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Assessing livelihood resilience in drought-affected areas: Lessons from Raya Kobo district, northeast Ethiopia

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ABSTRACT

In comparison to other types of resilience, livelihood resilience in the context of climate-related extremes like droughts is grounded in actual-life scenarios with the purpose of carefully assessing and improving the resiliency of individuals, households, communities, and nations. This study assesses households' livelihood resilience to droughts in Raya Kobo District. A mixed approach with a concurrent research design was used to achieve this goal. The quantitative data were collected from 354 randomly selected survey respondents, while the qualitative data were collected from purposefully chosen FGD and KI participants. Principal Component Analysis (PCA) and Multiple Linear Regression (MLR) models were employed to analyse the quantitative data, whereas thematic data analysis was used to analyse the qualitative data through the creation of major and sub-themes. To determine households' livelihood resilience, the livelihood resilience index (LRI) was measured using thirty-eight indicators of resilience based on the five livelihood assets. The study identified fifteen latent dimensions, such as infrastructure, technology, water harvesting scheme, land quality, cropping season, household working capacity, farm experience, educational status, social trust, risk response, social security, support service, income, crop diversity, and assets. The average score of these latent dimensions is 0.3999, suggesting that households in the study area are less resilient. The MLR results show a positive association between the latent dimensions and LRI and the relative importance of the latent dimensions for LRI. These findings provide significant policy implications regarding mitigating vulnerability, strengthening resilience, and establishing pathways out of livelihood insecurity. Education, healthcare, road construction, agricultural inputs (pesticides, herbicides, chemical fertilizers, and improved seeds), irrigation technologies (small-scale drip irrigation systems and human-powered pedals), income diversification, social trust, risk response, social security, support services, and asset building should be the focus of policymakers.

1. Introduction

There is no single definition of resilience because it has multiple dimensions; however, actors who are concerned about challenges to development, whether they are financial, political, conflict-related, or climate-related, share a common objective [1–4]. Resilience is the ability of a system to handle change by preserving or transforming the standard of living when faced with shocks or stresses

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without jeopardizing present or future well-being [5]. Resilience is more than just the ability of a system to bounce back to its pre-disaster state; it is also the ability to adapt to dynamic conditions and put in place systemic responses to the underlying causes of vulnerability [5,6].

The important point is that resilience [7] is a system's capacity to anticipate, absorb, accommodate, or recover quickly from the effects of a hazardous event. Resilience's contemporary prominence is largely due to growing concerns about the inadequacy of periodic humanitarian responses to address underlying vulnerabilities as well as the need to shift thinking to achieve lasting impact [8]. Developing resilience to climate-related extremes is currently a key objective of risk mitigation initiatives throughout the world since resilience guarantees that communities build capabilities to avert or reduce disaster losses [1,4]. It is worth noting that resilience develops through tackling hazards over a period of time at the individual, household, and societal levels in a manner that reduces costs, develops capacity to handle and preserve development momentum, and optimizes long-term potential [9].

Recently, resilience and livelihood resilience in particular have gained popularity in the development and humanitarian sectors that work to strengthen households' resistance to the consequences of hazards associated with climate change or other shocks [4,9–11]. Livelihood resilience [11] is the capacity of all people, across generations, to preserve and enhance their livelihood opportunities and well-being against environmental, economic, social, and political upheavals. In comparison to other types of resilience, livelihood resilience in the context of climate-related disasters like droughts is grounded in actual-life scenarios with the purpose of carefully assessing and improving the resiliency of individuals, households, communities, and nations [11].

Drought [11] adversely affects human development or destabilizes the livelihood systems of the poorest and most vulnerable people worldwide. Drought influences environmental assets, biodiversity, socioeconomic development, agricultural production, and people and their livelihood systems [12,13]. It directly affects agriculture through declining crop yields, and livestock production thereby increasing food insecurity and challenging farmers' livelihoods [14]. Drought destroys agriculture, depopulates villages, and drastically reduces rural household livability [15]. It may even widen social inequalities, spark social conflict, and potentially trigger human migration [16,17]. Meteorological, hydrological, agricultural, and socioeconomic droughts [12,14,18] collectively have devastating effects on people's livelihoods, their adaptation strategies, and regional development in rain-fed agricultural systems.

The food security and livelihoods of small-scale farmers [19] are severely threatened by drought because only a few people can cope with climate change-related risks, and this level of coping ability is far lower in developing countries. In Ethiopia, and more specifically in the research context, droughts threatened environmental resources, food production systems, and various income sources and severely eroded household livelihood resilience [20,21]. Assessing the livelihood resilience of drought-affected populations is an essential step for advancing development, and many stakeholders in the field take it for granted that it can potentially shape policy interventions to reduce the vulnerability of those marginalized populations [6]. Therefore, building up households' resistance to the effects of climate-induced droughts requires a focus on resilience thinking, particularly livelihood resilience [9].

There are a few studies on livelihood resilience issues in Ethiopia. Niemistö [22], for example, researched the resilience of rural livelihoods in Hararghe, showing that resilience and sustainability were low and fragile because of a lack of water and financial support. Eneyew and Bekele [23] examined the determinants of livelihood strategies in Wolaita and identified that education, credit, land size, livestock, dependency ratio, extension contact, farm inputs, and remittances determined livelihoods. Additionally, Vaitla et al. [24] investigated resilience and livelihood change in Tigray. They identified household food access, coping behaviour, dietary diversity, and illness score as determinants. Birhanu et al. [25] qualitatively explored drought-related resilience dimensions and adaptive strategies in Borana employing a context-specific and data-driven resilience framework and concluded that communities' resilience capacities were eroded because of a low level of adaptive capacities.

Mekuyie et al. [26] researched the resilience of pastoralists to climate change and variability in the Afar Region. They found that livestock assets, social safety nets, markets, credit, education, irrigation, and farm inputs enhance resilience. Besides, Adamseged et al. [27] investigated the dynamics of rural livelihoods and rainfall variability in Ethiopia's Northern Highlands. The results show that rainfall conditions during the main rainy season negatively affect non-farm livelihoods. Asmamaw et al. [28] also explored households' resilience to climate change-induced shocks in the Dinki watershed. They found that due to exposure to recurrent shocks and limited adaptive capacities, the study communities showed minimal resilience. Wassie et al. [29] studied agricultural livelihood resilience in northeast Ethiopia in the face of recurring droughts and discovered that absorptive capacity was a better predictor of livelihood resilience, but adaptive and transformative capacities were low.

These previous studies yielded invaluable insights into people's livelihoods, with an emphasis on rural settings. Nevertheless, the studies, such as those conducted by Niemistö [22], Eneyew and Bekele [23], Vaitla et al. [24], Birhanu et al. [25], and Adamseged et al. [27], have knowledge gaps. Household livelihood resilience indices were not constructed by identifying indicators of resilience based on capital assets (human, natural, financial, social, and physical). These studies neither measured the average score nor identified the latent dimensions of livelihood resilience. It is therefore difficult to better understand rural households' livelihood resilience to climate-related risks. However, to measure livelihood resilience, many researchers employ surrogates or indicators of resilience based on the sustainable livelihoods research framework, which includes five types of capital assets and/or a range of observable socio-economic variables [3,10,30]. Furthermore, neither of the previously published scholarly works adequately addressed the livelihood resilience of households in other drought-affected regions of Ethiopia, including the current study location and the livelihoods of vulnerable rural households. However, due to variations in local livelihood assets, and adaptation strategies, there are differences [29,31] in livelihood resilience under drought conditions in various locations. This attests that livelihood resilience is context-specific.

This study aims to fill these gaps by assessing the livelihood resilience of rural households in drought-affected areas in the case of Raya Kobo District, northeast Ethiopia. The specific objectives of this study are: (1) to measure indicators of livelihood resilience and determine households livelihood resilience to drought; and (2) to identify factors that determine livelihood resilience under drought conditions. The measurement of livelihood resilience was based on objective (human, natural, financial, social, and physical assets) indicators of resilience, which considered local conditions and resource availability and accessibility. This helps better understand [11] how rural households are resilient or vulnerable to drought, which paves the way for policy intervention to improve the standard of living of the poor, spur rural development, and establish pathways out of vulnerability. It is a context-specific study. Raya Kobo district was chosen for this particular study because it is unique among other districts in Ethiopia for the following reasons:

(1) Around 54.9 % of the study areas' agro-ecology [32] is Kolla (lowland), which is characterized by erratic rainfall and a hot climate and is vulnerable to hot climate-adaptive crop pests (drought-induced natural disasters) such as locust [33]. This has a devastating effect on people's livelihoods and livelihood resilience, most specifically. (2) The study area is vulnerable to drought. For example, droughts in 1981–1983 [34], 1992–1993, 1995, 2006–2008, 2007, and 2010 [35], and 2016 and 2017 [20,21] corroborate this. Thus, the study area is predominantly characterized by sorghum production systems [36] as the main livelihood strategy and is considered the Sorghum Belt region as the crop resists the problem of rain scarcity. Other types of crop production systems are sensitive to climate-related risks due to their dependency on the rain-fed system, and alternative means of livelihood are restricted, which affects livelihood resilience to drought. (3) Despite the fact that the study district has potential irrigation [37], it is a drought-affected region. The former becomes the resilience for the latter, and thus, to mitigate drought and build the livelihood resilience of households, it needs investigation on the topic under discussion. Irrigation accessibility is one of the physical capital indicators of livelihood resilience to drought and must be quantified together with other livelihood assets in order to determine the livelihood resilience index.

The study area also has a broad geographic scope, a diverse population, and a diverse agro-ecology. Thus, it can serve as an example for other areas with approximately similar characteristics and issues. It is possible to draw the conclusion that the research area and the subject under discussion desire both regional and global audiences. A sustainable livelihoods research framework (SLF) guided the study because it integrated vulnerability contexts, resources, resilience methods, and livelihood strategies and outcomes, which are imperative in rural studies **(**Fig. 1**)**. The UK Department for International Development (DFID) developed SLF to better understand how people develop and maintain livelihoods. SLF provides a framework for understanding the assets people draw on, the strategies they devise to make a living, the context in which a livelihood is developed, and the factors that make a livelihood vulnerable [38,39].

2. Materials and methods

2.1. Description of the study area

This study was conducted in Raya Kobo district, northeast Amhara Region (Fig. 2). Its town, Kobo, is about 727.2 km away from Addis Ababa. The Logiya River separates the study district from the Habru and Guba Lafto districts in the south; Gidan in the west; the Tigray Region in the north; and the Afar Region in the east [36]. As indicated in Fig. 2, the study district's agro-ecology [32] is divided into three: Dega, highland (7.9 %), Woina-Dega, mid-highland (37.2 %), and Kolla, lowland (54.9 %). The district is under moisture stress characterized by seasonality, poor distribution, and erratic rainfall. It obtains a maximum of 800 and a minimum of 500 mm of rainfall annually [41]. The temperature varies from a minimum of 12 °C to a maximum of 33 °C annually [42].

Soils in the district are divided into three types based on their colour, water-holding capacity, and fertility status: black, red, and sandy. Black soil is found in the highlands, midlands, and lowlands, while red and sandy soils are found in the wider areas of the lowlands [36]. There are 365,603 people in the district, with 186,788 (51 %) males and 178,815 (49 %) females. 82 % of the population is Ethiopian Orthodox Christian, with 16 % being Muslim and the rest being Protestant. The majority of people in the district speak Amharic as their first language. Mixed farming (crops and livestock farming) is the main income source for the residents. Non-farm activities like firewood and charcoal selling, trade, and migration are also significant income sources [41].

2.2. Research approach and design

To achieve the study's goal, a mixed research approach was used. Data requiring quantification and measurement, such as

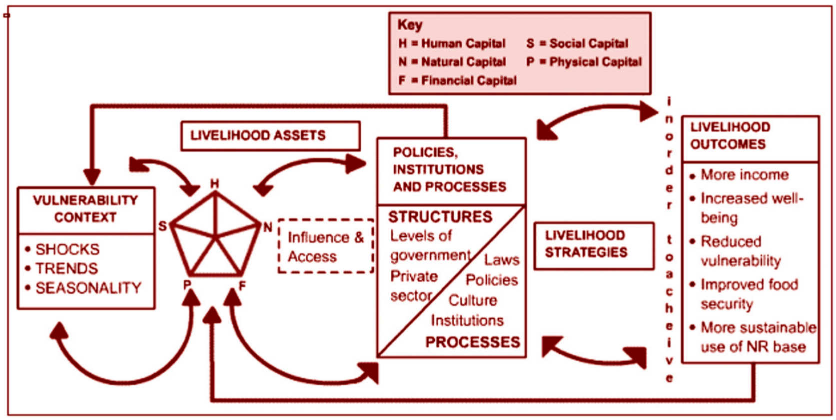

Fig. 1. SLF; source: Knutsson [40].

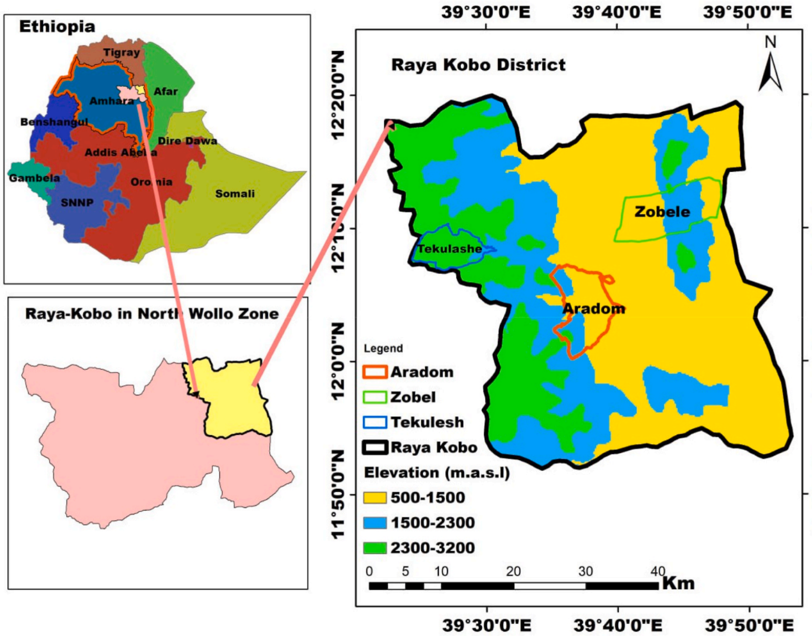

Fig. 2. Study Area Map (source: accessed from https://www.diva-gis.org/gdata).

standardized questions about resilience indicators, were gathered quantitatively. Moreover, interview guideline questions were prepared for data requiring qualitative collection, such as perceptions about drought occurrence, drought severity, coping strategies, and adaptation strategies. A mixed approach [43] facilitates the use of multiple data collection methods, offers strengths to offset the weaknesses of the other type, provides a more accurate picture of reality, and addresses research issues appropriately. Note that there were limitations to the mixed-method approach used, such as potential challenges in data collection and analysis. However, the researchers, who have a broad range of research knowledge and experience in data collection, management, and analysis, managed this. The researchers also have knowledge and experience in mixed-methods research. Additionally, the researchers organized and trained enumerators for data collection and management. The concurrent mixed-methods research design was also employed because it allows for data collection from both quantitative and qualitative sources simultaneously. Firstly, the quantitative data from respondents and the qualitative data from FGD and KI were collected concurrently. Secondly, the two datasets were analysed independently by employing quantitative and qualitative methods of analysis. Thirdly, the two sets of data were integrated to validate the results and obtain a full understanding of the issue under study.

2.3. Sampling and data sources

The study district was chosen purposefully given that it is prone to drought and the livelihoods of the households are increasingly vulnerable. According to the researchers' prior knowledge, households in the study area have low levels of capital accumulation and income diversification, degraded environmental resources, lack of irrigation infrastructure, poor public infrastructure, and inadequate agricultural inputs. These factors significantly influence their livelihoods' resilience to drought risks. Stratified sampling was employed to divide the study area into Kolla, Woina-Dega, and Dega, with elevations of 500–1500, 1500–2300, and greater than 2300 m above sea level, respectively. This is because households in similar agro-ecological regions possess similar local opportunities to ensure their livelihoods. It is also expected that households in similar agro-ecological settings integrate and use local norms and rules to manage resources in a sustainable and equitable manner to withstand climate change-related risks. Three kebele administrations (small administrative units in Ethiopia), i.e., one from each agro-ecology, were chosen by a stratified random sampling method. Tekulesh from Dega, Zobel from Woina-Dega, and Aradom from Kolla (Table 1) were chosen.

Table 1
Summary of sample kebele administrations by agro-ecologies.

Rural Kebele Administrations	Agro-ecology	Total households	Sample Households	Questionnaires Not Returned For Analysis
Tekulesh	*Dega*	2139	120	2
Zobel	Woina-Dega	2162	121	3
Aradom	Kolla	2172	122	4
	Total	6473	363	9

Source: Survey data (2022)

The reason why only one kebele was selected from each stratum is that a single kebele in Dega agro-ecology, for example, can represent other kebele in the same agro-ecology because it possesses essentially similar population diversity, geographic coverage, climatic conditions, resources, livelihood strategies, vulnerability types, and methods of adaptation. Kebeles in the Woina-Dega and Kolla agro-ecologies share the same characteristics. Additionally, sample household heads were chosen using a proportional stratified random sampling technique. Different household members [44] have different perceptions of resilience and the effects of climate change. This is true, but in the current study, only household heads were selected because, in Ethiopia, household heads are the main decision-makers and more likely to be active in local community meetings. The sample size was determined using Kothari's sample size determination formula [45] because the population is large and a large sample size is required to analyse the proportion. The formula is : $n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2 (N-1) + z^2 \cdot p \cdot q}$, where n represents sample size, z is confidence level, p stands for estimated proportion, q is 1 – p, N is population size, and e stands for allowable error.

After researchers and experts in the field verified the validity of the questionnaires, a pilot study was done with 30 respondents to measure the reliability of the questionnaire on livelihood resilience indicators. After a pilot study was carried out, these questionnaires were distributed to 363 household heads, but only 354 observations were returned for analysis (Table 1). The researchers, enumerators, and supervisors, all of whom speak the local language, participated actively in this section. The enumerators were experts from the fields of agriculture, health, and education. Six enumerators were selected in total, two from each field. Then, for each agro-ecology, two enumerators were assigned. This was done after the researchers got agreement from the heads of the district agriculture, health, and education offices. Finally, the enumerators were instructed by the researchers on how to present each question to the respondents. Besides, three supervisors were involved, one for each agro-ecology. The supervisors were Woldia University lecturers and researchers.

After the researchers verified the truthfulness of the interview guideline questions, FGDs were held with purposefully chosen, knowledgeable, and concerned discussants. There were two FGDs per agro-ecological area, so six FGDs were conducted overall. In each group, eight household heads participated. In order to select FGD participants, information was collected from group interviews (before the formal FGD was held, a group interview with the community was conducted during their meeting to discuss local security issues) and key informants, so active participants in local activities and those who had prior experience with interviews and group discussions were chosen. The discussants were model farmers who received regional recognition. These individuals are also co-ordinators of local organizations and are more actively involved in local initiatives. The discussion was focused on perceptions of drought occurrence, severity, coping strategies, and adaptation strategies. Every morning, for six days, the discussion was held on nearby farmlands. Note-taking and video-recording techniques were employed.

In-depth interviews with purposefully chosen experts were also undertaken to discuss the theme under discussion. The KIs were agricultural, health, emergency, and food security experts from the district. It is believed that these individuals work cooperatively with the community and have somewhat better environmental knowledge, experience with climate variability, agricultural activities, livelihood situations, livelihood outcomes, and livelihood resilience. Thus, three KIs overall, one from each sector, were selected. The interview was held in the afternoon near their working environment for three consecutive days using video recording and note-taking methods. Additionally, office data on landholding size, livestock production, and household size were collected from secondary data sources. There were also research reports and internet sources.

2.4. Data analysis techniques

Both quantitative and qualitative data analysis methods were employed. Principal component analysis (PCA) was employed to reduce dimensionality, identify key components with greater weights, and measure livelihood resilience indices. PCA reduces the observed livelihood resilience indicators into fewer main components and resolves their multicollinearity issues. Multiple linear regression (MLR) models were also employed to identify the effect of the latent dimensions on the livelihood resilience index (LRI). PCA and MLR were run with the help of SPSS version 20, and the results were presented in the form of descriptions, tables, and percentages. Additionally, the qualitative data on perceptions about drought occurrence, drought severity, coping strategies, and adaptation strategies were analysed thematically through the creation of major and sub-themes and the results were presented in the form of narratives and embedded with quantitative data. Finally, the two datasets were triangulated to make the analysis comprehensive, and scholarly works accompanied the discussion of the results.

2.4.1. Livelihood resilience measurement and analysis

It is difficult to measure resilience, and many researchers suggest different methods to do so [10,30,46,47]. Gillespie et al. [46] distinguish three main reasons for the difficulties in developing robust, accurate, and contextually applicable knowledge about resilience measurement: a lack of consensus on its definition, a great disparity in the contexts studied, and the primarily qualitative nature of the studies. However, by using objective approaches and socioeconomic variables (access to basic services, assets, adaptive capacity, social safety nets, and sensitivity to shock), for example, FAO measures resilience [48]. Using objective indicators of resilience based on the sustainable livelihoods research framework, Quandt [44]also studied variability in perceptions of household livelihood resilience and drought. Besides, Quandt and Paderes [9] used an objective approach to measure livelihood resilience. Similarly, objective measurement using quantifiable indicators of livelihood resilience, such as capital assets, is imperative [10,30].

The inclusion of objective indicators is advantageous because it can produce resilience composite scores by employing standardized indicators of resilience, which enable compression across households [49]. It enables a quick study of resilience and facilitates comparisons between households, communities, and nations [9]. Based on these premises, this study's resilience measurement relies on objective indicators of resilience grounded in SLF's livelihood assets: financial, human, social, physical, and natural capital. The integration of assets enables the development of a livelihood strategy since, in SLF; the methods for sustaining livelihoods are dependent on people's access to assets [47]. Thus, financial capital [50,51] refers to the financial resources available to households, such as annual income generated from on-farm, off-farm, and non-farm activities and savings. Financial assistance; supplies of credit; remittances; a salaried job; and access to a bank account are financial indicators [44,47]. Liquid assets like land, livestock, and jewellery are also included under financial assets [51].

The other is human capital, which includes investments in education, health, and the nutrition of individuals. Labour is a critical asset linked to investments in human capital. Health status determines people's capacity to work, and experience, knowledge, skills,

Table 2
Summary of indicators of livelihood resilience.

Major indicators	Sub-indicators	Quantitative indicators (measurement)	Hypothetical relationship between indicators & resilience
Financial capital	• On-farm income	Annual income from crops (ETB)	Livelihoods are more resistant to drought when there is a range of income sources, access to credit services, savings accounts, livestock holdings, diverse livestock production, and crop diversification.
	• Non-farm income	Annual income from petty trade, remittance and property income (ETB)	
	• Credit service	Yes or no (%)	
	• Saving accounts	Yes or no (%)	
	• Livestock holding	TLU (Tropical Livestock Unit)	
	• Number of crops grown	Number (types of crop harvest in 2022)	
Human capital	• The HH education level	Attained educational status in years	Education level, HH ages, HH general health status, the number of family members (15–64 years old), households capable of engaging in agricultural activities, and access to training regarding technologies related to agriculture, agricultural inputs, and newly introduced agricultural crops increase livelihood resilience to droughts.
	• HH age	Number of years of birth of the HH	
	• HH general health	HH perception: a scale of extremely poor to extremely good	
	• Family size	The number of household members	
	• Household who are capable to participate in agricultural activities	Number	
	• Access to training	Yes or no (%)	
Social capital	• Strength of HH social capital	HH perception: ranges from extremely weak to extremely powerful	These social capital assets optimize livelihood resilience in drought-stricken areas.
	• Household stability	HH perception: a scale of strongly disagree to strongly agree	
	• Climate information, early warning system, and preparedness	Yes or no (%)	
	• Access to government subsidies	Yes or no (%)	
	• Disaster relief assistance	Yes or no (%)	
	• Crop insurance	Yes or no (%)	
	• Extension contact	Yes or no (%)	
	• Female representation in local organizations	Yes or no (%)	
	• Believing in the expertise of development agents	Yes or no (%)	
		Yes or no (%)	
Physical capital	• Access to irrigation	Yes or no (%)	Access to irrigation, agricultural inputs, improved water, a water harvesting system, and nearby roads, marketplaces, health centers, schools, extension service offices, and veterinary service centers increase resilience.
	• Access to agricultural inputs	Yes or no (%)	
	• Distance to the main road	Walking times in hours	
	• Distance to nearby market	Walking times in hours	
	• Distance to health centre	Walking times in hours	
	• Distance to school	Walking times in hours	
	• Distance to extension service office	Walking times in hours	
	• Distance to veterinary service centre	Walking times in hours	
	• Access to improved water	Yes or no (%)	
	• Build water-harvesting scheme	Yes or no (%)	
	• Agricultural technology utilization	Yes or no (%)	
Natural capital	• Own crop land	Yes or no (%)	Own cropland, crop farm size, grazing land, irrigable land, perceived soil fertility conditions of farm plots, and cropping season all increase livelihood resilience in drought-prone areas.
	• Crop farm size	Total farm size in Timad	
	• Grazing land	Yes or no (%)	
	• Irrigable land	Yes or no (%)	
	• Perceived soil fertility conditions of farm plot	Fertile or poor	
	• Cropping season	Yes or no (%)	

and education determine the returns from their labour [44,52]. Additionally, social capital [51] is an intangible asset that is defined as the rules, norms, obligations, reciprocity, and trust embedded in social relations and societies' institutional arrangements that enable their members to achieve their individual and community objectives. Social capital is embedded in social institutions at the micro-institutional level, in communities and households, and in the rules and regulations governing formalized institutions in the market place, the political system, and civil society. Social capital [44] includes proximity to relatives, political influence, group engagement, and the strength of the neighbourhood, which are resilient indicators. Resilience to drought necessitates components of social capital, including social awareness, group membership, social trust, and social participation [50].

Physical capital is also of paramount importance for measuring households' livelihood resilience in this study. According to Scoones [51], Dani and Moser [52], and Sati [39], it refers to the stock of plants, production equipment, agricultural inputs, affordable public infrastructure, technology, secure shelter, adequate water supply and sanitation, clean and affordable energy, and access to information owned by communities. Physical assets [47], like infrastructure, irrigated land, and farming devices, are resilience indicators. Finally, natural capital is one of the factors used to measure livelihood resilience under drought conditions. The stocks of assets provided by the environment, such as soil, atmosphere, forests, minerals, water, wetlands, aesthetics, and biodiversity, are all referred to as natural capital [39,51,52]. In rural regions, land is a critical productive physical asset for the poor; in urban areas, land for shelter is also a critical productive asset [52]. Examples of indicators of resilience under physical assets include farm size, farmland ownership, and crop diversity [47].

It is useful to obtain data on such indicators of resilience, but some of those indicators are redundant. Some of them are correlated with one another; perhaps they are going to measure the same construct. It is worthwhile to reduce the observed variables into a smaller number of principal components that account for the majority of the observed variables' variance. The multicollinearity phenomenon usually occurs when attempting to analyse [53] a large set of p variables that are typically closely correlated. It is therefore imperative to use PCA for dimensionality reduction. PCA helps create new uncorrelated variables that successively maximize variance. Finding such new variables, the principal components, reduces an eigenvalue or eigenvector problem, and the new variables are defined by the dataset at hand, not a priori. The objective is to explain the variance of the observed data through a few linear combinations of the original data [54]. In this study, assumptions in PCA were considered, such as sufficient cases, interval-level measurement, random sampling, no outliers, linearity, normality, and underlying dimensions. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy [55] was also used to test the null hypothesis that the individual resilience indicators in a correlation matrix are uncorrelated.

Concisely, for this study, 38 indicators of resilience were identified to measure livelihood resilience through a literature review of livelihood assets. The selected indicators of resilience are metric, dichotomous (dummy-coded nominal), ordinal, and/or Likert scales (Table 2). These resilience indicators are context-dependent, considering the study area's livelihood situation. This does not necessarily mean that the context and feedback for all household heads in the study community were the same. Researchers and development practitioners [56] must abandon the notion of a community as homogeneous and instead just acknowledge internal variability and differences. For example, survey respondents' perceptions of social capital were substantially different within the same community, primarily depending on a household's strong degree of horizontal social integrity and vertical social linkage. Even contextual indicators could differ across geographic communities. The indicators prominently emphasize not only the availability but also the accessibility of resources to households. This is significant because the existence of a resource does not imply that an individual has access to it.

To measure the livelihood resilience index, this study applied the FAO's [21] resilience index measurement and analysis (RIMA) model, which is important to measure households' resilience to food insecurity. With contextualization, the model employed in various studies, for example, Mekuyie et al. [26], Asmamaw et al. [28], and Wassie et al. [29], was used with the purpose of analysing the resilience of households to risks associated with climate change, such as droughts. Thus, after contextualizing this model, LRI was measured. Because each major component is made up of various numbers of subcomponents measured on various scales, the data were standardized using two fundamental methods. Indicators that are hypothesized to have a direct relationship with resilience [28,31], for example, on-farm and non-farm income sources, credit services, saving accounts, livestock holding, level of education, and access to irrigation, were standardized using Eq. (1).

$$SVIa = \frac{Y_x - Y_{min}}{Y_{max} - Y_{min}} \tag{1}$$

Conversely, indicators that are hypothesized to have an indirect relationship with resilience [28,31], for example, distance to school, health center, nearby market, veterinary service center, extension service office, and road, were standardized using Eq. (2).

$$SVIa = \frac{Y_{max} - Y_x}{Y_{max} - Y_{min}} \tag{2}$$

Where *SVIa* is the standardized value for the resilience indicator a, Y_x is the observed (average) value of the resilience indicator, Y_{min} and Y_{max} are defined as the minimum and maximum values of the resilience indicator. It is thus worthwhile to calculate the index of each indicator. This was done by multiplying the indicator's standard value by its factor loading [28,29,31], as shown in Eq. (3).

$$Ia_{index} = SV * FL \tag{3}$$

Where, *Ia* is one of the sub-resilience indicator of the major component of livelihood assets, *SV* is the standard value of the sub-indicator, and *FL* is the factor loading of the sub-indicator. Following all preceding steps, various principal components and their corresponding latent names and indices were developed. That is, the average value of each latent variable was calculated by multiplying each indicators standard values by its factor loading and dividing by the total number. Based on this, the index of each major component of livelihood asset [10,28,29,31] was calculated using Eq. (4).

$$MrC = \frac{\sum LVMrC}{\sum NLV} \tag{4}$$

Where, *MrC* is one of the major components of livelihood assets, *LVMrC* is the latent variable of the major component, *NLV* is the number of resilience indicators in each latent variables of the major component. After calculating the average value of each of the major component, the LRI was constructed from the weighted average values [10,28,29,31] of each major components Eq. (5).

$$LRI = \frac{\sum_{i=1}^{n=5} WMrCiNMrCi}{\sum_{i=1}^{n=5} WNMrCi} \tag{5}$$

Where, *WMrCi* is the weight of major component i, and *NMrCi* is the number of latent variables of the major component. Thus, the livelihood resilience index [10,28,29] is the function of the five major components of livelihood capital assets Eq. (6). Note that *Pc* is physical capital, *Hc* is human capital, *Nc* is natural capital, *Sc* is social capital, and *Fc* is financial capital.

$$LRI_r = f(Fc_r, Hc_r, Sc_r, Pc_r, Nc_r) \tag{6}$$

2.4.2. Issues of reliability and validity

A reliability test (pretesting and piloting) was conducted with 30 respondents to ensure the study's reliability. The reliability test shows that the prepared questions were reliable, with a Cronbach alpha value of 0.8146. The person who designed the study, the report's readership, and experts in the field also checked for validity. The researchers checked the trustworthiness (credibility, transferability, dependability, and confirmability) of the data. Trustworthiness was also measured by the member-checking method. Predominantly, the quantitative findings were triangulated with the qualitative findings and scholarly works.

3. Results and discussion

3.1. Respondents' demographic characteristics

In all studied agro-ecological zones, 61.6 % were male respondents, while 38.4 % were female. Of the respondents, 6.2 % were below the age of 25, 10.7 % were between the ages of 46 and 55, 19.5 % were between 36 and 45, 17.8 % were between 56 and 65, and 7.6 % were older than 65 years. Regarding the respondents level of education, 61.9 % were illiterate; 20.6 % could read and write; 13.8 % were in grades 1–4; and 3.7 % were in grades 5–8. Besides, 3.9 %, 74.6 %, 9.6 %, and 11.9 % of the respondents were single,

Table 3
Respondents' demographic characteristics.

Demographic characteristics	*Dega*		*Woina-Dega N = 118*		*Kolla*		*Total*	
	N = 118				*N = 118*		*N = 354*	
	N	%	N	%	N	%	*N*	*%*
Gender Male	74	62.7	68	57.6	76	64.4	218	61.6
Female	44	37.3	50	42.4	42	35.6	136	38.4
<25	7	5.9	6	5.1	9	7.6	22	6.2
25–35	44	37.3	48	41	43	36.4	135	38.1
Age 36-45	25	21.2	18	15	26	22.1	69	19.5
46–55	11	9.3	13	11	14	11.9	38	10.7
56–65	20	16.9	24	20.3	19	16.1	63	17.8
>65	11	9.3	9	7.6	7	5.9	27	7.6
Illiterate	81	68.6	74	62.7	64	54.2	219	61.9
Education Read and write	21	17.8	25	21.2	27	22.9	73	20.6
Grade 1-4	13	11	15	12.7	21	17.8	49	13.8
Grade 5-8	3	2.5	4	3.4	6	5.1	13	3.7
Grade 9-12	–	–	–	–	–	–	–	–
Marital status Single	4	3.4	4	3.4	6	5.1	14	3.9
Married	96	81.4	86	72.9	82	69.5	264	74.6
Divorced	9	7.6	12	10.2	13	11	34	9.6
Widowed	9	7.6	16	13.5	17	14.4	42	11.9
Family size <3	32	27.1	28	23.7	22	18.6	82	23.2
3–6	35	29.7	39	33.1	43	36.4	117	33
7–10	34	28.8	33	28	38	32.2	105	29.7
>10	17	14.4	18	15.2	15	12.7	50	14.1

Source: Survey data (2022)

married, divorced, and widowed, respectively. Of the respondents, 23.2 % had a total family size of less than 3, 33 % had 3-6, 29.7 % had 7–10, and 14.1 % had more than 10 (Table 3).

3.2. Estimating the indices of latent indicators of livelihood resilience

3.2.1. Physical capital

Eleven indicators of livelihood resilience under physical capital assets were identified to measure LRI. The central premise is that the more households [29] employ these indicators, the greater their resilience to shocks will be. The PCA result shows that the KMO value of these indicators of resilience is 0.891; thereby, there is no multicollinearity problem among them, and the data used are perfectly adequate for the model. Three components are retained, and the first component accounts for the maximum amount of total variance. These principal components explain 63 % of the total variance. The first component holds six sub-indicators (highlighted in gray), the second component holds three sub-indicators, and the third component holds two sub-indicators (Table 4). The corresponding latent names of these sub-indicators are infrastructure, technology, and water harvesting scheme, respectively.

Based on Eq. (4), the latent variable score for natural capital was constructed, which was used as an input variable to measure the overall LRI. Because the latent variables, such as basic infrastructure, agricultural technology, and building a water-harvesting scheme, were used to estimate the LRI [28,29]. Vyas and Kumaranayake [57] and Banda et al. [55] normalized the PCA scores with a mean value of zero and a standard deviation of one and decided that the threshold for identifying households as resilient or not is set at zero. Having this in mind, the score of physical assets in the Dega agro-ecological zone is 0.3968 (Table 9). Due to the limited accessibility of physical resources (infrastructure, agricultural technology utilization, and water harvesting schemes), the resilience score of physical capital in Daga is relatively lower than that of households in Woina-Dega and Kolla. In agreement with the current result, the absence [57] of ownership over any asset or the inability to access infrastructure facilities would result in a poorer resilience score and less favourable socioeconomic growth in rural Ethiopia. Kolla is relatively more resilient than Dega and Woina-Dega in terms of infrastructure, agricultural technology utilization, and water harvesting; however, the overall resilience score of physical assets in all studied agro-ecologies is low (Table 9).

3.2.2. Natural capital

Natural capital assets also play significant roles in measuring LRI in this study. The PCA result shows that the KMO value of these natural capital indicators of resilience is 0.729, which enables further analysis. Based on the Eigenvalue-One criterion, the first two principal components are retained, which entirely explain 59 % of the total variance of the data. The first component captures five sub-resilience indicators, and the second component captures one sub-resilience indicator. These sub-resilience indicators have a strong positive relationship with resilience because they have high component loadings (Table 5). Loadings close to −1 or 1 indicate that a variable has a strong relationship with the principal component, whereas loadings close to zero indicate that the variable has a weak relationship with that principal component [57–60]. The matching latent names of the natural capital sub-indicators of resilience are land quality and cropping season, respectively.

In order to estimate the overall score of LRI, the score of the latent variables of natural capital was created using Eq. (4). It is a fact that latent variables such as land quality and cropping season are essential natural assets to estimate the livelihood resilience index [39,47,52]. As a result, the latent variables score for natural capital is 0.2800 in Dega, 0.5645 in Woina-Dega, and 0.7406 in Kolla (Table 9). In terms of natural capital such as land quality and cropping season, respondents in Dega are relatively less resilient than

Table 4
Communalities, factor loadings, and total variance.

Sub-indicators of LR	Communalities		Factors and their loadings		
	Initial	Extraction	1	2	3
Access to agricultural inputs	1.000	.783	−.253	−.847	−.029
Access to irrigation	1.000	.728	.126	.839	.089
Distance to the main road	1.000	.605	.476	.559	.258
Distance to nearby market	1.000	.565	.711	.230	−.081
Distance to health centre	1.000	.507	.660	.211	.165
Distance to school	1.000	.619	.748	.213	.121
Distance to veterinary service centre	1.000	.617	.727	.292	.067
Build water-harvesting scheme	1.000	.837	−.009	.031	.914
Access to improved water	1.000	.676	.819	.067	.034
Agricultural technology utilization	1.000	.483	.399	.269	.501
Distance to extension service office	1.000	.512	.687	.116	.166
Eigenvalues			4.735	1.186	1.011
% of variance			43.041	10.781	9.191
Cumulative %			43.041	53.822	63.013
KMO Measure of Sampling Adequacy				.891	
Approx. Chi-Square				1375.290	
Bartlett's Test of Sphericity				DF = 55	
				P = .000	

Extraction Method: Principal Component Analysis.

Table 5
Communalities, factor loadings, and total variance.

Sub-indicators of LR	Communalities		Factors and their loadings	
	Initial	Extraction	1	2
Own cropland	1.000	.709	.818	.199
Crop farm size	1.000	.671	.810	.119
Grazing land	1.000	.293	.528	.121
Irrigable land	1.000	.495	.694	−.116
Perceived soil fertility	1.000	.461	.627	−.261
Cropping season	1.000	.903	−.083	.947
Eigenvalues			2.486	1.046
% of variance			41.433	17.440
Cumulative %			41.433	58.873
KMO Measure of Sampling Adequacy				.729
Approx. Chi-Square				430.951
Bartlett's Test of Sphericity				DF = 15
				P = .000

Extraction Method: Principal Component Analysis.

households in Kolla, and Woina-Dega. Kolla is relatively more resilient than Woina-Dega and Dega. For all agro-ecologies combined, the average score of natural capital is 0.5284.

3.2.3. Human capital

As shown in Table 6, six sub-resilience indicators under human capital are presented. The PCA results, that is, the communalities and KMO values, show how good the goodness-of-fit is, that there is no multicollinearity problem among the sub-resilience indicators, and that the data used fit the model. Similar to the outcomes in Table 6, a variable with a positive factor score [57] is highly correlated to its component, whereas a variable with a negative factor score is weakly correlated with that component. In the present scenario, three components account for 59 % of the variation in the original six variables. The first component holds three sub-resilience indicators, whereas the second and third components hold one and two sub-resilience indicators, respectively (Table 6). The equivalent latent names of the sub-resilience indicators are working capacity, farm experience, and educational status, respectively.

Based on Eq. (4), the scores for each of the previously three latent variables were averaged to create the human capital score as well as the overall agro-ecology base livelihood resilience score. For the reason that level of education [10,61], working capacity, and farm experience [52] are significant indicators in determining LRI, The results of the present study demonstrate that the human capital asset score in Dega is 0.3477, whereas in Woina-Dega and Kolla, it is 0.4084 and 0.4930, respectively. It shows that Kolla agro-ecological zone respondents have the relatively highest human capital asset score, and Woina-Dega and Dega have the lowest. Nevertheless, the overall score of human capital assets in all studied geographic locations is low, at 0.4164 (Table 9**)**. It implies that respondents' resilience to drought in terms of human capital is low in all studied agro-ecologies. In line with the present results, over 62 % of households in Salima, Malawi [55] were not resilient and were vulnerable to dry spells. The same authors noted that the working capacity and/or age of the household head, as well as a low level of education, contributed to the low score of resilience and vulnerability.

3.2.4. Social capital

Nine indicators of resilience were included in the analysis to create the score of social capital assets. The indicator test outcomes show a KMO Measure of Sampling Adequacy = 0.719, Bartlett's approximation of chi square value = 46.781, and P = .000. This

Table 6
Communalities, factor loadings, and total variance.

Sub-indicators of LR	Communalities		Factors and their loadings		
	Initial	Extraction	1	2	3
HH level of education	1.000	.505	−.306	.265	.584
HH age	1.000	.807	−.007	.895	−.077
Family size	1.000	.612	−.373	−.041	.687
HH general health	1.000	.477	.648	.219	.096
Capable to work	1.000	.544	.685	.161	.219
Access to training	1.000	.584	.593	−.305	.374
Eigenvalues			1.473	1.040	1.015
% of variance			24.552	17.328	16.923
Cumulative %			24.552	41.880	58.803
KMO Measure of Sampling Adequacy				.576	
Approx. Chi-Square				56.031	
Bartlett's Test of Sphericity				DF = 15	
				P = .000	

Extraction Method: Principal Component Analysis.

indicates that the data variables comply with PCA's requirements and enable the next step of analysis. The PCA analysis extracts four principal components with eigenvalues greater than one, which jointly explain 62.38 % of the total variance. The first and second components hold two sub-indicators each; component three carries three sub-indicators, whereas component four contains two sub-indicators (Table 7). Social trust, risk responses, social security, and support services are the latent names given to these sub-indicators of resilience.

The score of the latent variables under social capital was constructed, which was further used as an input variable to create the overall livelihood resilience index. Integral parts of risk response, such as early warning systems, vulnerability assessments, risk mitigation measures, and disaster relief assistance [62], social support [28], social security [63], social trust, and social participation [50] are significant latent indicators to measure livelihood resilience under drought conditions. As a result, the score of social capital in Dega is 0.2670, whereas it is 0.2933 and 0.3308 in Woina-Dega and Kolla, respectively. The overall score of social capital in all studied agro-ecologies is 0.2970 (Table 9). In general, the figures demonstrate that the scores of social capital are low, predominantly in Dega and Woina-Dega geographic regions. Consistent with the current findings, Chen et al. [61] used social capital to measure LRI, and due to the low levels of government subsidies, social support, social organization participation, social trust, social security, organizational leadership capacity, and security accessibility, the indicators' combined score was 0.237.

3.2.5. *Financial capital*

Financial capital [10] is one of the five types of livelihood capital assets that is used as an input variable to create the overall livelihood capital score. Based on this premise, six indicators of resilience under financial capital were analysed. The PCA result shows that the KMO value of these indicators is 0.550, proving that the variables meet PCA's standards and allow the continuation of the analysis. In this case, three components are retained with eigenvalues greater than one. The components contain 61.57 % of the variation of the six original variables. The highest component loadings, such as on-farm income, non-farm income, and access to credit services, are found in component one, whereas component two carries the number of crops grown. Livestock holdings and savings accounts have the highest component loadings found in component three (Table 8). The latent names of these indicators are income, crop diversity, and assets, respectively.

Based on Eq. (4), the score of financial capital assets was created. It is important to note that assets [10], income sources such as on-farm and non-farm income [29], and crop diversification [31] are significant latent dimensions to create LRI. As a result, the financial capital indices are 0.3074, 0.3746, and 0.3639 in Dega, Woina-Dega, and Kolla, respectively (Table 9). Because of greater remittances from Middle Eastern countries, the data demonstrate that households in Woina-Dega are relatively more resilient than households in Dega, and Kolla agro-ecologies. Nevertheless, the figures show that the score of financial capital asset is low in each studied agro-ecology, which makes it difficult for households to withstand hazards associated with climate change (drought in this case). In summary, all studied agro-ecologies share a low score value of 0.3486 for financial indicators because of low levels of income, crop diversity, and assets. Correspondingly, Chen et al. [61] found that owing to low levels of assets, agriculture-related activities, wage operation type, annual income, income diversification, and remittance, the LRI is below average.

3.2.6. *The overall livelihood resilience index (LRI)*

The overall livelihood capital asset score [10,64] can be constructed based on the average score of each of the five capital assets. The same is true in the present study, where the average score of each of the five types of livelihood capital assets was created, and then the scores of the five types of livelihood capital assets were averaged based on Eq. (5) in order to construct the overall LRI in each agro-ecological zone and/or all studied agro-ecologies. In view of that, the overall LRI scores are 0.3133, 0.4057, and 0.4805 in the Dega, Woina-Dega, and Kolla agro-ecologies, respectively. The findings show that households in Kolla (Aradom) agro-ecology are

Table 7
Communalities, factor loadings, and total variance.

Sub-indicators of LR	Communalities		Factors and their loadings			
	Initial	Extraction	1	2	3	4
Strength of HH social capital	1.000	.509	−.677	−.220	.029	−.034
Household stability	1.000	.538	.286	−.318	−.472	.363
Climate information	1.000	.584	.449	.152	.090	−.593
Access to government subsidies	1.000	.523	.141	−.058	.695	.132
Disaster relief assistance	1.000	.378	.149	.563	−.121	−.155
Crop insurance	1.000	.514	−.138	.696	−.097	−.016
Extension contact	1.000	.642	−.310	.507	.143	.518
Female representation	1.000	.431	.346	−.054	.498	.246
Believe development agents	1.000	.506	.528	.133	−.202	.410
Eigenvalues			1.697	1.555	1.047 1.024	
% of variance			24.413	14.948	11.638 11.381	
Cumulative %			24.413	28.361	39.999 62.380	
KMO Measure of Sampling Adequacy				.719		
Approx. Chi-Square				46.781		
Bartlett's Test of Sphericity				DF = 36		
				P = .000		

Extraction Method: Principal Component Analysis.

Table 8
Communalities, factor loadings, and total variance.

Sub-indicators of LR	Communalities		Factors and their loadings		
	Initial	Extraction	1	2	3
Livestock holding	1.000	.740	.411	−.414	.632
Saving accounts	1.000	.803	.136	.523	.715
On-farm income	1.000	.489	.695	.026	−.069
Non-farm income	1.000	.516	.680	.006	−.229
Access to credit service	1.000	.432	−.588	−.136	.261
Number of crops grown	1.000	.715	−.003	.841	−.087
Eigenvalues			1.479	1.172	1.043
% of variance			24.650	19.533	17.391
Cumulative %			24.650	44.183	61.574
KMO Measure of Sampling Adequacy				.549	
Approx. Chi-Square				71.937	
Bartlett's Test of Sphericity				DF = 15	
				P = .000	

Extraction Method: Principal Component Analysis.

Table 9
Livelihood assets and their indices based on agro-ecology.

Agro-ecologies		Physical Capital	Human Capital	Social Capital	Financial Capital	Natural Capital	LRI
Dega	Mean	.3968	.3477	.2670	.3074	.2800	.3133
	N	118	118	118	118	118	118
	Std. Deviation	.12408	.10671	.12730	.10340	.14322	.05243
Woina-Dega	Mean	.5148	.4084	.2933	.3746	.5645	.4057
	N	118	118	118	118	118	118
	Std. Deviation	.13779	.11793	.14222	.12112	.25910	.06688
Kolla	Mean	.6760	.4930	.3308	.3639	.7406	.4805
	N	118	118	118	118	118	118
	Std. Deviation	.10225	.11611	.16897	.15246	.21699	.06763
Total	Mean	.5292	.4164	.2970	.3486	.5284	.3999
	N	354	354	354	354	354	354
	Std. Deviation	.16733	.12811	.14908	.13031	.28420	.09272

Source: Survey data (2022)

relatively more resilient than households in Dega (Zobel) and Woina-Dega (Tekulesh) agro-ecologies. Households in Dega are also relatively less resilient than households in Woina-Dega agro-ecology (Table 9). The differences in livelihood assets are what resulted in the disparity in livelihood resilience scores among agro-ecologies. In the central highlands of Ethiopia [28], the midland (Woina-Dega) agro-ecology is relatively more resilient, with a score of 0.461; however, the current study demonstrates that Kolla (lowland), which is

Table 10
MLR results on the relative importance of latent dimensions to LRI.

Independent Variables	Unstandardized Coefficients	Standardized Coefficients	T	Sig.	Collinearity Statistics	
	B	Beta			Tolerance	VIF
(Constant)	5.016	–	1.988	.000		
Infrastructure	.186	.220	102.675	.000	.675	1.482
Technology	.043	.077	415.513	.000	.902	1.109
Water harvesting	.054	.056	305.241	.000	.934	1.070
Land quality	.319	.427	179.084	.000	.554	1.804
Cropping season	.074	.121	663.241	.000	.939	1.065
Working capacity	.107	.265	128.830	.000	.741	1.349
Farm experience	.036	.100	554.817	.000	.970	1.031
Educational status	.271	.130	718.661	.000	.959	1.043
Social trust	.063	.229	126.195	.000	.961	1.041
Risk response	.163	.232	126.416	.000	.924	1.082
Social security	.195	.253	139.379	.000	.947	1.056
Support service	.163	.195	106.308	.000	.937	1.068
Income	.307	.192	102.093	.000	.887	1.127
Crop diversity	.036	.068	375.375	.000	.960	1.042
Assets	.276	.212	116.264	.000	.945	1.058

The dependent variable is LRI; R^2 & Adjusted $R^2 = 0.999$; All-latent variables are significant at $p < .000$.

located in northeast Ethiopia, is relatively more resilient. This is due to differences in livelihood capital assets and proves that livelihood resilience is context-specific [29,31].

The overall LRI for all examined agro-ecologies is 0.3999, which is minimal. This is due to a lack of sufficient livelihood capital assets to make a living. Communities in the central highlands of Ethiopia [28] had minimal resilience capacity because of restricted likelihood capital assets, such as poorly developed public infrastructure and subpar livelihood diversification practices, which is in line with the present findings. More than half of North Wollo households [29] lacked resilience because of limited livelihood activities, which is associated with the current findings. Rural households in Iran [19,50] had weak resilience or adaptability to droughts owing to a low level of assets, and in the case of the present study, the low score of each livelihood capital asset supports this.

3.3. MLR analysis of factors that determine livelihood resilience

The MLR model was used to identify the relative importance of latent dimensions to households' LRI. R^2 and Adjusted R^2 coefficients are 0.999, indicating that all the latent dimensions combined explained 99.9 % of the total variations in the model. The assumption of MLR was presupposed. The independent variables are categorical or continuous, whereas the dependent variable is continuous. Outliers, normality, linearity, and multicollinearity were preconceived notions. The results confirm that the multicollinearity assumption has not been violated because the tolerance value (1/VIF) for each independent variable is close to one and much greater than zero. The VIF (variance inflation factor) value, which is significantly less than the cut-off of 10, further supports this (Table 10).

Other variables being constant, a one-unit increase in infrastructure is estimated to increase LRI by 18.6 % under droughts conditions (Table 10). This means that for every additional unit of infrastructure such as school, healthcare, market, veterinary service, extension service, and access to improved water, LRI is expected to increase by a coefficient of 0.186, which is significant at a 1 % level. FGD participants in Dega and Woina-Dega confirmed that such infrastructures are important to enhance livelihood resilience under drought conditions but seriously inadequate. FGDs in Woina-Dega also noted that the inability to cope with the effects of drought and reduce the likelihood of its occurrence is due to a lack of available and accessible resources. The results so far demonstrate that public infrastructures are essential [28,63,65–69] livelihood assets in tackling particular hazards, building rural households livelihood resilience, and ensuring the viability of people; however, they are restricted.

Access to technology (agricultural inputs such as pesticides, herbicides, chemical fertilizers, improved seed, and access to irrigation) and the water-harvesting scheme are also positively associated with LRI (Table 10). This implies that, a one-unit increase in the accessibility of technology and water-harvesting increases LRI by 4.3 % and 5.4 %, and this is statistically significant at $p = .000$ in both cases. In Kolla, a household head FGD participant also reported that fertilizer application, water harvesting, and farming management are major activities to increase resilience. The participants further underlined that households want to access more irrigation technologies and agricultural inputs. In general, the results indicate that agricultural technology and water harvesting [29], access to irrigation [70], improved water, and proper sanitation [65,69,71] are the major latent factors driving resilience.

Besides, every one-unit increase in HH working capacity and educational status increases LRI by 10.7 % and 27.1 %, respectively, with all other factors remaining constant (Table 10). At the 1 % level, this is statistically significant in both cases. In this regard, a study district health expert and KI participant reported regarding the relations among working capacity, educational status, and resilience to drought. That is, the more educated the household members, the more working capacity they develop, and the more they can withstand droughts because they can develop alternative livelihood strategies. The participant further noted that in reality, this is not practiced, and education and training services are inadequate. From the results, it is possible to understand that household working capacity and educational attainment [65,69] play important roles in enhancing livelihood resilience.

In addition, a one-unit increase in social trust, risk response, social security, and support services increases LRI by 6.3 %, 16.3 %, 19.5 %, and 16.3 %, respectively, which is significant at the 1 % level in all cases (Table 10). In this scenario, FGDs in Dega, and Kolla highlighted the fact that drought causes low crop yields and food inaccessibility. It increases insect outbreaks, livestock deaths, grazing resource depletion, school dropout rates, and health effects. The participants further stated that households try to resist drought risks by selling assets and natural resources, engage in a productive safety net program, strengthening social networks, and building social trust. On their parts, FGDs in Dega noted that having good social interaction, social participation, and believing in and helping each other are fundamental to sharing happiness, enduring adversity, and boosting resilience. Agricultural insurance, disaster relief assistance, access to government subsidies, household stability, gender equality and women's participation, and an early warning system are also significant input variables to increase resilience to drought. The findings suggest that social trust [50], risk response [62], social security [63], and support services [69], are helpful to strengthening livelihood resilience.

A one-unit increase in household income results in a 30.7 % increase in LRI, with all other factors remaining constant (Table 10). A study district emergency and food security expert KI participant emphasized that the study area is a resource-limited region. Due to the absence of additional land for farming, grazing, or investment, farm households are unable to intensify agricultural income. In addition, the area is increasingly affected by political unrest, ethnic tensions, and extreme weather events, all of which pose threats to the region's capacity to rely on reliable supplies of food, income, and livelihoods. As per the participant, in order to increase their resilience, households look for solutions and engage in various income sources: off-farm, and non-farm income sources. Overall, income is an important contributor to LRI. In line with the current findings, income [65,67,70,71] is what causes resilience gaps; those with higher incomes can become more resilient, and low income limits households' ability to recover from disasters.

All other variables being constant, a one-unit increase in household assets is predicted to increase LRI by 27.6 % at $p = .000$ (Table 10). Access to assets such as livestock holdings and savings accounts increases livelihood resilience to drought. The district agricultural expert and KI participant noted that drought influences environmental assets, infrastructure, agricultural productivity, socioeconomic development, and households' livelihoods. As per the participant, households with better livelihood capital assets such as education, savings accounts, livestock holdings, farmland, grazing land, irrigation, and irrigable land have a greater capacity to cope with drought risks. However, these assets are scarce almost everywhere in the district, reducing the degree to which households can handle drought risks. Overall, the results show that assets [50,63,69,70,72] are fundamental drivers of rural livelihood resilience, and the larger the assets, the greater the resilience index and the ability to tackle drought risks. The MLR analysis also shows that crop diversity and land quality are essential in enhancing resilience. FGD in Woina-Dega pointed out that increasing the number of crops grown and improving the quality of the land are significant contributing factors in enhancing livelihood resilience. Farm quality, intercropping, and crop diversity [65,69,73] are imperative in building farming system resilience to agro-climatic shocks and stressors, which is consistent with the present findings.

4. Conclusions and implications

Measuring indicators of resilience is essential for determining households' livelihood resilience under drought conditions. Thirty-eight indicators of resilience organized around the five livelihood assets: financial, human, social, physical, and natural, were used in this study to assess households' livelihood resilience to drought. This was accomplished in four steps: (1) identifying livelihood resilience indicators based on livelihood assets; (2) constructing principal components and selecting high component loadings using PCA; (3) giving appropriate latent names for principal components; and (4) constructing agro-ecology-based livelihood resilience indices. Accordingly, fifteen latent variables were identified, namely infrastructure, technology, water harvesting scheme, land quality, cropping season, household working capacity, farm experience, educational status, social trust, risk response, social security, support service, income, crop diversity, and assets. The average score of these latent variables is minimal (0.3999), suggesting that households in the study region are less resilient to drought. The MLR analysis also demonstrated how the latent dimensions affected the livelihood resilience index in particular and provided a solid foundation for understanding household livelihood resilience in the study area in general.

Droughts are neither uncommon nor unexpected in resource-poor regions, and because of that, it is worthwhile that households employ adaptive strategies like savings, asset accumulation, income diversification, social capital building, livelihood diversification, farmland management, water harvesting, and crop diversity. In addition, policymakers should look for strategies to improve households' resilience to drought, such as infrastructure development (education, healthcare, and road construction). Policymakers also focus on the supply of agricultural inputs (pesticides, herbicides, chemical fertilizers, and improved seed) and irrigation technologies (small-scale drip irrigation systems and human-powered pedal or treadle pumps). Rural non-farm enterprise, income diversification, microcredit services, social trust, risk response, social security, support services, and asset building should also be the focus of policymakers. The data used in this study are cross-sectional, collected in August and September 2022, and depict households' livelihood resilience to drought at a point in time. The study provides insights into the real livelihood resilience scenarios and the resilience methods employed during data collection; however, it does not show the households livelihood resilience trends to droughts repeatedly over a period of time. Therefore, we recommended future researchers show household livelihood resilience trends to drought using longitudinal data. Additionally, further research on similar issues in different districts is needed to provide a more comprehensive understanding of livelihood resiliency to droughts because this study focused only on Raya Kobo district.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Sisay Demeke Molla: Conceptualization, Formal analysis, Investigation, Writing - original draft. **Menberu Teshome Zeleke:** Methodology, Writing - review & editing. **Sisay Misganaw Tamiru:** Methodology, Writing - review & editing.

Declaration of competing interest

We declare that we do not have any known competing financial interests or personal relationships that could appear to have influenced the work reported in this study.

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