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**Climate Resilience Index as a tool to explore households’ resilience to climate change-induced shocks in Dinki watershed, central highlands of Ethiopia**

**Households’ resilience to climate change impacts**

Mengistu Asmamaw<sup>\*1, 2#a, #b</sup> Argaw Ambelu<sup>1‡</sup> and Seid Tiku Mereta<sup>1 ‡</sup>

\*corresponding author: Email: [mengistuasmamaw21@gmail.com](mailto:mengistuasmamaw21@gmail.com) (Asmamaw M.)

#a,1 Current address: Department of Environmental Health Science and Technology, Jimma University, Jimma, Ethiopia

#b, 2 Current address: Department of Biology, Debre Berhan University, Debre Berhan, Ethiopia

‡ These authors also contributed equally to this work.

# Abstract

This study assessed households' resilience to climate change-induced shocks in Dinki watershed, northcentral highlands of Ethiopia. The data were collected through cross-sectional survey conducted on 288 households, six focus group discussions and 15 key informant interviews. The Climate Resilience Index (CRI) and the Livelihood Resilience Index (LRI) based on the three-resilience capacities (3Ds) frame, using absorptive, adaptive and transformative, were used to measure households' resilience to climate change-induced shocks on agro-ecological unit of analysis. Findings indicate that the CRI and the resilience capacities based on the indexed scores of major components clearly differentiated the study communities in terms of their agro-ecological zones. Specifically, the LRI score showed that absorptive capacity (0.495) was the leading contributing factor to resilience followed by adaptive (0.449) and transformative (0.387) capacities. Likewise, the midland was relatively more resilient with a mean index value of 0.461. The study showed that access to and use of livelihood resources, such as farmlands and livestock holdings, diversity of income sources, infrastructure and social capital were determinants of households' resilience. In general, it might be due to their exposure to recurrent shocks coupled with limited adaptive capacities including underdeveloped public services, poor livelihood diversification practices, among others, the study communities showed minimal resilience capacity with a mean score of 0.44. Thus, in addition to short-term buffering strategies, intervention priority focusing on both adaptive and transformative capacities, particularly focusing on most vulnerable localities and constrained livelihood strategies, would contribute to ensure long-term resilience in the study communities.

**Keywords:** Climate resilience index, climate change-induced shock, Dinki, Resilience index.

# 1. Introduction

Climate change-induced shocks are the major livelihood threats of humanity, where underdeveloped countries are disproportionately hit by adverse effects (1). The projections by the Intergovernmental Panel on Climate Change (IPCC) shows that the frequency and intensity of climate change-induced shocks, such as heat waves, droughts, floods, etc. are growing all over the world (2). The effects of such extreme weather events would add extra stress on human health, food security and water resources, where the rural poor are extremely susceptible and adversely impacted [3, 2]. The IPCC report emphasized that disaster risk management programs should focus on reducing exposure and vulnerability while enhancing resilience to shock impacts (2).

The concept of resilience stems to the Latin 'resilire' to denote to 'bouncing back' or 'recoiling' (4). The term was primarily applied in mechanics in 1858 to denote the capability of a material to resist a force (rigidity) as well as to absorb the force with deformation; later it was used in psychology in 1950s, in system ecology in 1973 and in social-ecological systems in 1990s (4). The intensification of two huge societal trends-climate change and globalization, which amplify multifaceted and non-directional impacts have caused resilience to be acknowledged in wide range of disciplines globally (5). Aiming to address the overwhelming environmental issues, such as disaster risk reduction, climate change adaptation, vulnerability, social protection, etc.(6), its application has gradually expanded into social-ecological system and defined as the potential of a social-ecological system to sustain basic structures and continue functioning following shock events [7, 8]. Being a multidisciplinary term, it has been applied in diversity of connotations, yet all share common point on 'the ability to respond to changes, particularly unprecedented changes'(5).

75 The capability of a social-ecological system to respond to extreme shock events  
 76 encompasses multiplicity of abilities including “shock absorbing”, “buffering”, “bouncing  
 77 back”, and “transforming” (8). Its application in various disciplines has broadened its  
 78 understanding from its original narrowed engineering resilience- ‘the potential of a system  
 79 to bounce back after disturbance’ into more comprehensive concept- ‘the ability not only to  
 80 bounce back but also to adapt to and even to transform into new system’ (6). Furthermore,  
 81 a socio-ecological resilience is perceived as a process than a static state and should acquire  
 82 and maintain the three-core resilience capacities, namely absorptive, adaptive and  
 83 transformative to sustain long-term resilience [6, 10]. As absorptive, adaptive and  
 84 transformative capacities are considered as the three major structural elements and best to  
 85 capture resilience (6), this study followed the three-capacities (absorptive, adaptive and  
 86 transformative capacities) frame to explore households’ resilience to climate change-  
 87 induced shocks.

88 The three core responses or resilience capacities can be linked depending on shock  
 89 intensity. Accordingly, during minimal shock incidence, it is natural that the system would  
 90 block or resist it (6). Hence internal resistance is known as the natural characteristic of a  
 91 system manifested on daily basis where resources could block the shock enabling the  
 92 system to continue functioning-highly comparable to the human immune system (9).  
 93 Absorptive capacity is especially basis to buffer short-term disturbances as well as during  
 94 the beginning phase of coping of huge shocks (5).

95 The next adaptive resilience involving system adjustment to sustain system functioning will  
 96 be exercised if the shock exceeded the absorptive capacity (10). Adaptive capacity is “the  
 97 ability of a system to adjust itself to sustain system functioning”(11). These adjustment  
 98 practices are incremental as well as learning through failure and success that adds to

99 adaptability (12). This capacity involves “resourcefulness-the potential to identify challenges,  
100 develop priorities, mobilize resources, to integrate experience and knowledge during crises,  
101 to plan for upcoming shock impacts” (5). These multi-level (individuals, households,  
102 community) and incremental adjustment mechanisms for farming communities may include  
103 livelihood diversification, establishing market networks, empowering storage facilities,  
104 developing pooling among communities, introducing of shock resistance varieties, new  
105 farming practices, strengthening social networks, etc. (6).

106 In the case of high intensity and recurrent shocks, it may be difficult to sustain system  
107 functioning through adaptive resilience, involving transformative resilience. It is often  
108 associated to system-level changes in factors like infrastructure (example: road,  
109 communication, credit access, health facilities, etc.), governance, formal safety nets which  
110 substantially strengthen long-term resilience (13). For instance, changing of the agrarian  
111 livelihood into resource extraction economy, ecotourism, change in resource management  
112 practices, etc. Transformative response may require institutional reforms, behavioral  
113 changes and technological innovations (14). Factors like socioeconomic policies, land-use  
114 policies, resource management trends, institutions and technology may limit the  
115 performance of transformative resilience (14).

116 In the face of environmental uncertainty, households’ capacities to effectively respond to the  
117 alarmingly growing shock events needs to be strengthened (5) to enable smallholder  
118 farmers to better withstand the upcoming shock impacts (15). Because resilient households  
119 are more active to anticipate, resist, cope with and recover against shock impacts (16) as  
120 well as to sustain or improve standard of living in the face of environmental changes (17).  
121 The findings of the study would help to prioritize intervention measures for livelihood

resilience by identifying adaptation limits in Dinki watershed, northcentral highlands of Ethiopia.

## 2. Materials and Methods

### 2.1 The Study Area

Dinki watershed is found in Ankober district in central highlands of Ethiopia (Fig. 1). Ankober is located between 9° 22'-9° 45' N latitude and 039° 40'-039° 53' E longitude (Fig. 1). Most of the district area are hills and mountainous (75%), where rugged terrains and plain topography account for 17% and 8%, respectively. More than half of the district (53%) has *woinadega* (equivalent to sub-tropical), climatic condition followed by *kola* (tropical) climate; where *dega* (temperate) and *wurich* (cool) climates constitute 10.5 and 1.5 percent, respectively (18). The Rainfall pattern is bimodal where some short and long-term rainy periods are recorded in March and in late June to September, respectively. A 30 year (1987-2016) of metrological data showed a mean annual rainfall of 1,179 mm; where the mean minimum and maximum monthly temperature was 6.47 and 19.99 °C, respectively.

Figure 1 . Map of the Dinki watershed, central highlands of Ethiopia

### 2.2 Data Collection Techniques

Data were collected through participatory rural appraisal between December 2017 to February 2018 through focus group discussion, key informant interview and household survey viz: highland, midland and lowland agro-climatic zones (AEZs). Prior to data collection, an ethical clearance letter was received from the Institutional Review Board (IRB), institute of Health, Jimma university.

## 143 **2.2.1 Qualitative data collection**

144 Six focus group discussions (FGDs) (two gender-segregated FGDs in each agro-ecology),  
 145 each comprising 8-12 participants were conducted to collect data on livelihood vulnerability  
 146 and resilience to climate change-induced shocks. Some of the questions asked were: What  
 147 socioeconomic and environmental factors do you think determine resilience in this locality?  
 148 Do you think inter-household resilience variability in this locality? What experience are there  
 149 in this locality to prepare for, mitigate with and cope with (absorptive capacities); adjust to  
 150 sustain system functioning (adaptive capacities) and strengthen long-term resilience like  
 151 through system changes in land-use, natural resource management, governance, etc.  
 152 (transformative capacities)?

153 The same interview questions were used to conduct 15 face-to-face interviews involving  
 154 various community members, such as religious leaders, watershed management group  
 155 members, elders, youth, women as well as representatives from school and development  
 156 agents to explore the incidences of climate change-induced shocks and adaptation  
 157 strategies contributing to manage disturbances. A snowball approach was used to  
 158 purposively select participants for interview and information redundancy was used as an  
 159 insurance for information saturation.

## 160 **2.2.2 Quantitative data collection**

161 Based on the feedback and information from qualitative data, a standardized questionnaire  
 162 was developed. In addition to the questions used in the interviews, a sample of questions  
 163 asked in the questionnaire survey were: What do you think the resilience status of this  
 164 locality? Was there any environmental and/or socioeconomic shock during the last 12  
 165 months? Do you think climate change-induced shocks affect your livelihood strategies?

166 What coping strategies do you use to prepare for, mitigate with or prevent the negative  
167 impacts of shocks? What adjustment strategies (example: livelihood diversification, farming  
168 practice, social networking, etc.) do you apply to sustain system functioning even during  
169 crises? Is there any system-level change (example: infrastructure, governance, social  
170 networking, etc.) that supports to strengthen long-term resilience in this locality? A simple  
171 random sampling technique was employed to select 294 respondents from a total of 1,245  
172 households; where prescriptions by Kothari (19) was used to calculate the sample size.

### 173 **2.3 Climate Resilience Index (CRI) calculation**

174 As resilience is a complex concept, its quantification remains debatable. Currently, however,  
175 proxy indicators through composite index frame has been used to measure resilience in  
176 wide range of literature [21, 22]. The climate resilience index (CRI) development followed  
177 the prescription by Tambo (21). Accordingly, a tool developed by FAO (20) to measure food  
178 insecurity was customized to assess households' resilience to climate change-induced  
179 shocks. The tool consists of ten major components and a household with higher in average  
180 values of each component is hypothesized to be resilient to climate change-induced shocks.  
181 Stakeholders consultation (extension workers, development agents, experts and elders) and  
182 review literature [21, 10, 22] were used to select relevant indicator and the details are  
183 presented in Table 1 below.

184 The CRI uses a balanced weighted technique (23) where each sub-component (indicator)  
185 contributes equally to the index. Using a household-level data on these indicators, a Climate  
186 Resilience Index (CRI) was developed on agro-ecological unit of analysis. As each major  
187 component is composed of different number of indicators measured on different scales, the  
188 standardization considered the functional relationship between indicators and resilience



(21). In effect, two methods of standardization were employed. Indicators that are expected to have direct relationship with resilience, such as income and food access, diversity of income sources, coping strategies, etc. were standardized using equation (1) as:

$$Ia = \frac{Sr - Smin}{Smax - Smin} \quad (1)$$

Whereas indicators expected to have inversely related to resilience, such as household food insecurity and access score (HFIAs), illness score, shock events, etc. were standardized using equation (2):

$$Ia = \frac{Smax - Sr}{Smax - Smin} \quad (2)$$

Where Ia is the standardized value for the indicator a, Sr is the observed (average) value of the indicator for agro-ecology r, min and max are the minimum and maximum values of the indicator across all the agro-ecology, respectively. Once each indicator has been standardized, the average value of each major component was computed using equation 3:

$$Mr = \frac{\sum lai}{N} \quad (3)$$

Where Mr is one of the ten major components for agro-ecology r, lai is the indicator indexed by i, that make up each major component, N is the number of indicator in each major component. After values for each of the ten major components for each agro-ecology were calculated, the CRI was obtained from the weighted average of the ten components as:

$$CRIr = \frac{\sum_{p=1}^{10} WMiMr_i}{\sum_{p=1}^{10} WMr_i}$$

$$CRIr = \frac{WndcvNDCVr + WifaiIFAr + WhHr + WwWr + WsbSBr + WsdpSDPr + WlvsLVsr + WasASr + WscSCr + WabsABsr}{Wndcv + Wifa + Wh + Ww + Wsb + Wsdp + Wlvs + Wa + Wsc + Wabs} \quad (4)$$

209 Where CRI<sub>i</sub> is the Climate Resilience Index for each agro-ecological zone, M<sub>i</sub>= the number  
 210 of indicators of the major component, W<sub>Mi</sub>= weight of major component i, NDCV=natural  
 211 disaster and climate variability, IFA= income and food access, H=health, W=water,  
 212 S<sub>b</sub>=stability, SDP=sociodemographic profile, LVS=livelihood strategy, A=assets, SC=social  
 213 capital, ABS=access to basic services.

214 In order to better understand resilience, the Climate Resilience Index (CRI) frame indicators  
 215 were aggregated into the three resilience capacities (3Ds) viz: absorptive, adaptive and  
 216 transformative capacities [6, 10, 5, 25] absorptive capacity is the ability of a socio-ecological  
 217 system to prepare for, mitigate with or prevent negative impacts through coping strategies  
 218 in order to preserve and restore basic structures and functions (24). The index was  
 219 computed based on the perceived ability of households to climate change-induced shocks,  
 220 access to early warning system, preparedness, stability and social capital like sharing of  
 221 resources, technology and membership to community-based organizations (13).

222 Adaptive capacity is the ability of a system to adjust impacts to moderate potential damage,  
 223 to take advantage of opportunity, so that it continues functioning without significant change  
 224 in system structures (3). Examples include, livelihood diversification, introducing drought  
 225 resistant seed varieties (like growing of *Vigna radiate* or mung bean/ *masho*). In effect,  
 226 income and food access, assets, livelihood diversification strategies, etc. were placed under  
 227 adaptive capacity [10, 26]. Transformative capacity is the ability to create an enabling new  
 228 system in times of crises (7). It is often associated to system-level changes in factors like  
 229 infrastructure (example: road, communication, credit access, health facilities, etc.),  
 230 governance, formal safety nets which substantially strengthen long-term resilience. As a  
 231 result, access to basic services, social capital like conflict management mechanisms and

vertical linkages were captured under transformative capacity [10, 26]. Therefore, indicators presented in equation (4) were aggregated into respective resilience capacities to generate the livelihood resilience index (LRI) as follows:

$$LRI_r = \frac{W_{abc}ABCr + W_{adc}ADCr + W_{tc}TCr}{ABCr + ADCr + TCr} \quad (5)$$

Where  $LRI_r$  is the resilience index for the agro-ecology  $r$ ;  $W_{abc}$ ,  $w_{adc}$  and  $w_{tc}$  are the weight of absorptive, adaptive and transformative capacities, respectively;  $ABCr$ ,  $ADCr$  and  $TCr$  are the number of indicators in absorptive, adaptive and transformative capacities in each agro-ecological zone, respectively.

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Table 1. Resilience capacities, major components, sub-components and hypothesized relationships

Resilience capacities	Major component	Indicators	Hypothesized relationship: relatively resilient if:
Absorptive capacity	Natural disaster and climatic variability	Early warning system, preparedness, shock events during the last 12 months	the household has access to early warning system and get prepared to shock impacts
	Stability	Landscape position, soil fertility, SWC and perception to climate change impacts	the majority of households' farm land is gentle slope, good soil quality and most of it under SWC as well as if he has knowledge on climate change impacts
	Social capital	Sharing of resources and technology and membership to community-based organizations	there exist experiences of resources and technology and get involved in community-based organization
Adaptive capacity	Income and food access	Income, food insecurity and dietary diversity	a HH has an annual per capita income comparable to national average, lower HFIAS values in the range of 0-27, eat balanced diet ( $\geq 7x$ carbohydrate, $\geq 3x$ protein, $\geq 3x$ vegetables and fruits in a week)
	Health	Illness score and improved toilet	lower values in the range of 0-24; has access to improved toilet open pit
	Water	Access to improved water, water sufficiency and water conflict	the HH has access to improved drinking water that can be collected within 30 minutes' walk from home (round trip), water sufficiency during the last 12 months, no conflict due to water
	Sociodemographic status Assets	Sex of the household head, dependency and education Asset and livestock holding, ownership to communication device and saving	male-headed households with lower dependency ratio and literate With having large asset and livestock holding, access to saving and communication devices
	Livelihood strategy	Livelihood diversity, social support score, number of coping strategies and technology utilization (irrigation, improved seeds, etc.)	who have multiple income sources, higher social support score, utilize technology and apply varieties of coping strategies

Transformative capacity	Social capital		Conflict management, vertical linkage through involvement in governance	Who participate in elderly institutions, governance sustain peace and security
	Access to basic services		Access to basic public services, such as market, health services, primary school, road, credit and electricity	HH who access public services in $\leq 5$ km or $\leq 1$ hr walking distance from home

## 244 3. Results and Discussion

### 245 3.1 Resilience indicators identified in Dinki watershed socio-ecological system

246 The study households perceive resilience as a state of recovery against climate  
 247 change-induced shocks without significant help from external institutions. The effects of  
 248 climate change-induced shocks and consecutive rate of recovery are not uniform across  
 249 households. In effect, households in Dinki watershed socio-ecological system were  
 250 classified into poor resilient, moderately resilient and resilient based on their recovery time  
 251 to climate change-induced shocks. Such classification was also reported in other parts of  
 252 Ethiopia (25). Key determinants of resilience and major features of each resilience category  
 253 are presented in Table 2 below.

254 Discussant noted that access to and size of farmland to be determinants of household'  
 255 livelihood and resilience to shock impacts. They stressed that land ownership is a priority  
 256 for farming community for long-term decision and soil fertility management options.  
 257 Accordingly, landless households are less likely to work on natural resource management  
 258 practices even may amplify environmental degradation through overexploitation. Whereas,  
 259 households with large farm sizes are more likely to invest on land and soil fertility  
 260 management works, diversify income sources (crop-livestock integration, polyculture,  
 261 agroforestry, etc.) and more likely to bounce back quickly against shock impacts. In  
 262 agreement with this finding, studies state that landlessness and small land holding are  
 263 determinant factors causing land degradation and resilience erosion (25). Besides, a study  
 264 in central Ethiopia discloses that natural resource management practices, which in turn  
 265 determined by farm size, among others, are strategies for rural communities to enhance  
 266 their resilience to shock (26).

267 Livestock holding is argued to signify wealth and dignity in rural Ethiopia. Discussants  
 268 disclosed that livestock ownership is a determining factor for household livelihood and  
 269 sustainability; as households having domestic animals are more likely to enhance and  
 270 diversify income sources. However, the number and diversity of animals critically influence  
 271 their economic returns. Accordingly, Oxen ownership is a priority for every farmer to secure  
 272 his agricultural production. The next priority is reported to have milking cow to sustain  
 273 livestock production and dietary diversity. Depending on the agro-ecology and households'  
 274 choice, having of transportation animals, such as donkey/horse/mule/camel would be the  
 275 next interest. Because, in areas with limited car access, like the study area, humans and  
 276 materials, including agricultural inputs (fertilizer, improved seeds, pesticides), market inputs  
 277 and related commodities are transported through these animals; markedly supporting  
 278 livelihood options, asset accumulation and recovery to shocks. As a result, households with  
 279 more than two TLU (a minimum of 2 Oxen or 1 Ox + 1 cow) are more likely to be resilient to  
 280 climate change-induced shocks. In line with this finding, a study in other parts of Ethiopia  
 281 states that asset holding, including land and livestock unit, is determinant to diversify income  
 282 sources, improves income and critical for the households' resilience to food insecurity (27).

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288 Table 2. Resilience categories and factors influencing households' resilience to climate  
289 change-induced shocks in Dinki watershed socio-ecological system.

factors	Resilience category		
	Poor resilience or likely highly vulnerable	Moderate resilience	Highly resilience or likely less vulnerable
Recovery time to normal agricultural operation	Bounce back in more than two agricultural seasons	Bounce back within one-two agricultural seasons	Bounce back within one agricultural season
Farm plot size (ha)	≤one	one-two	≥two
Livestock holding (TLU)	≤one	one-two	>two
Social protection (resource, labor, group)	Poor social protection	Moderate social protection	Strong social protection
Diversity of income sources	Solely rely on rainfed crop farming	a minimum of 2 income sources	2-3 income sources at least some period of the year
Ecological stability (location, fertility and soil and water conservation (SWC) measures)	≥50% of their land is in steep slope and/or infertile and or located at the edge of river bank or no SWC or ≤25% SWC cover	25-50% of their land in steep slope and/or infertile and or located in near river bank or 25-50% SWC cover	≤25% of their land in steep slope and/or infertile; most of their lands are located a bit distant from river banks or ≥50% SWC cover
Infrastructure	Access to major public services in ≥2-hour walk	Access to major public services in 1-2-hour walk	Access to major public services in ≤1-hour walk

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291 Participants disclose that social networking is a determinant factor for mankind to share  
292 labor and resources, manage disputes as well as to mitigate with, adapt to and quickly



293 recover against shock impacts. See also [10, 29, 26, 30]. In terms of ecological stability,  
 294 discussants disclosed that households whose farm lands are located in steep slopes and  
 295 near to river banks are highly vulnerable to soil erosion and flooding impacts. Likewise, land  
 296 fertility is also reported as a principal factor influencing households' productivity and wealth  
 297 status. Accordingly, households whose farm lands are in gentle slope and with better soil  
 298 fertility are better off in production and are relatively resilient to shock impacts than their  
 299 counter parts.

300 Moreover, soil and water conservation practices are identified as determinant factors  
 301 affecting households' resilience to erosion. In effect, households who experience intensive  
 302 soil and water conservation measures are less likely impacted by erosion and more likely to  
 303 recover quickly against the adverse impacts of erosion. Thus, poor households are those  
 304 whose most of their lands are located in steep slopes, proximate to river banks, with infertile  
 305 and minimal soil and water conservation practices and thereby less resilient to shock  
 306 impacts. In line with this finding, studies disclose that land location and fertility are critical to  
 307 determine farm productivity. Accordingly, households with improved land fertility are better  
 308 off in farm production and more resilient to shocks [27, 26].

309 **Diversity of income sources:** Discussants and key informants disclosed that households  
 310 who experience multiple livelihood options have more assets and improved living standards.  
 311 In this aspect, female discussants stated that small-scale irrigation, home garden and small-  
 312 scale trading are essential in supporting the income-generating ability of women and youth.  
 313 Two female informants in *Mehal-Wonz* and *Zego* sites disclosed that selling of alcohol,  
 314 locally termed as *tela* and *areki* has substantial contribution in improving their standard of  
 315 living, especially in fulfilling children's demands of clothing and stationary materials. In  
 316 general, households with diversity of income sources are less vulnerable; instead more likely

317 quickly recover against climate change-induced shocks than who solely depend on single  
318 source of income. In agreement with this finding, studies state that income diversification is  
319 a strategy to improve income-generating ability of women in rural households (28). As a  
320 result, livelihood diversification is attributed with both coping strategy to risks in times of  
321 hazard events, as well as a means of livelihood development in conducive economic settings  
322 (29).

323 **Access to basic infrastructure:** key informants noted that infrastructure, mainly road and  
324 market are basis for further societal developments. In this aspect, access to basic  
325 infrastructures is minimal where only 18.06 and 55.56% of households access all weather  
326 road and market within five km distance, respectively, making the study communities  
327 isolated from market centers. In agreement with this finding, studies state that  
328 underdeveloped infrastructure is a driving cause for insufficient access to public services,  
329 minimal market integration and little returns on investments (30). Hence, geographically  
330 isolated communities who live distant from the main road and local market experience  
331 minimal access to inputs, market exchange, information as well as livelihood diversification  
332 opportunities [33, 27]. Likewise, Alinovi et al. (32) argue that access to basic infrastructure  
333 is determinant in promoting households' resilience to shocks by enhancing their access to  
334 assets. Access to credit services was also minimal where only 59.38% of households access  
335 credit facilities in their proximity. Studies state that insufficient physical structures  
336 significantly limit access to basic services like health and credit facilities, contributing  
337 socioeconomic marginalization (33). In effect, lack of access to cash needs during crises is  
338 a major factor limiting households' resilience to climate change-induced shocks (26).

### 3.2 Households' resilience as measured by Climate Resilience Index and resilience capacities

The livelihood resilience analysis through the three-capacities and Climate Resilience Index showed relatively comparable results. Accordingly, the highland is better off in sociodemographic profile, water and health; the midland is better off in exposure to natural disaster and livelihood strategies and the lowland is better off in income and food access, asset, stability, social capitals and access to basic services (Annex 1; Table 3).

Table 3. Indexed major components, core-capacities and overall Livelihood Resilience Index of Dinki watershed socio-ecological system. (NDCV=Natural Disaster and Climate Variability; IFA=Income and Food Access; SDP=Sociodemographic Profile; LVS=Livelihood Diversity and ABS=Access to Basic Services).

Resilience capacities	Major components	Agro-ecology					
		Highland	Resilience score	Midland	Resilience score	Lowland	Resilience score
		Component value		Component value		Component value	
Absorptive	NDCV	0.472		0.657		0.503	
	Stability	0.45	<b>0.448</b>	0.414	<b>0.517</b>	0.412	<b>0.520</b>
	Social capital	0.404		0.419		0.693	
Adaptive capacity	IFA	0.412		0.491		0.516	
	Health	0.46	<b>0.436</b>	0.416	<b>0.495</b>	0.399	<b>0.417</b>
	Water	0.544		0.465		0.361	
	SDP	0.569		0.455		0.459	
	Assets	0.288		0.31		0.371	
	LVS	0.343		0.444		0.385	
Transformative capacity	Social capital	0.505		0.499		0.542	
	ABS	0.35	<b>0.389</b>	0.327	<b>0.37</b>	0.355	<b>0.402</b>
Overall LRI							<b>0.444</b>

The livelihood resilience analysis through resilience capacities more clearly differentiated the agro-ecological zones in terms of their absorptive, adaptive and transformative capacities. In effect, the leading contributing factor to the resilience of Dinki watershed socio-ecological system to climate change-induced shocks was observed to be absorptive capacity with a mean index value of 0.495 followed by adaptive capacity with a mean index

value of 0.449 (Fig.2a). In terms of agro-ecology, the midland was found to be relatively more resilient to climatic shocks with a mean index value of 0.461(Fig. 2b).

Figure 2. The resilience capacities (a) and resilience score of agro-ecological zones (b)

Relatively higher score of absorptive capacity in the lowland agro-ecology is evident by the fact that its exposure to recurrent climate change-induced shocks might have enabled residents to acquire more knowledge and get prepared for future likely shocks. Besides, large farm and livestock holding, social capital (CBOs, SSS, sharing of resources and technology) as well as coping strategies (in economic and management options) might have enabled lowland residents to better absorb shocks compared to the highland and midland agro-ecological zones.

In line with this study, Boka (34) disclose that households in Ethiopian lowland areas often have quick access to climate change information and early warning system contributing to their improved preparedness compared to other climatic zones. Other studies argue that large farm and livestock holding enable households to spread risks through income diversification and asset accumulation opportunities (27). Moreover, Frankenberger and his colleagues disclose that households' ability to diversify financial capital, natural capital and social capital, among others, reduces their vulnerability, whilst enhancing their absorptive and adaptive capacities to properly respond to changing conditions (13).

On the other hand, the resilience score in terms of adaptive capacity was higher in the midland followed by the highland. It might be due to the fact that improved livelihood diversification practices (trade, irrigation, tree garden), technology utilization (improved seed and fertilizer) and improved access to credit might have enabled the midland and highland residents to better adapt climate change-induced shocks. Moreover, informal institutions like *idir* and *equib* are basic economic leverage contributing households to better adapt to shock

380 impacts. In agreement with this finding, studies state that livelihood diversification,  
381 information exchange and economic leverage institutions contribute to enhance households'  
382 adaptive capacity to shock impacts (13).

383 Although the mean resilience score in terms of transformative capacity (0.387) is lower to  
384 other resilience scores (Fig. 2a), the lowland showed the highest transformative capacity  
385 (0.402) than the other agro-ecological zones (Table 4). Relatively higher proportion of  
386 households who access market in their proximity coupled with higher social capital  
387 (transformative) scores through conflict management and vertical linkages in the lowland  
388 and highland might have contributed to higher transformative capacity in these agro-  
389 ecological zones. In this aspect, disputes over access to water, pasture and related land  
390 resources are repeatedly report as major sources of conflict in the study community. As a  
391 result, conflict management options through elders' institutions might have contributed to  
392 build peace and security among the study communities.

393 In agreement with this finding, studies state that managing conflict ensures information  
394 exchange and market linkage with other communities leading to knowledge sharing.  
395 Besides, participation of community members in decision options facilitates information  
396 dissemination, access to basic assets during crises and enhance transformative capacity  
397 through institutional reforms (13). Furthermore, conflict management through customary  
398 laws are recognized as plausible options to sustain social capital among Africans (35).  
399 These institutions are participatory, easily accessible and sustainable in keeping peace and  
400 thereby resilience (13).

401 Furthermore, households' resilience capacity was graphically presented in four quadrant  
402 charts following the Andersen and Cardona (36) and Weldegebriel and Amphune (25). The  
403 graph was established based on households' income per capita and mean LRI values drawn

on x and y-axes, respectively. Accordingly, based on the mean LRI value (0.44), households falling above the mean were poor but resilient, resilient and extremely resilient. Whereas rich but not resilient, vulnerable and extremely vulnerable households were presented below the mean. Likewise, based on the mean monthly income (18.66 per month or 0.622 USD per day), households falling to the right of the mean include rich but not resilient, resilient and extremely resilient. Whereas households who were poor but resilient, vulnerable and extremely vulnerable were presented in the left of the mean (Fig.3).

Figure 3. Resilience typologies by household monthly income

The average daily income value is far below the poverty line of sub-Saharan Africa, indicating the poverty level of the study communities. Moreover, even with this minimal cutoff, more than half of the households (56.59%) were vulnerable for poverty (Fig. 3). Factors, such as small asset holdings coupled with underdeveloped infrastructure might have limited their adaptive capacities signified by poor diversification practices, while amplifying their vulnerability.

In this study, considerable proportion (32.29%) of households own less than one hectare of land, nearly half (47.22%) of the study communities have less than two livestock unit and the overall infrastructure is underdeveloped (Annex 1). Moreover, the majority of households (94.79%) experience a single income-dominated livelihood options, making them vulnerable to climate change-induced shocks. In agreement with this finding, studies disclose that land and livestock are two of the most known financial assets in farming communities of Ethiopia critically determining their wealth status (27). Thus, poor households are often with small land size, few livestock unit and minimal livelihood options as well as are with minimal access to key household assets (natural, physical, human and social capitals) to diversify livelihoods and to empower their adaptive capacity (37). However, poor people are not

necessarily vulnerable if have access to communication, infrastructure and support systems  
(38).

## 4. Conclusion

In this study, the Climate Resilience Index (CRI) and the resilience capacities (3Ds) frame were tested to measure households' resilience to climate change-induced shocks. The methods presented detail description of factors contributing to households' resilience to shock impacts. Likewise, access to and use of livelihood resources, such as farmlands, livestock, livelihood diversification, infrastructure, as well as social capital and ecological stability are identified to influence households' resilience to climate change-induced shocks. However, it might be due to their exposure to recurrent shocks coupled with constrained adaptive capacities like limited diversification practices, poor access to infrastructure, underdeveloped social capital, among others, the mean resilience score of the study communities is minimal. Similarly, although improved absorptive capacity through early warning system, social protection, climate change information, etc. contributes to prepare, anticipate and cope with shock impacts, it is equally important to strengthen both the adaptive (adjustment strategies) and transformative (system-level change) capacities to ensure long-term resilience in the study communities.

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# Annex 1. Indexed major components, sub-components and overall CRI of Dinki watershed socio-ecological system

Major component	Indicator	Highland		Midland		Lowland	
		Value of indicator	value of major component	Value of indicator	value of major component	Value of indicator	value of major component
Natural disaster and climatic variability	%HH reporting >1 Environmental shock during the last 12 months	0.147	0.472	0.633	0.657	0.168	0.503
	%HH reporting >1 Socioeconomic shock during the last 12 months	0.14		0.694		0.126	
	%HH with injury/death due to shocks during the last 12 months	0.453		0.776		0.453	
	%HH having early warning system	0.86		0.479		0.905	
	%HH prepared to future likely CC impacts	0.76		0.704		0.863	
	%unsuitable land slopes(topography)	0.472	0.450	0.588	0.4145	0.613	0.412
	%infertile soil	0.518		0.518		0.482	
Stability	%land under SWC	0.632		0.172		0.073	
	perception to CC impacts	0.179		0.38		0.48	
	resources sharing b/n HHs	0.54	0.404	0.56	0.419	0.947	0.693
Social capital	technology sharing b/n comm	0.52		0.52		0.9474	
	membership to CBOs	0.152		0.1777		0.184	
Income and food access	Annual per capita income	0.274	0.412	0.325	0.491	0.358	0.516
	HFIAS	0.605		0.711		0.675	

Major component	Indicator	Highland		Midland		Lowland	
		Value of indicator	value of major component	Value of indicator	value of major component	Value of indicator	value of major component
Health	Dietary diversity	0.358		0.439		0.516	
	Illness score	0.801	0.460	0.7912	0.416	0.689	0.399
	Improved toilet	0.12		0.04		0.11	
Water	Improved water	0.421	0.544	0.429	0.465	0.453	0.361
	Water sufficiency	0.526		0.327		0.189	
	Water conflict	0.684		0.64		0.44	
Sociodemographic status	%female headed households	0.906	0.569	0.663	0.455	0.747	0.459
	Age of household head	0.362		0.415		0.351	
	Dependency ratio	0.78		0.47		0.475	
	%Literate HH heads	0.523		0.418		0.421	
	Family size	0.275		0.31		0.3	
Assets	Farm size	0.4027	0.288	0.473	0.310	0.541	0.371
	Livestock ownership	0.247		0.278		0.287	
	%access communication device	0.432		0.45		0.568	
	Saving and loan associations	0.07		0.04		0.09	
Livelihood strategy	Diversity of income sources	0.315	0.343	0.44	0.444	0.325	0.385
	Information exchange/SSS/	0.46		0.495		0.553	
	Coping strategies	0.179		0.36		0.484	
	Technology utilization	0.42		0.48		0.18	
Social capital	Conflict management	0.558	0.505	0.551	0.499	0.621	0.542
	vertical linkages (involvement in decision)	0.453		0.449		0.463	
Access to basic services or infrastructure	market	0.38	0.35	0.36	0.327	0.44	0.355

Major component	Indicator	Highland	Midland	Lowland
		Value of indicator	value of major component	Value of indicator
	health services	0.4	0.48	0.32
	primary school	0.66	0.54	0.52
	all weather road	0.18	0.051	0.18
	saving and credit	0.43	0.48	0.42
	electricity	0.05	0.051	0.25



## List of Figures

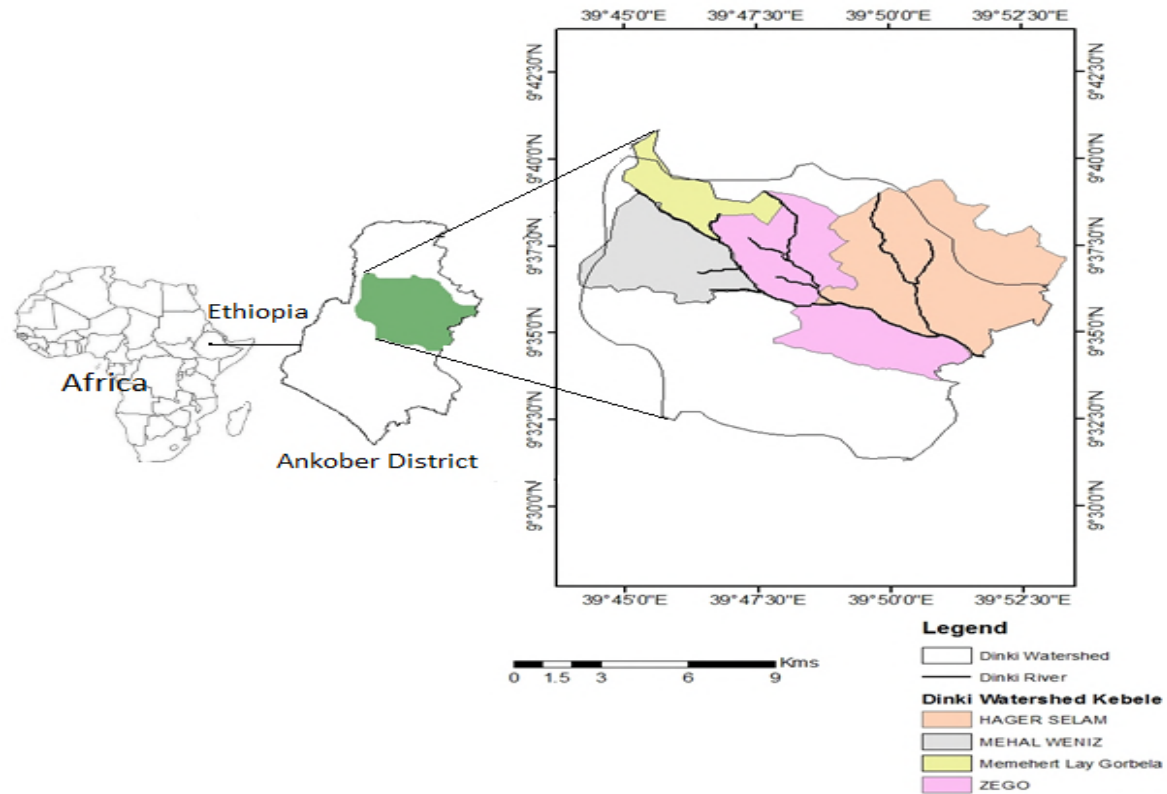


Figure 1. Map of the Dinki watershed, central highlands of Ethiopia

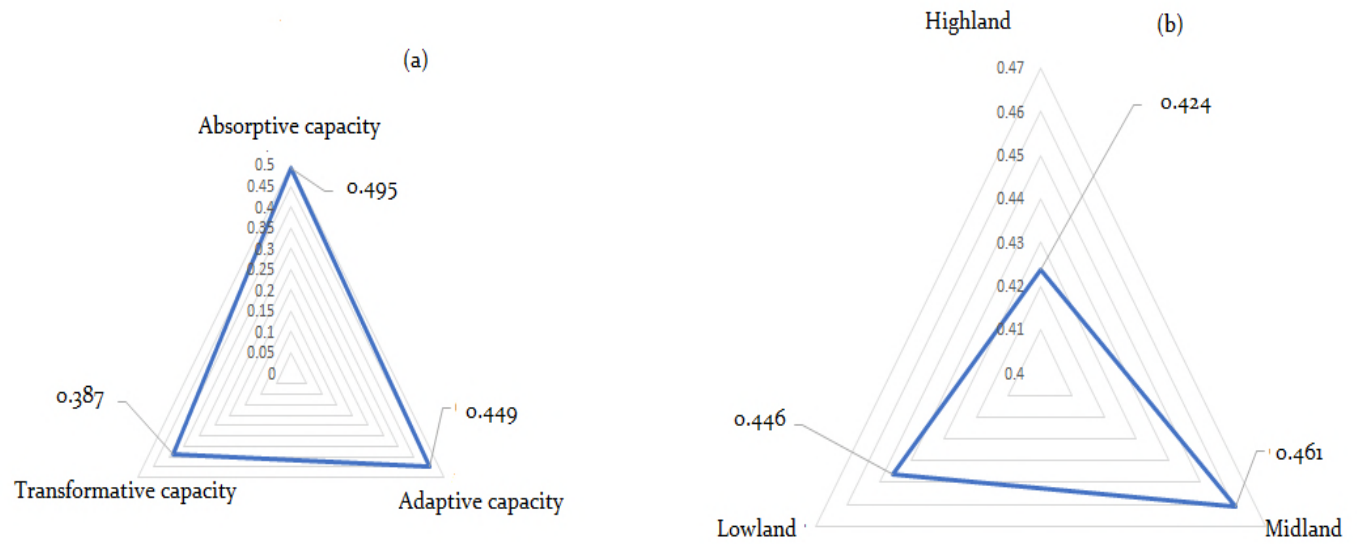


Figure 1. The resilience capacities (a) and resilience score of agro-ecological zones (b)

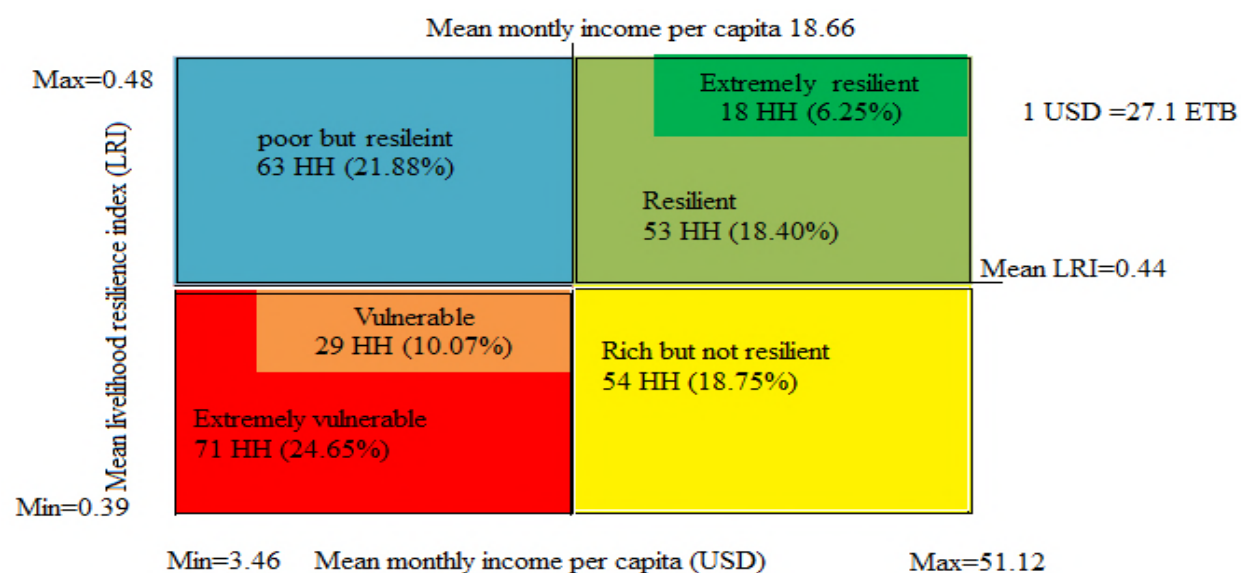


Figure 1. Resilience typologies by households' monthly income