné et al., 2012). Resilience is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a shock or stress in a timely and efficient manner (IPCC, 2012; Mitchell & Harris, 2012). It is viewed as a policy tool that connects humanitarian and development approaches to address people's chronic vulnerability to recurring shocks and stresses (Choularton et al., 2015). The idea helps not only to design and advance livelihood enhancement strategies, but also capacity building packages, as well as in integrating climate change adaptation strategies (Amphune, 2019).

The majority of scholars and specialists from a variety of disciplines agree that resilience emerges as a result of all three capacities: absorptive, adaptive, and transformative capacities, each of which leads to different outcomes: persistence, incremental adjustment, or transformational responses respectively (Choularton et al., 2015; Béné et al., 2012). Thus, depending on the context, the terms absorptive, adaptive, and transformative can be viewed as components, capacities, or structural elements of resilience (Asmamaw et al., 2019). However, in this study, resilience is described as the ability to deal with climate-related events, with the terms absorptive, adaptive, and transformative referring to households' ability to resist, adapt, and transform in response to climate-induced shocks.

Adaptation and resilience to climatic impacts are critical and growing global priorities as disasters and shocks continue to rise, while inadequate adaptation is already costing lives and livelihoods around the world through weather- and climate-related disasters (Dicker et al., 2021). Climate change adaptation strategies need to build livelihood resilience in the context of climate change/variability while also addressing the variables that drive farmers' vulnerability (Mwasha & Robinson, 2021; Afifi et al., 2014). A farmer's decision to use an adaptation strategy to mitigate the effects of climatic impacts is heavily influenced by some socioeconomic factors that must be understood. Factors influencing farmers' adaptation decisions are critical in developing policies to promote effective adaptation in the agricultural sector and build livelihood resilience (Mabe et al., 2014).

Some empirical studies in Ethiopia that attempted to investigate resilience and livelihood resilience at the household level differed in terms of their focus, type of data and methodologies used. For instance, Asfaw et al. (2018) and Vaitla et al. (2012) employed panel data sets evidence from Ethiopia and Tigray, Mekuyie et al. (2018) used proxy variable approach in southern Afar, Weldegebriel & Amphune (2017) employed PCA and simple linear regression in northwest Ethiopia, and Asmamaw et al. (2019) and Tofu et al. (2023) employed climate resilience index in north central highlands and Borana zone of Ethiopia respectively.

Despite the fact that the studies mentioned above have documented key factors influencing households' resilience to shocks, most are geographically limited to northern and central Ethiopia, whereas others focus on national-level analysis using panel data sets. As a result, none of the evidence from these studies can completely explain the situation in the context of the study area. Furthermore, the study area's livelihood resilience capacities to climate shocks, along with the factors influencing households' resilience level and choice of adaptation strategies, have not been adequately studied. Thus, the purpose of this study is to a) measure farm household livelihood resilience abilities to climate-induced shocks; and b) investigate factors influencing farm household resilience abilities and adaptation strategy choices. Finally, the findings of this study will serve as a basis for future research and a reference point for policymakers in developing proper adaptation policies to assist rural communities in building livelihood resilience against future climate-related risks.

2. Research Methodology

2.1. Description of the Study Area

This research was carried out in the Damot Woyde district of southern Ethiopia, which lies between 6^0 40'56" and 6^0 59'30" N latitudes and 37^0 52'20" and 38^0 04'35" E longitudes (Fig.1). *Bedessa*, the district's administrative center, is 335 kilometers south of Addis Ababa and 26 kilometers east of Sodo, the capital of Wolaita Zone. The district presently has 24 kebeles (Ethiopia's lowest administrative units), a total size of 352 square kilometers, and a population of 121,478 (CSA, 2020). As to Bergene (2014), the research location is distinguished by two ACZs (*Woina Dega* (Midland, 60%) and *Kolla* (Lowland, 40%), which cover 1600m-2100m and 1000m-1600m above sea level, respectively. The area has two main rainy seasons, March-May (*Belg*) and June-October (*Meher*), though the amount and intensity of rainfall vary throughout the year. Subsistence agriculture is the primary source of income in the study area, with some non-farms/off-farms. The main crops in the district are enset, cereals, and root crops (Bergene, 2014).

2.2. Research Design and Sampling Techniques

This study used a cross-sectional survey design and a quantitative dominant mixed research approach. The convergent mixed methods enables the simultaneous collection of qualitative and quantitative data (Creswell & Creswell, 2018). A multistage sampling procedure was used to choose the survey sample households. Firstly, Damot Woyde district selected purposely based on the vulnerability. Secondly, the study district stratified in to two agro-climatic zones (ACZs). Thirdly, four kebeles from *Woina Dega* and two kebeles from *Kolla* randomly selected on their proportionality. Fourthly, 346 sample households selected randomly using the sample size determination formula (Kothari, 2004).

$$n = \frac{Z^2 * p * q * N}{e^2 * (N-1) + Z^2 * p * q}$$

Where, z=1.96 (95% confidence interval); p=sample proportion, 0.5; q=1-p; e= error margin=0.05 (5%); N=total number of households (sampling frame) =3327.

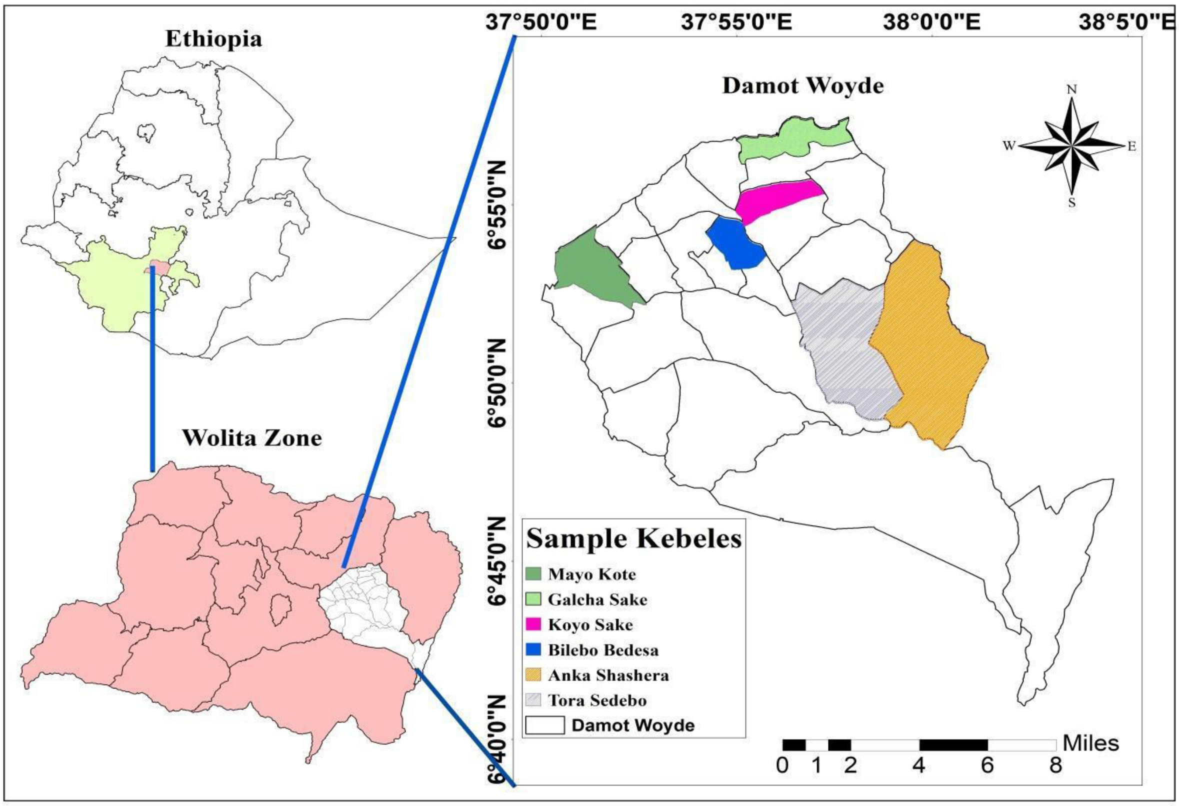

Figure 1: Location Map of the study district

2.3. Data Sources and Methods of Collection

Both primary and secondary data sources were used to achieve the intended objectives. The structured questionnaire was used to survey 346 household heads, 27 key informants, six focus group discussions (FGD), and field observations were utilized to collect primary data. Secondary information was obtained from important published and unpublished sources such as books, journal articles, websites, documents, thesis and official reports.

2.4. Methods of Data Analysis

The Livelihood Resilience Index (LRI) was used to measure rural farm households' resilience to climate-induced shocks on an agro-climatic unit of analysis using the three resilience capacities (absorptive, adaptive, and transformative). To determine livelihood resilience, a multiple linear regression model was used to predict the resilience index as a dependent variable based on a set of independent variables. The binary logic model was also used to investigate the factors influencing a farmers' adaptation strategy selection.

Livelihood Resilience Index (LRI) Calculation

Since resilience has a dynamic multidimensional concept, quantifying it remains debatable (Béné et al., 2016). However, proxy indicators via a composite index frame have been used to measure resilience in various contemporary literatures (Tambo & Wu, 2017; FAO, 2016). In this study, the resilience tool developed by FAO, 2016 and implemented by (Tambo & Wu, 2017; Tambo, 2016) was adopted to measure households' resilience to climate-induced shocks. The tool was included major components and indicators in their respective three resilience capacities. The selections of major components and indicators was based on literature (Asmamaw et al., 2019) and stakeholder consultation. Table 1 reveals the resilience capacities, major components, indicators and their hypothesized relationships.

Table 1: Resilience capacities, major components, indicators and hypothesized relationships

Resilience capacities	Major components	Indicators	Hypothesized relationship: Household is resilient if:
Absorptive Capacity	Natural disaster & climate variability	Early warning system, shock events during the last 12 months	Access to early warning system and get prepared to shock impacts
	Farmland & soil condition	Landscape position, soil fertility, SWC and awareness to climate extremes	The majority of farm land is a gentle slope, fertile soil, high SWC & has knowledge on climate change impacts
	Social capital	Sharing of resources and technology and membership to community-based associations	High experience of sharing of resources and technology and member of community-based associations
Adaptive capacity	Income & food access	Income, saved crops & seeds, food insecurity and food coverage from own production	High annual per capita income, saved crops & seeds and food secure
	Health	Sickness report and access to health extension	Lower illness report and access to health services
	Water	Improved, sufficient water and water conflict	Access to improved drinking water, water sufficiency and no water conflict
	Socio-demographic	Sex of the household head, dependency and Education	Male-headed households, lower dependency ratio and literate
	Assets	Asset, livestock holding and land size	Large asset, livestock holding and land size
	Livelihood strategy	Livelihood diversity, social support score, number of coping strategies and technology utilization	Multiple income sources, higher social support score, utilize technology and apply varieties of coping strategies
Transformative Capacity	Social security status	Conflict management, participation in local governance	Who participates in elderly institutions, governance sustains peace and security
	Formal safety nets	Food and non-food assistance, disaster response program	Accessed food and non-food assistance and get ready to shock exposure
	Access to basic services	Access to market, health services, primary school, road, credit and Electricity	Access public services in ≤5 km or ≤1 hr. walking distance from home

According to Sullivan (2002), the LRI uses a balanced, weighted technique where each indicator contributes equally to the index. In this study using household-level data on the indicators, a Livelihood Resilience Index (LRI) will develop on an agro-climatic unit of analysis. Two methods of standardization will employ to explain the livelihood resilience index (Asmamaw et al., 2019). Indicators that are expected to have a direct relationship with resilience, such as income, land size, livelihood diversification, SWC, etc. were standardized using equation as:

$$Ia = \frac{Yz - Ymin}{Ymax - Ymin} \quad (1)$$

Whereas indicators expected to have inversely related to resilience, such as climatic shocks, household food insecurity, health problem, etc. were standardized using equation as:

$$Ia = \frac{Ymax - Yz}{Ymax - Ymin} \quad (2)$$

Where *Ia* is the standardized value of the indicator a, *Yz* is the observed (average) value of the indicator for agro-climatic zone z, *min* and *max* are the minimum and maximum values of the indicator across all the agro-climatic, respectively.

After standardizing of each indicator, the average value of each major component will compute using equation as:

$$Mz = \frac{\sum Iai}{N} \quad (3)$$

Where *Mz* is one of the major components for agro-climatic zone z, *Iai* is the indicator

Indexed by *i*, that frame each major component, *N* is the number of indicators in each Major component.

After values for each of the major components for each agro-climatic zone will be calculated, the LRI will be obtained from the weighted average of the major components as:

$$LRIz = \frac{\sum_{i=1}^{11} WMiMzi}{\sum_{i=1}^{11} WMzi}$$

This is in a more expanded way:

$$LRI_z = \frac{WndcvNDCVz + WlscLSCz + WscSCz + WifaIFAz + WhHz + WwWz + WsdpSDPz + WaAz + WlsLSz + WsssSSSz + WfsFSz + WabsABSz}{Wndcv + Wlsc + Wsc + Wifa + Wh + Ww + Wsdp + Wa + Wls + Wsss + Wfs + Wabs} \quad (4)$$

Where *LRIz* is the Livelihood Resilience Index for each agro-climatic zone, *Mzi* is the number of indicators of the major component, *WMi* is weight of major component I, *NDCV* is natural disaster and climate variability, *LSC* is Location & soil condition, *SC* is Social capital, *IFA* is Income & food access, *H* is Health, *W* is Water, *SDP* is Socio-demographic profile, *A* is Assets, *LS* is Livelihood strategy, *SSS* is Social security status, *Fs* is formal safety nets and *ABS* is Access to basic services.

FAO's Resilience Index Measurement and Analysis (FAO, 2016) indicators were aggregated by equal weighting approach and subsumed into the three resilience components to capture households' resilience to climate-induced shocks. Where resilience is the function of the three core components (absorptive, adaptive and transformative capacities) expressed as:

$$LRIz = f(ABCz, ADCz, TCz) \quad (5)$$

Where *LRIz* is the Livelihood resilience index of the agro-climatic zone, *ABCz* is the absorptive capacity for the agro-climate, *ADCz* is the adaptive capacity of the agro-climate and *TCz* is the transformative capacity of the agro-climate.

Therefore, the indicators presented in Eq (5) will aggregate into respective resilience capacities to generate the Livelihood Resilience Index (LRI) as follows:

$$LRIz = \frac{WabcABCz + WadcADCz + WtcTCz}{ABCz + ADCz + TCz} \quad (6)$$

Where *LRIz* is the resilience index for the agro-climate z; *Wabc, Wadc* and *Wtc* are the weight of absorptive, adaptive and transformative capacities, respectively; *ABCz, ADCz* and *TCz* are the number of indicators in absorptive, adaptive and transformative capacities in each agro-climatic zone, respectively.

Multiple linear Regression

The regression employed to investigate factors influencing farm household resilience abilities Therefore, a multiple linear regression model was used to predict the resilience index as a dependent variable based on a set of independent variables using the equation as follows (Tabachnick, 2013):

$$Y = \alpha + B_1X_1 + B_2X_2 + \ldots + B_nX_n + e \quad (7)$$

Where, Y is the resilience index (dependent variable); *a* is the intercept; B_n and X_n are the Coefficients and the set of predictors, respectively.

Binary Logit Regression

Farm households utilize their own experience, ascribed information and resources based on their experience with these risks to handle climate variability and extreme weather conditions (Khan et al 2020). The binary logic regression model was used to identify the factors that have a considerable impact on the choice of the adaptation strategy in minimizing the adverse effect of climatic impacts on crop and livestock productivity. The dependent variable is a binary choice because each farmer has two options: to select or not to select a strategy *K*. If the farmer selects a k^{th} adaptive strategy in response to the perceived climate variability, then the binary choice is assumed to be 1, otherwise 0 (Bryan et al., 2013). The binary logit model has specific benefits that will allow people to examine the farmer's decisions and determine the relevant probabilities (Khan et al., 2020). Binary logit model use to analyze the effect of vector X on the response probabilities expressed by (Acquah, 2011; Mabe et al., 2014) as:

$$P\left(Yi = \frac{J}{Xi}\right) = f(Zi) = \frac{e^{Zj}}{1+e^{Zi}} = \frac{1}{1+e^{-Z}} \quad (8)$$

$$Zi = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} \ldots\ldots + \beta_k X_{ki} + \mu_i \quad (9)$$

Or

$$ln\left[\frac{Pj}{1-Pj}\right] = \beta 0 + \beta 1\, X1i + \beta 2\, X2i \ldots\ldots + \beta k\, Xki + \mu i \quad (10)$$

Where k = 1, 2, 3… n, β0 is intercepted, β*i* is regression coefficients to be estimated, μi is a disturbance term and

Xi is vectors of independent variables.

3. Results and Discussion

3.1. Rural Livelihood Resilience Capacities

Among the most compelling aspects of resilience strategy is identifying how the cumulative effect of climate change, economic forces, and social conditions has accelerated the severity and frequency of risk exposure among vulnerable populations (FAO, 2016). Climate shock and other forms of socioeconomic hardship are very prevalent in Ethiopia, disproportionately affecting less prepared poor households with varying degrees of severity across different ACZs (Amphune, 2019). The same author pointed out that the magnitude of the destruction of livelihoods is exacerbated when shocks strike households with varying resilience capacities at the same time, especially in the case of natural disasters and other climatic disruptions. The LRI based on 12 major components and 42 indicators as well as multiple regressions were used to measure the rural livelihood resilience capacities of different ACZs and investigate the factors that contribute to different levels of household livelihood resilience. The analysis of livelihood resilience via resilience capacities clearly distinguished the ACZs.

Absorptive capacity is the ability to reduce exposure to shocks and stresses through preventative measures and appropriate coping strategies in order to avoid long-term, negative consequences (TANGO International, 2018). The study used 11 indicators that jointly procedure absorptive capacity of the rural households (Table 2). The results show that the absorptive capacity of rural households in terms of natural disaster and climate variability, the *Kolla* households (0.333) are poorly resilient than *Woina Dega* (0.520). This may contributed from their poorly access to early warning systems (0.043), climate shock events- crop pest (0.363) and livestock disease (0.365) than their counterparts (0.101, 0.603 and 0.683) respectively (Table 2). Though *Kolla* households are slightly better in terms of farmland location and soil condition major components, poor soil fertility, relatively sloppy farmland, less application of soil and water conservation (SWC), and inability to climate-induced shocks forecast forced both ACZs to be poorly resilient.

In terms of social capital, both ACZs performed better, with *Kolla* households scoring slightly higher (0.842) than *Woina Dega* (0.761) (Table 2). This reflects social capital, particularly membership in social institutions (*Idir*) and the sharing of experiences and resources during shocks, which contribute significantly to absorptive capacity. This is consistent with the findings of Amphune (2019) and Asmamaw et al (2019), who identified social capital as a significant contributor to absorptive capacity. When comparing the combined effects of absorptive capacity forming indicators across ACZs, the *Woina Dega* (0.419) performs better than *Kolla* (0.372). This outcome corresponds with Amphune (2019) but not with Asmamaw et al (2019).

Table 2: Absorptive capacity and its indicators scores by ACZ

Indicators	**Agro-climatic Zone (ACZ)**					
	W/Dega Indexed	*Kolla* Indexed	Major Components	*Woina Dega*	*Kolla*	All HH
Drought (N0) (Inverse)	0.558	0.375				
Flood (N0) (Inverse)	0.653	0.521				
Crop disease (N0) (Inverse)	0.603	0.363	ND & CV	0.520	0.333	0.427
Livestock disease (N0) (Inverse)	0.683	0.365				
Early warning system (%)	0.101	0.043				
Soil fertility status (%)	0.024	0.165				
Flatness of farmland (%)	0.261	0.424	Farmland & soil	0.122	0.185	0.154
SWC (%)	0.164	0.151				
Access to climate shock forecasts (%)	0.039	0				
Sharing of experiences & resources (%)	0.536	0.683	Social capital	0.761	0.842	0.801
Membership to social institution (%)	0.986	1				
Absorptive Capacity Index (ABCI)				**0.419**	**0.372**	**0.396**

Source: Survey result, 2022

Adaptive capacity is the ability to make proactive and informed decisions about alternative livelihood strategies based on an understanding of changing circumstances (TANGO International, 2018; Smith et al, 2015 and Frankenberger et al, 2013). The study computed the adaptive capacity score using 6 major components and 20 indicators. The outputs reveal that the *Woina Dega* ACZ outperformed in five major components- IFA (0.378), Health (0.410), Water (0.468), SDP (0.567), and Livelihood strategy (0.335) than *Kolla* (0.291,0.291, 0.336, 0.533 and 0.251 respectively) (Table 3). This is due to *Kolla* households scoring lower in gross income (0.175), crop and seed saving habits (0.252), food security (0.343), healthiness report (0.137), livelihood diversification (0.433), number of coping strategies (0.291), and application of improved seeds (0.273) than their counterparts (0.352, 0.324, 0.443, 0.386, 0.633, 0.441 and 0.377 respectively). Both ACZs reported that safe drinking water sufficiency and irrigation access were extremely difficult. However, the *Kolla* ACZ has a higher asset value (0.251) than *Woina Dega* (0.182), despite its small cumulative contribution to livelihood resilience when compared to other major components. This is because *Kolla* households perform better in terms of TLU (0.351) and farmland size (0.192) than *Woina Dega* households (0.239 and 0.078 respectively). According to the total weighted value of adaptive capacity, the *Woina Dega* ACZ (0.383) contributed more to household resilience than *Kolla* (0.318) (Table 3). The results are also consistent with the findings of Asmamaw et al (2019).

Table 3: Adaptive capacity and its indicators scores by ACZ

Indicators	Agro-climatic Zone (ACZ)					
	W/Dega Indexed	*Kolla* Indexed	Major Components	*Woina Dega*	*Kolla*	All HH
Gross Income (Birr)	0.352	0.175				
Saved crops & seeds (%)	0.324	0.252	IFA	0.378	0.291	0.334
Food covered from own production (months)	0.391	0.393				
HFIAS Category (Inverse)	0.443	0.343				
Sickness report (%) (Inverse)	0.386	0.137	Health	0.410	0.291	0.351
Access to health extension (%)	0.435	0.446				
Access to improved water (%)	0.444	0.086				
Water sufficiency (%)	0	0	Water	0.468	0.336	0.402
Water conflict (%) (Inverse)	0.961	0.921				
Male HH head (%)	0.831	0.791				
Dependency ratio (Inverse)	0.678	0.687	SDP	0.567	0.533	0.550
Education level (Schooling years)	0.192	0.12				
Total asset value (Birr)	0.229	0.209				
Livestock holding (TLU)	0.239	0.351	Assets	0.182	0.251	0.216
Farmland Size (ha)	0.078	0.192				
Livelihood diversity	0.633	0.433				
Social support score	0.223	0.258				
Number of coping strategies (N0)	0.441	0.291	Livelihood strategy	0.335	0.251	0.293
Irrigation access (%)	0	0				
Using improved seeds (%)	0.377	0.273				
Adaptive Capacity Index (ADCI)				**0.383**	**0.318**	**0.351**

Source: Own survey data (2022)

Transformative capacity is the final resilience capacity, and it includes the governance mechanisms, policies, infrastructure, community networks, and formal and informal social protection mechanisms that create an enabling environment for systemic change (TANGO International, 2018 & Frankenberger, 2013). This index is made up of 11 indicators organized into 3 major components. Among the 11 indicators, food assistances from different sources, access to health, school, and credit services contributed better to rural livelihood resilience. However, disaster response programs to shocks, non-food assistance during and after shocks, and access to electricity were the main causes of observed poor resilience capacity of households in *Woina Dega* (0.029, 0.077, & 0.145) and *Kolla* (0.043, 0.129, & 0.000), respectively (Table 4). With the exception of access to basic services (ABS), *Kolla* households are slightly higher than *Woina Dega* households in terms of social security (0.338) and formal safety nets (0.271). However, the cumulative score of *Woina Dega* ACZ is higher than *Kolla* in the formation of a transformative capacity index (Table 4). The result is consistence to Amphune (2019) but not to .Asmamaw et al (2019)

Table 4: Transformative capacity and its indicators scores by ACZ

Indicators	**Agro-climatic Zone (ACZ)**					
	W/Dega Indexed	*Kolla* Indexed	Major Components	*Woina Dega*	*Kolla*	All HH
Conflict management (%)	0.348	0.374				
Participation in governance (%)	0.314	0.302	Social security	0.331	0.338	0.335
Food assistance (%)	0.657	0.640				
Non-food assistance (%)	0.077	0.129	Formal safety nets	0.254	0.271	0.263
Disaster response program (%)	0.029	0.043				
Distance to market/Km/ (Inverse)	0.368	0.342				
Distance to health services/Km/(Inverse)	0.493	0.434				
Distance to 1ry school/Km/ (Inverse)	0.454	0.40	ABS	0.386	0.328	0.357
Distance to road/Km/ (Inverse)	0.376	0.341				
Distance to credit/Km/(Inverse)	0.482	0.452				
Access to Electricity (Km)	0.145	0				
Transformative Capacity Index (TCI)				**0.340**	**0.314**	**0.327**

Source: Own survey data (2022)

Among the 12 major components calculated, social capital from absorptive capacity and socio-demographic from adaptive capacity contributed most to the study area's livelihood resilience, with mean scores of 0.801 and 0.550, respectively. Whereas, the mean score of farmland locations and soil fertility (0.154) from absorptive capacity, assets (0.216) and livelihood strategy (0.293) from adaptive capacity, and formal safety nets (0.263) from transformative capacity reveals the main causes for poor resilience capacity of rural households in the study area (Table 5).

Table 5: Livelihood resilience score

Major components	**Agro-climatic Zone**		
	W/Dega	***Kolla***	**All HH**
Natural disaster & climate variability (ND & CV)	0.520	0.333	0.427
Farmland & soil condition	0.122	0.185	0.154
Social capital	0.761	0.842	0.801
Absorptive Capacity Index (ABCI)	***0.419***	***0.372***	***0.396***
Income & food access (IFA)	0.378	0.291	0.334
Health	0.410	0.291	0.351
Water	0.468	0.336	0.402
Socio-demographic profile (SDP)	0.567	0.533	0.550
Assets	0.182	0.251	0.216
Livelihood strategy	0.335	0.251	0.293
Adaptive Capacity (ADCI)	***0.383***	***0.318***	***0.351***
Social security status	0.331	0.338	0.335
Formal Safety Nets	0.254	0.271	0.263
Access to basic services (ABS)	0.386	0.328	0.357
Transformative Capacity Index(TCI)	***0.340***	***0.314***	***0.327***
Livelihood Resilience Index LRI	**0.381**	**0.331**	**0.356**

Source: Own survey data (2022)

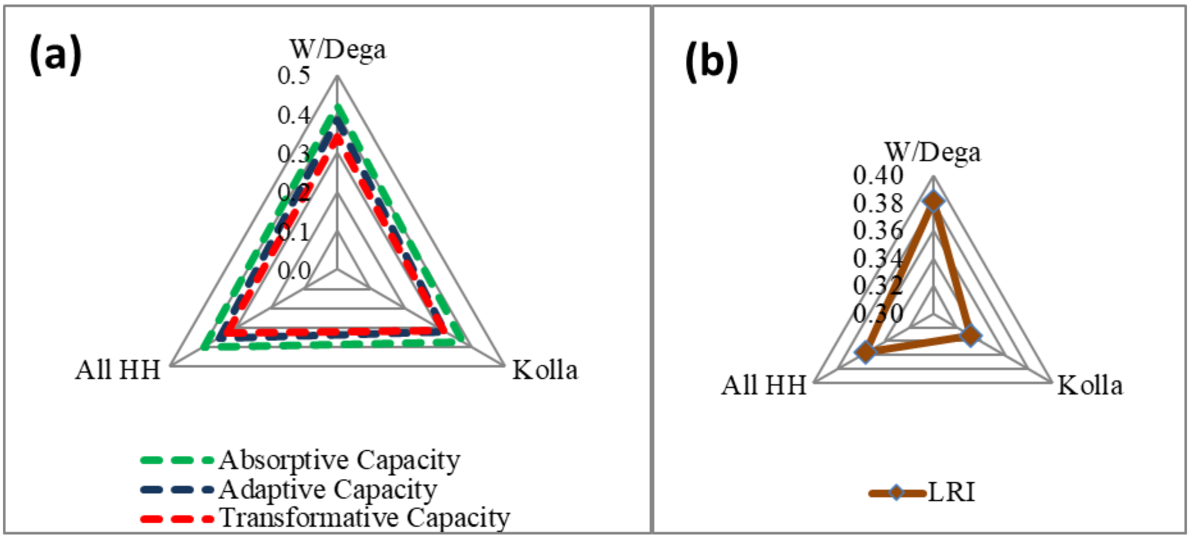

Figure 2: Three resilience capacity scores (a); Livelihood resilience index scores (b)
Source: Own survey data (2022)

The livelihood resilience analysis using resilience capacities distinguished the ACZs more clearly in terms of their absorptive, adaptive, and transformative capacities. As a result, absorptive capacity was found to be the most important factor of rural livelihood resilience to climate-induced shocks in Damot Woyde district with a mean index value of 0.396, followed by adaptive capacity with a mean index value of 0.351 (Table 5; Fig 2a). With a mean index value of 0.381 in terms of ACZ, the *Woina Dega* was found to be relatively resilient to climatic shocks (Table 5; Fig 2b). However, the cumulative livelihood resilience score of both ACZs is only 0.356 (35.6%), which is far below the 50% threshold (Table 5; Fig 2b).

3.2. Determinant of resilience as estimated by multiple regression analysis

Occurrence of shock events (drought, flood and crop diseases), soil fertility and location of farmland: These are some of the indicators which included under the category of absorptive capacity (Table 2). It is assumed that households with high exposure to shock events, those with infertile farmlands located in sloppy areas, are less resilient to climate variability-induced shocks. Because of their increased sensitivity and limited livelihood options, these households are more susceptible to climate variability-induced shocks. In this study, households that experienced a higher frequency of flood (-0.011), crop disease (-0.011), and drought (-0.005) had a less likelihood of recovery by 1.1%, 1.1%, and 0.5%, respectively, than households that had not been exposed to any shock. Households with a higher proportion of fertile and flat farmlands, on the other hand, have 0.013 and 0.010 points, respectively. This reflects the fertility and flatness position of farmlands being positively associated with rural farm households' resilience capacity (Table 6). According to Asmamaw et al (2019), households exposed to shock events and owning infertile and sloppy farmlands have a lower chance of recovering from climate-induced shocks.

Climate variability influences, land degradation, and the lack of an early warning system were also mentioned by discussants and key informants as affecting their resilience to climate extremes. Similarly, land fertility is cited as a major influencer of household productivity and wealth status. As a result, households with gentle slopes and higher soil fertility perform better in production and are more resilient to shocks than their counterparts. They also noticed that soil and water conservation help to influence household resilience to climate-related shocks such as soil erosion. In practice, households that practice intensive soil and water conservation measures are less likely to be affected by erosion and more likely to recover quickly from the effects of erosion (Asmamaw et al, 2019).

Income and food access, Land size, Livelihood diversification, Coping strategies, Education and Dependency ratio: These are some adaptive capacity indicators that have statistically significant contributions to the livelihood resilience of rural households in the study area (Table 6). It is assumed that households with sufficient income, the ability to cover their households' food requirements from own production, large land ownership, diverse sources of income, experience with many coping strategies, and a low dependency ratio are more resilient to climate variability-induced shocks than their counterparts. The coefficient of food requirement from self-production and livelihood income diversity in this study was 0.008. This discloses that when the household food feeding capacity from own product increases by one month and they add one additional income source, the likelihood of increasing household resilience following shock impacts is 0.8%. Asmamaw et al (2019) also reported that households with a variety of income sources are less susceptible and more likely to recover quickly from climate change-induced shocks than those who rely solely on a single source of income.

Similarly, the coefficient of land size was 0.016, indicating that increasing the productive land size of a household by one hectare increases their resilience capacity by 1.6%. The size of the farmland, according to the discussant, is the most important factor determining a household's resilience to shock impacts. In accordance with this study, households with larger farm sizes are more probable to invest in agricultural land and soil fertility control works, expand sources of income (crop-livestock integration, applying different crops, agro-forestry, etc.), and recover quickly from shock impacts (Asmamaw et al, 2019). However, increasing dependency reduces the livelihood recovery time after shock events by 2.1%, ($P < 0.001$) (Table 6). This implies that the rural community's resilience capacity to quickly recover from climate-induced shock is determined by a lack of labor force.

Access to Basic Services (Road, Save and credit, school and Veterinary): These variables were included under transformative capacity, and it was hypothesized that as the distances to access basic services from their homes increased, the household's livelihood resilience to climate-induced shocks decreased. In this study, the distance to access all weathered roads (-0.006), save and credit (-0.004), school (-0.005), and veterinary (-0.003) increases by one kilometer, while rural households' resilience capacity decreases by 0.6%, 0.4%. 0.5% and 0.3%, respectively (Table 6). Access to basic infrastructure is a key factor in increasing households' resilience to shocks by increasing their access to assets (Alinovi et al., 2010). The majority of FGD participants also reported that they have access to all weathered roads and veterinary service delivery over long distances, and that being unable to use credit may challenge their level of resilience to climate-related impacts. Underdeveloped infrastructure is a major cause of insufficient access to public services, limited market integration, and low returns on investments (Bird et al., 2010).

Table 6: Determinants of livelihood resilience to climatic shocks- Multiple linear regression

Explanatory variables	Regression coefficient & standard errors of each ACZ		
	Woina Dega	*Kolla*	All Households
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Education of HH/ schooling years	0.004***(0.001)	0.002(0.002)	0.004***(.001)
Dependency ratio	-0.015*(0.008)	-0.021**(0.009)	-0.021***(.006)
Drought frequency	-0.003(0.003)	-0.009**(0.004)	-0.005**(.003)
Flood occurrence	-0.010***(0.002)	-0.010***(0.003)	-0.011***(.002)
Occurrence of crop disease	-0.009***(0.003)	-0.022***(0.006)	-0.011*** (.003)
Fertility status of farmland	0.028**(0.012)	0.002(0.008)	0.013**(.007)
Flatness of farmland	0.014**(0.006)	0.006(0.008)	0.010**(.005)
Access to early warning system	0.003(0.010)	0.004(0.009)	0.005(.006)
Monthly income	0.002*(0.001)	0.004***(0.001)	0.003***(.001)
Food covering months from own production	0.008***(0.002)	0.008**(0.004)	0.008***(0.002)
Access to health services	0.006(0.006)	0.007(0.007)	0.005(0.005)
Distance to safe water/km	-0.002(0.003)	-0.003(0.002)	-0.002(.002)
Estimated asset value	0.000***(0.000)	0.000***(0.000)	0.000*** (0.000)
Total land size/hectare	0.038(0.026)	0.008(0.011)	0.016**(0.008)
Livestock ownership / TLU	0.009**(0.004)	0.003(0.004)	0.004(0.003)
Livelihood diversification	0.003(0.005)	0.018***(0.006)	0.008**(0.004)
Number of coping strategies	0.003**(0.001)	0.003**(0.002)	0.003***(0.001)
Distance to all-weather roads/km	-0.013***(0.004)	-0.003(0.002)	-0.006***(0.002)
Distance to savings and credit/km	-0.006***(0.001)	0.162*(0.089)	-0.004***(0.001)
Distance to school/km	-0.001(0.004)	-0.004(0.003)	-0.005**(0.002)
Distance to veterinary services/km	-0.007**(0.003)	-0.167*(0.089)	-0.003**(0.001)
(Constant)	0.367***(0.049)	0.398***(0.057)	.363***(.037)
R Square	*0.907*	*0.877*	*0.891*
F	*85.874*	*39.600*	*126.079*
Df	*21*	*21*	*21*
N	*207*	*139*	*346*

*Notes: ***, ** and * are statistically significant at 99 %, 95 % and 90%*

Source: Own survey data (2022)

Notes: The regression model result has passed the diagnostic assumptions such as multicollinearity, normality and linearity.

3.3. Adaptation strategies of rural farm households to climate shocks

Investing in climate change adaptation and resilience can be a low-cost way of protecting communities, livelihoods, and businesses while also promoting economic development and growth (Dicker et al., 2021). Climate-induced shocks-related adaptations should be used to reduce the negative effects of climate extremes and strengthen livelihood resilience. The adaptation practices of rural farm households are based on their understanding and perception of climate-induced impacts. Rural farming communities are exposed and vulnerable to a variety of weather and climatic perils, and farm households' susceptibility is determined by their ability to adapt to the corresponding risks (Khan et al., 2020). Table 7 depicts participants' perceptions of climate variability and the occurrence of climate extreme events. Almost all rural households reported increasing temperatures and decreased rainfall over the last ten years (Table 7). Respondents also reported that climate extreme events such as drought, flood, crop pest, and livestock diseases occurred averagely of 6, 2.4, 5, and 3.7 times in the previous ten years, respectively. Those living in rural and remote areas are the most vulnerable to changing climate and adverse weather (Abid et al., 2016; Ali & Erenstein, 2017). Weather extremes can have a significant impact on agricultural productivity (Khan et al., 2020).

Table 7: Household perceptions and climate variability-induced shocks (2012-2022)

Household head perceptions			**Frequency of shock events affected the products**				
	N0	%		Max.	Min	Mean	SD
Increase in Temperature	343	99.1	Drought	9	3	6.09	0.987
			Flood	7	0	2.4	1.823
Decrease in Rainfall	345	99.7	Crop pest	8	2	4.96	1.053
			Livestock Disease	7	1	3.67	1.286

Source: Own survey data (2022)

Following an exploration of farm household perceptions of climate change and its associated risks, households were asked to indicate which climate-induced shocks adaptation measures they use to ameliorate climatic hurdles. As illustrated in Fig. 3, households used a variety of adaptation strategies to deal with climate variability. Farmers commonly used various adaptation strategies to reduce the negative effects of climate variability-induced shocks, including adjusting the planting date (93.6%), planting early maturing crops (92.2%), intercropping (86.4%), farming drought tolerant crops (79.8%), waiting aid/support from various sources (55.2%), crop diversification (46.8%), livestock diversification (40.5%), and crop rotation (34.7%).

Composting (26%), mulching (24.9%), using new crop varieties (16.5%), planting marketable fruits and trees (13.9%), water harvesting (13.6%), and keeping improved animal breeding (11%) are all underutilized adaptation strategies to alleviate climate-related impacts. However, various studies show that the previously mentioned poorly implemented adaptation strategies are critical to reducing climate-induced shocks in different parts of the world (Fantahun et al., 2021; Khan et al., 2020; Masud et al., 2017; Bahinipati, 2015).

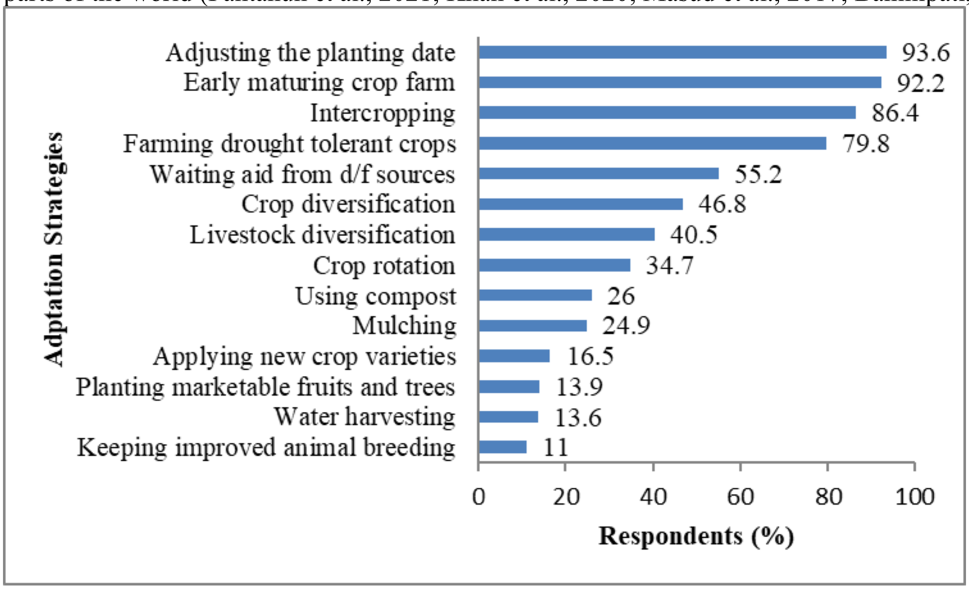

Figure 3: Figure 3: Common adaptation strategies adopted by the respondents

Source: Own survey data (2022)

The binary logit model was used to identify the factors that have a significant influence on the choice of adaptation strategy in minimizing the negative climatic impacts on crop and livestock productivity. Six different binary logistic models were developed to analyze the influence of farmers' socioeconomic and farm-related attributes on the adoption of the least adopted yet most effective adaptation strategies, namely, improved animal breeding, water harvesting, planting marketable fruits and trees, applying new crop varieties, mulching, and compost application (Table 8). The results are interpreted using the Odd Ratio (Exp (B)) along with the significance level (related p-value). A value of odds ratio less than one indicates that for every unit increase in the predictor variable, the likelihood of strategy adoption decreases. In contrast, an odds ratio greater than one indicates that for every unit increase in the predictor variable, the likelihood of strategy adoption increases.

The binary logit model results show that male-headed households are less likely than female-headed households to adopt water harvesting ($p < 0.05$), mulching ($p < 0.05$), and composting ($p < 0.1$) as an adaptation strategy to climate-related shocks. The odds ratios also show that a female household head increases the likelihood of using water harvesting, mulching, and composting by a factor of 0.42, 0.38, and 0.46, respectively, compared to a male-headed household. The implementations of adaptation strategies to climate extreme impacts are also determined by age. The odd ratio (Exp (B)) of age indicates that increasing the age of the household head by one year reduces the probability of adopting new crop varieties by a factor of 0.95. This implies that older household heads are less likely than younger ones to adopt climate-smart crop varieties. The result is consistent with the findings of (Fantahun et al., 2021; Abid et al., 2015), who found a significant negative effect of farmers' age on their capacity to change crop varieties, possibly because old age farmers are fearful of risk and do not adopt new seeds, which could be risky in terms of not yielding anticipated earnings (Khan et al., 2020).

Education is thought to be a key factor in gaining advanced knowledge about new improved agricultural technologies and increasing agricultural productivity (Elahi et al., 2015). Adaptation strategies to climate extremes are also influenced by literacy level (Khan et al., 2020). The findings show that the level of education of household heads increases, as does the likelihood of using water harvesting, new crop varieties, mulching, and composting as adaptation strategies to a negative climate impacts (Table 8). In terms of agro-climate zone, *Woina Dega* households are less likely than *Kolla* households to harvest water and plant marketable fruits and trees. This could be because the *Kolla* ACZ has a relatively large land area and is more vulnerable to water scarcity. However, *Woina Dega* households are more likely to use mulching ($p < 0.01$) and composting ($p < 0.05$) as climate adaptation strategies than *Kolla* households. Furthermore, the positive and statistically significant annual income values indicate that a farm household with a high level of income is more likely to keep improving the animal breeding, plant marketable fruits and trees, mulch, and compost.

Table 8: The binary logit model's maximum likelihood estimates

Explanatory Variables	Dependent Variables					
	Keeping improved breeds (Model 1) Exp(B)	Water harvest (Model 2) Exp(B)	Planting fruits & trees (Model 3) Exp(B)	Using new crop varieties (Model 4) Exp(B)	Mulching (Model 5) Exp(B)	Using compost (Model 6) Exp(B)
Sex(male)	0.80	0.42**	2.34	2.07	0.38**	0.46*
Age	1.04	1.02	1.01	0.95**	1.02	1.01
Education	0.93	1.16**	0.96	1.97**	1.18**	1.16**
Household size	0.83	1.34**	1.10	1.16	0.87	0.87
ACZ(W/Dega)	2.26	0.29**	0.25**	1.65	7.70***	4.29**
Income	1.04***	1.00	1.03***	1.00	1.05***	1.01***
Land size	0.75	0.87	4.89***	1.47	0.42	0.55
Agricultural extension(yes)	3.92**	0.81	1.99	2.17**	2.31**	2.52**
Early warning system (yes)	7.72***	0.43	5.37***	1.77	1.38	0.98
Training(yes)	2.06	3.85**	3.98**	1.55	11.01***	7.30**
Credit(yes)	4.72**	1.03	4.81***	3.40**	1.71	2.58
Constant	0.00***	0.008***	0.001***	0.15	0.00***	0.001***
Negelkerke R^2	0.507	0.123	0.428	0.185	0.598	0.568
Hasmer & Lemeshow Test	0.361	0.216	0.580	0.949	0.583	0.360
Model prediction success	93.4	86.4	91.0	85.8	88.2	87.9
N	346	346	346	346	346	346

*Notes: ***, ** and * are statistically significant at 99 %, 95 % and 90%*
Source: Own survey data (2022)

Agricultural extension services are a continuous endeavor that can be described as a systematic tool for disseminating useful and practical agricultural information, such as upgraded farm inputs, farming techniques, and skills, to farmers with the aim of enhancing farm production and income (Syngenta, 2014) cited in Abid, 2015. Table 8 shows that providing extension services is significantly and positively related to maintaining improved animal breeding, changing crop varieties, mulching, and composting. The odds ratios also show that a household head who used agricultural extension services has a higher likelihood of adopting improved animal breeding, new crop varieties, mulching, and composting by a factor of 3.92, 2.17, 2.31, and 2.52, respectively, than those who did not use agricultural extension services. The greater likelihood of the outputs of having access to extension service demonstrates that farmers obtain advice about their agricultural productions; thus, they cultivate the methods recommended by the advisors (Fantahun et al., 2021). Similarly, households who accessed early warning system to climate shocks were 7.72 and 5.37 times more likely to adopt improved animal breeding and planting fruits and marketable trees respectively compared to their counterparts.

Credit availability and utilization improve rural households' ability to adapt to climate change through the use of smart seed varieties (Fantahun et al., 2021). The findings of this study also show that households who used credit services were 4.72, 4.81, and 3.40 times more likely to adopt improved livestock breeding, planting marketable fruits and trees, and growing new crops respectively than those who did not use credit services. Similarly, results show that farm households with access to trainings were 3.85, 3.98, 11.01, and 7.30 times more likely to collect rain water, grow fruits and trees, mulch, and use compost, respectively, than those without access to agriculture-related training.

4. Conclusions and Policy Suggestions

The study used an indicator-based livelihood resilience index (LRI) and multiple regression analysis to identify the determinants of livelihood resilience, as well as a binary logit model to determine the main factors that influence the choice of adaptation strategies. The overall rural livelihood resilience capacity level was 0.356, with a slight variation across two ACZs. Despite the small total livelihood score, absorptive capacity was found to be the most important factor of livelihood resilience to climate-induced shock, with a mean index value of 0.396, followed by adaptive capacity (0.351). The *Woina Dega* was found to be relatively more resilient to climatic shocks than *Kolla* households, with a mean index value of 0.381 in terms of ACZ. Yet, the combined livelihood resilience score of both ACZs is only 0.356 (35.6%), which is far below the 50% threshold.

The LRI results show that low soil fertility, lack of continuous SWC, and lack of shock event forecasting (absorptive capacity), small farm size, lack of irrigation, and low use of improved seeds (adaptive capacity), and lack of electrification, limited non-food assistance, and lack of disaster response program (transformative capacity) indicators all contributed significantly to the low livelihood resilience score. Multiple regression analysis revealed that household head literacy, dependency ratio, food security, income, livelihood diversification, farm size, soil fertility, occurrence of climate-induced shocks, accessibility of social services, and infrastructure development are significant drivers of livelihood resilience.

Households were taking a variety of adaptation actions in the face of climate extreme risks in agricultural production. Among several adaptation strategies, adjusting the planting date, farming early maturing crops, intercropping, growing drought tolerant crops, waiting aid, and crop diversification appeared to be the most widely used. Whereas, keeping improved livestock breeding, water harvesting, planning marketable fruits and trees, the use of new crop varieties, mulching and using compost was reported to be the least adopted measures. Logistic analysis revealed that the literacy level of the household head, income, land size, extension services, early warning system, agriculture-related training, and access to and utilization of credit are significant drivers of important adaptation strategies.

The findings conclude that the livelihood resilience capacity of farm households affected by climate-induced shocks in collaboration with socioeconomic and institutional factors. We found strong evidence that farm households' adaptation to climate risk is largely associated with their access to important institution-led services such as agriculture extension service, early warning system, agriculture-related training and access and utilization of credit service. Based on these findings, we recommend that relevant stakeholders, policymakers, and institutions enhance the access of farmers to these vital services in order to improve their adaptation and thus livelihood resilience to climate hazards.

Authors' Contribution

The first author prepared the material, collected and analyzed data, and wrote the first draft. The other two authors reviewed, edited, and approved the manuscript before it was submitted for journal publication.

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Availability of data and materials
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