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Research Article

Assessing Rural Households' Adaptive Capacity to Climate Variability: A Comparative Study from Three Agro-Climatic Zones in North-West Ethiopia

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Abstract

Effective planning for climate change adaptation programming in developing countries requires a fine grained assessment of local vulnerabilities, practices and adaptation options and preferences. The study was aimed to assess and measure the levels of adaptive capacity of rural farming households to climate variability and to identify the factors that cause the differences in adaptive capacity in three ago-ecological zones of Northwest Ethiopia. The level of adaptive capacity of farming household was determined using a composite index adopted from previous studies conducted in the same socio-economic and bio-physical settings. The index included five indicators namely human resources, physical resources, financial resources, information and diversity. The finding elucidated that variations in adaptive capacity were caused by differences in information resources, physical and financial resources. Farming households that scored low in these three indicators had lower adaptive capacity. Households with higher adaptive capacity however employed more adaptation strategies. The study elucidated that adaptive capacity score of the Misrak Belessa, Janamora, and Simada agro-climatic were found to be 0.394, 0.524 and 0.68 respectively. These values show that Kolla (Misrak Belessa) agro-climatic zone has low adaptive capacity to climate change. Results suggest that the district is more vulnerable in terms of financial assets (0.74) followed by natural assets (0.67). Policy measures and development efforts should be taken towards improving the adaptive capacity of the rural households, while keeping the post-disaster emergency relief measures in place for localities with higher exposure to climate extremes.

Keywords: Climate change, rural households, adaptive capacity, agro-climatic zone, climate extremes.

Introduction

Climate change impacts and the expected increase in magnitude and frequency of both slow and rapid onset events like floods, droughts, cyclones and desertification processes place developing country populations at increased risk and can undermine efforts to reduce poverty. Reducing the vulnerability of poor and disadvantaged groups and regions requires an understanding of the intersecting inequalities faced by women, livelihood groups, ethnic minorities, and children and the elderly in order to identify jointly with these groups appropriate adaptation measures and pathways for regions that improve asset bases and promote resilience (Eriksen *et al.*, 2007). Ethiopia is one of the most vulnerable countries to climate risks because of its geographical location and level of economic development. One of the sectors in Ethiopia that have been severely affected by climate change is small-scale agriculture. Manifestations of the changing climate have been observed in the trend of increasing temperatures, highly variable rainfall, and extreme weather events (Hailemariam, 1999).

The vulnerability of small-scale agriculture to climate variability and change is caused by the inherent climate and weather-sensitivity of agricultural livelihoods and the chronic poverty that plagues the sector. Adaptation has been recognized as an important strategy to reduce these impacts because it can lower vulnerability, and can increase resilience to climate change. The enhancement of adaptive capacity is an effective means of facilitating adaptation to climate change and variability especially for vulnerable groups such as small-scale farmers in developing countries (IPCC, 2001). Adaptation however is costly and can strain the already limited funds of individual farmers and government in developing countries like Ethiopia. Measures of adaptive capacity are useful in this context. Thus, measures of adaptive capacity would be valuable inputs in designing policies and interventions for adaptation. Currently, however, there are very few studies in Ethiopia that measure household level adaptive capacity to climate change. Most of the researches are either macro in scope, focusing on the municipal, provincial, or regional level.

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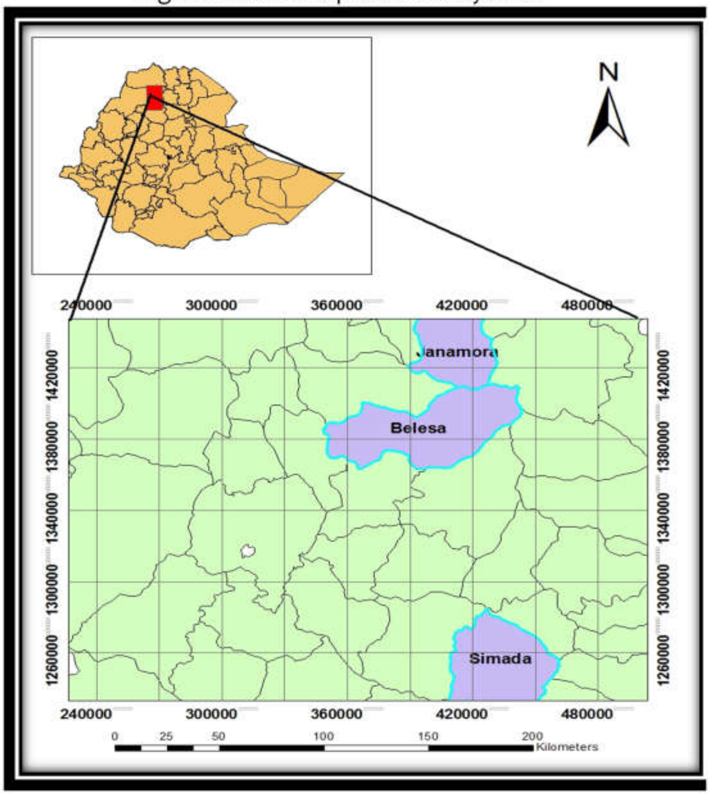
Fig. 1. Location map of the study area.



These studies cannot capture the unique social coping mechanisms and best practices or the hindrances to adaptation of households to climate change. This study fills this gap by focusing on the understanding of adaptive capacity at the household level. Adaptive capacity in this study was determined using a menu of indicators based mainly on the sustainable livelihoods (SL) framework which seeks to better understand the factors that affect poor people's livelihoods and the relationships between these factors (www.ifad.org). This framework has been widely applied in poverty and vulnerability studies of rural communities. More recently, the SL approach has also been applied in vulnerability and impact assessments of disasters and climate change. The SL framework identifies five asset categories; human, social, natural, physical and financial capital; from which livelihoods are built (DFID, 1999).

The indicators of adaptive capacity enumerated in the third assessment report of the IPCC (2001) were generally based on assets and resources which reflect the SL framework. These include economic resources, technology, infrastructure, information and skills, institutions and equity (IPCC 2001). However, adaptive capacity indicators in this study were adopted based on local capacity of rural farming households to address climatic risk is a function of indicators of access to different resources namely information, technology, wealth and financial, and institutional resources.

Materials and methods

Simada district (midland agro-climatic zone): The district is located between 12°40’00” N and 36°8’00”E. The altitude of this agro-ecology ranges between 1500 to 2300 msl (Fig. 1). The district is characterized by mean annual temperature which ranges between 12°C and 29°C. The mean annual rainfall for the area ranges from about 850 mm to around 1840 mm Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), a total of 416,378 households were counted, resulting in an average of 4.15 persons to a household. It is dominantly lies under moist Kola, Woina-Dega, and Dega agro-ecological zone (ACZ).

Misrak Belesa district (lowland agro-climatic zone): Geographically it lies between 11°-13°N longitude and 38°E To 40°E latitude. The altitude of this agro-ecology ranged between 1500 to 760 m to 1512 asl. The area receives sufficient rain varies from 712 to 1023 mm with a mean annual value of 842 mm. According to the daily air temperature data collected at Guhala station, the mean monthly temperature ranges between 14°c to 34°c. Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), a total of 305,820 households were counted, resulting in an average of 5.75 persons to a household. It is dominantly lies under semi-arid lowland agro-climatic zone (ACZ).

Janamora district (High altitude ago-climatic zone): Geographically it lies between 39°28’08” and 38°18’12” longitudes and 12°14’22” and 12°36’32” latitude. The altitude of this agro-ecology ranges between 2290 to 3650 m asl. The area receives sufficient rain varies from 1100 to 2400 mm with a mean annual value of 1800mm. The mean monthly maximum and minimum temperature of the area is about 16°c and 2°C respectively (ARARI, 2012). Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), a total of 298,476 households were counted, resulting in an average of 4.92 persons to a household. It is dominantly lies under semi-moist highland zone (ACZ).

Data collection: A total of 346 households were selected for the survey following Taro Yemane’ formula (1968). Semi-structured questionnaire was used to elicit responses between February and July 2016. Purposive sampling was used to select drought-prone divisions in the Ethiopia from the three agro-climatic zones to compare which one has high adaptive capacity to climate variability. Households were selected proportionally using simple random sampling technique. In addition, rainfall and temperature datasets relevant for this study were obtained from Meteorological Services Agency of Ethiopia. The STATA 12 was used to analyze the socio-economic data obtained.

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Table 1. The composite sub-indices and their component indicators to measure adaptive capacity.

Indicators of adaptive capacity	Components	Sub-components and unit of measurements
Human Capital	Socio-Demography	1).Years of education of head of households (50%) 2).Households where head of households has attended school (50%)
Social Capital	Relationship and Affiliates with CBOs	1).HHs who have loose ties with neighbours/relatives (50%) 2).HHs who do not receive any kind of support/help from neighbours/relatives (50%)
Physical Capital	Access to infrastructure	1).Distance to the nearest major Road (25%) 2).Distance to the nearest Health Facility (25%) 3).Distance to the nearest Primary School (25%) 4).Distance to the nearest Drinking Water Source (25%)
Technological Capital	Access to technologies	1).Access to Agricultural inputs (50%) 2).Total value of Agricultural assets (50%)
Information	Access to information	1).Households own asset that allows them to have up-to-date information (Mobile, Network, TV, Radio) (100%)
Financial Capital	Income, access to credit, and diversification	1).HHs family member with off farm employment (25%) 2).HHs who haven't debt to pay back to individual lender (25%) 3).HHs who do not receive remittance (25%) 4).HHs with access to credit to any financial institutions (25%)
Institutions	Policy and Leadership	1).HHs satisfied by their local leaders decisions (50%) 2). HHs access to extension in the last 1 month (50%)

The data was entered into Epi-Data software for data quality control before exported into STATA for analysis.

Method of analysis: The adaptive capacity to climate change and variability of farming households was measured using a composite index. The index consists of various indicators of adaptive capacity following the sustainable livelihoods framework. Based on this approach, adaptive capacity is determined by ownership and access to resources, information and technology, and ability to diversify livelihoods to cope with climate-related stresses. In this study, we adopted an approach that captures a household's adaptive capacity relative to other households taking into account the socio-economic settings of Ethiopia. Physical capital as measured in terms of access to major infrastructure is one such institutional resource that is critical to adaptive capacity. Access to clean drinking water, is an especially important measure of infrastructure, as water-borne illnesses often reduce the body's ability to absorb nutrients (Hutchinson, 1992), leading to malnutrition and other serious health issues, which would significantly hinder a household's ability to adapt. As it can be elucidated from the table below, distance to the nearest water source has low index value, which reduces adaptive capacity of rural farming households to the changing climate. Distance to nearest health facility and distance to nearest primary school indicators were selected based on the assumption the distance to these locations has some influence on how likely households are to utilize these services.

Financial resources are also inadequate because most of them do not receive remittances, do not avail of financial assistance from the government, have low off farm incomes and lack access to credit. Similarly there is shortage of information resources due to lack of training, technical assistance and non-participation in organizations. They also have low livelihood diversity because of too much concentration on farming as indicated by few alternative income sources, specialization in a single crop and high percentage of land allotted for crop production. This is a reasonable assumption given that agriculture in Ethiopia is typically associated with high risk and low economic returns and non-farm income is critically important to rural farming households in different agro-climatic zones of Ethiopia.

Adaptive capacity indicators are formed from the sum of the scores from the following seven composite sub-indices: 1) human capital; 2) social capital; 3) financial capital; 4) institutional capital; 5) access to information; and 6) physical capital; and 7) technological capital (Table 1). The sub-indices each represent one theoretical determinant of adaptive capacity. The approach of creating an aggregate index from several composite sub-indices was chosen to maintain transparency, which is critical for end-users as there are no absolute values in adaptive capacity and these are modified based on Vincent, 2007 proposition. Where the sub-index is comprised of more than one indicator, an average of those indicators was used so that each indicator in the index is weighted equally, and each sub-index is scored between zero and one.

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Table 2. Farming households' average scores in seven indicators of adaptive capacity.

Major Components	*Misrak Belessa (Lowland ACE)*	*Simada (Midland ACZ)*	*Janamora (Highland ACZ)*
Human Capital	0.47	0.74	0.59
Social Capital	0.41	0.91	0.55
Physical Capital	0.33	0.44	0.61
Technological Capital	0.39	0.84	0.69
Information	0.37	0.53	0.32
Financial Capital	0.31	0.58	0.49
Institutions	0.48	0.72	0.42
Over all adaptive capacity score	*0.394*	*0.68*	*0.524*

Assigning equal weight to indicators and sub-indices is consistent with the approach used by Patnaik and Narayanan (2005) and Vincent (2007) among others. The sub-indices utilized a combination of binary and continuous variables. All continuous variables were scored according to the maximum observed value of that variable in the data set and were turned into proportional variables:

$$Indicator\ Score\ for\ household\ X = \left(\frac{\text{Observed value for household X}}{\text{Maximum value of the variable}}\right)$$

Or

$$Indicator\ Score\ of\ X = 1 - \left(\frac{\text{Observed value for household X}}{\text{Maximum value of the variable}}\right)$$

Where, a score of '1' represents the best score for that variable and '0', the worst score. This is consistent with the approach of finding the adaptive capacity of households relative to one another, and to ensure the indicators are sensitive enough to show differentiation.

For variables with extreme outliers a rank order approach was taken to reduce the impact of outliers on our result.

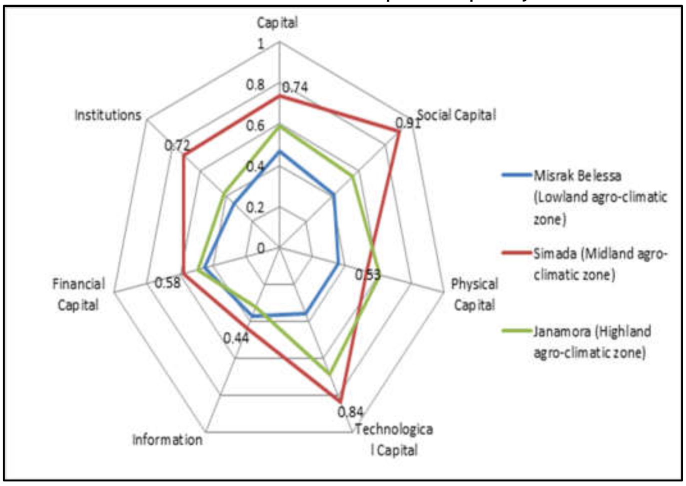
$$\text{Adaptive capacity of ACZ}_\text{n} = \frac{\sum_{k=1}^{n} W_{Mi} W_{di}}{\sum_{k=1}^{n} W_{Mi}}$$

Where, ACZ_n is the adaptive capacity of farmers in each agro-climatic zones which is equal to the weighted average of the seven major components. The weights of each major variable, WMi, are determined by the number of sub-variables that make up each major component and are included to ensure that all sub-components contribute equally to the overall adaptive capacity score.

Results and discussion

Among the 346 respondents, the average age of respondents was approximately 48 years, with an experience in farming of about 27 years. Most respondents were men, and only 23.4% of the respondents were women. Empirically, the adaptive capacity scores of the major components ranged from 0.31-0.91 as shown in Table 2.

Fig. 2. Average scores of rural farming households in the seven indicators of adaptive capacity.



The scores relative values are compared across three agro-climatic zones in North-West Ethiopia. As seen in Fig. 2, the financial component has the largest contribution to the low adaptive capacity of Misrak Belessa (lowland agro-climatic zone with a value of 0.31 followed by physical component with a value of 0.33). Having adequate financial backups help to overcome the external risks and shocks, thus we can say that this high level in the financial sector will possibly have a negative effect on the rest of the components, because without a stable economy and economic resources, and mostly dependent on agriculture as their only source of income, makes it very difficult to cope with climate change impacts due this lack of resources, and the possibility to apply some mitigation strategies is reduced. In Simada (Midland agro-climatic zone), physical component has the lowest value (0.44) among others which affects the adaptive capacity of farming households. This is not surprising as physical resources are very important for a society that depends completely on them for their daily subsistence. The same way, in Janamora (Highland agro-climatic zone), access to information has the lowest value (0.32) among others which affects the adaptive capacity of farming households.

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Table 3. Percentage of rural farming households by levels of adaptive capacity.

Level of adaptive capacity	Agro-climatic zone in percentage			Average adaptive capacity
	Simada (Midland)	*Janamora* (Highland)	*Misrak Belessa* (Lowland)	
Low	18	59	68	0.394
Moderate	33	25	20	0.524
High	49	16	12	0.68

Fig. 3. Adaptive capacity score of rural farming households' triangle diagram.

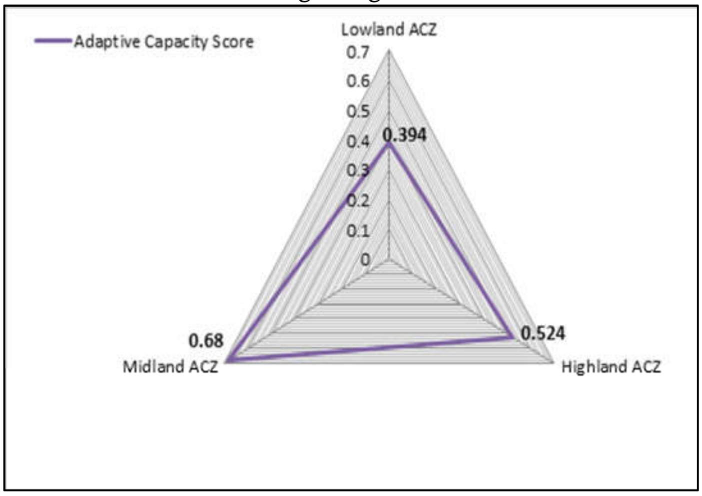
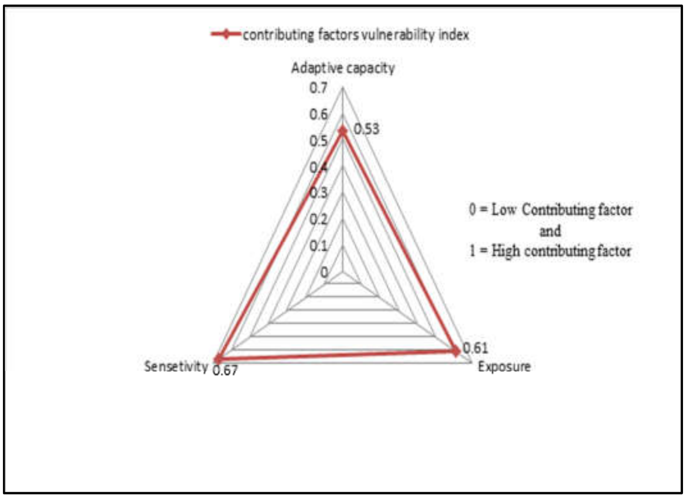


Fig. 4. Contributing factors for vulnerability index based on the LVI-IPCC framework.



Among the components that have a low weight on the vulnerability, we find knowledge and skills. Having Radio, Mobile, and Network at home, thus being connected to external information, is very important for example to consulting weather information, government decisions, events and can be helpful to perform their functions in agriculture. Also we can observe that most farmers exchange information between them, and that for the dynamics of a society is very useful. The classification of scores in three adaptive capacity levels shows that majority of the respondents (68%) in *Misrak Belessa* (lowland agro-climatic zone) have low adaptive capacity, 20% have moderate adaptive capacity and only 12% have high adaptive capacity. In *Simada* (midland agro-climatic zone), majority of the respondents (49%) have high adaptive capacity, 33% have moderate adaptive capacity and only 18% have low adaptive capacity. With respect to the context in *Janamora* (highland agro-climatic zone), majority of the respondents (59%) have low adaptive capacity, 25% have moderate adaptive capacity and only 16% have high adaptive capacity. The low adaptive capacity rating of most farming households in almost all the three ago-climatic zones is explained by their low scores in information and physical capital indicators of adaptive capacity. Higher values for the Fig. 3 Radar chart of major components of adaptive capacity score indicates that the community is capable of coping with adverse situations more effectively, so acts by decreasing the vulnerability.

Therefore this medium value of the adaptive capacity means that the community has some good capacities to cope with the climate change and climate variability but not good enough to decrease the exposure and the sensitivity. The computed average adaptive capacity in highland, midland, and lowland agro-climatic zones are 0.68, 0.524, and 0.394 respectively. LVI-IPCC index value was computed for the three agro-climatic zones of Northwest Ethiopia to identify the most contributing factor for the vulnerability of rural farming households (i.e. exposure, sensitivity and adaptive capacity). In this case, the overall result is 0.129 and therefore, the results suggest that the studied agro-climatic zones have a moderate vulnerability to climate change and climate variability (Tables 4-6 and Fig. 4). On the average, farming households scored highest in information resources and lowest in diversity. Differences in adaptive capacity were caused by large disparities in information, physical and financial resources. These were also the most important indicators based on expert judgment. The differences among households as far as human resources and diversity scores are concerned were not as high. There is little disparity among the average scores because farmers have similar characteristics in terms of the number of livelihoods, number of crops planted, and fraction of land devoted to crops.

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Table 4. Computation of LVI–IPCC for *Misrak Belessa* (Lowland agro-climatic zone).

Contributing factors	Major components	Major component values	Number of sub components per major component	Contributing factor values	LVI-IPCC value
Adaptation capacity	Socio-demographic characteristics	0.66	5	0.634	0.0285
	Financial capital	0.611	4		
	Social Capital	0.62	3		
Sensitivity	Health	0.56	4	0.62	
	Food	0.53	4		
	Water	0.72	6		
Exposure	Climate variability	0.68	6	0.68	

Source: filed computation 2016.

Table 5. Computation of LVI–IPCC for *Simada* (Midland agro-climatic zone).

Contributing factors	Major components	Major component values	Number of sub components per major component	Contributing factor values	LVI-IPCC value
Adaptation capacity	Socio-demographic characteristics	0.71	5	0.583	0.0259
	Financial capital	0.53	4		
	Social Capital	0.44	3		
Sensitivity	Health	0.81	4	0.7	
	Food	0.68	4		
	Water	0.64	6		
Exposure	Climate variability	0.62	6	0.62	

Source: filed computation 2016.

Table 6. Computation of LVI–IPCC for *Janamora* (Highland agro-climatic zone).

Contributing factors	Major components	Major component values	Number of sub components per major component	Contributing factor values	LVI-IPCC value
Adaptation capacity	Socio-demographic characteristics	0.73	5	0.55	0.234
	Financial capital	0.46	4		
	Social Capital	0.37	3		
Sensitivity	Health	0.64	4	0.6	
	Food	0.75	4		
	Water	0.48	6		
Exposure	Climate variability	0.94	6	0.94	

Source: filed computation 2016.

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Table 7. Index values of the indicators of adaptive capacity.

Indicators of Adaptive Capacity	Components	Sub-components and unit of measurements	Index values		
			Lowland ACZ (Misrak Belessa)	Midland ACZ (Simada)	Highland ACZ (Janamora)
Human Capital	Socio-Demography	Years of education of head of households	0.66	0.71	0.73
		Households where head of households has attended school	0.611	0.53	0.46
Social Capital	Relationship and Affiliates with CBOs	HHs who have loose ties with neighbours/relatives	0.62	0.44	0.37
		HHs who do not receive any kind of support/help from neighbours/relatives	0.56	0.81	0.64
Physical Capital	Access to infrastructure	Distance to the nearest major Road	0.53	0.68	0.75
		Distance to the nearest Health Facility	0.72	0.64	0.48
		Distance to the nearest Primary School	0.68	0.62	0.94
		Distance to the nearest Drinking Water Source	0.52	0.74	0.62
Technological Capital	Access to technologies	Access to Agricultural inputs	0.627	0.56	0.438
		Total value of Agricultural assets	0.516	0.88	0.809
Information	Access to information	Households own asset that allows them to have up-to-date information (Mobile, Network, TV, Radio)	0.491	0.72	0.697
Financial Capital	Income, access to credit, and diversification	HHs family member with off farm employment	0.34	0.75	0.744
		HHs who haven't debt to pay back to individual lender	0.301	0.575	0.682
		HHs who do not receive remittance	0.412	0.216	0.615
		HHs with access to credit to any financial institutions	0.452	0.51	0.564
Institutions	Policy and Leadership	HHs satisfied by their local leaders decisions	0.371	0.518	0.496
		HHs access to extension in the last 1 month	0.461	0.415	0.729

Access to information can significantly impact the level of adaptive capacity at the micro level (Yohe and Tol, 2002), since information provides a basis from which households can anticipate or react to minimize the impact climate change has on their household. Access to information is measured based on household ownership of the following assets that assist in the diffusion of information: 1) radio, 2) network, and 3) telephone. It is assumed that households who own assets that assist in the diffusion of information have better access to information. The access to technologies sub-index is calculated using the value of each household's agricultural assets as well as an assessment of whether the household reported having access to any of the following three important agriculture inputs: 1) irrigation, 2) fertilizer and/or, 3) pesticides. In this case, agricultural assets can be directly tied to household income, as our sample is farm households who make some portion of their income from farming.

In the context of adaptive capacity and climate change, the most important component of social capital is the ability of a society to act collectively (Adger, 2003). It follows then that the ability to act collectively is enhanced by membership in social capital groups. Based on this assumption, social capital is measured using two indicators: 1) the number of government organizations in which the household participates, and 2) the number of household members participating in at least one community organization. Having indicators of membership in both government groups and community organizations allows us to evaluate a household's involvement in collective action at the community level, and it also encompasses some measure of access to institutional programs (i.e. government programs), providing a more robust measure of adaptive capacity (Table 7).

Coefficient of determination between the level of adaptive capacity and sub-components: Table 8 demonstrates the sub-components that were found to correlate strongly with the adaptive capacity score of rural farming households in Northwest Ethiopia. Therefore, these are the 9 drivers that best explain the adaptive capacity of rural farming community. Correlations vary within and between sub-components. The type of component with the greatest number of highly correlated sub-components is the physical capital, where 62.4% of the subcomponents were found to have a strong correlation (R^2>0.80) with the adaptive capacity sores. The second type of major component with the largest number of subcomponents correlated to the adaptive capacity sore is the financial resources with 34.8%.

Non-parametric test result: The next step was to determine whether there were statistically significant differences in household adaptive capacity once households were grouped based on various demographic characteristics. Non-parametric statistical tests were used, where household adaptive capacity was the test variable, and the demographic variables were used to group the households in a way that is relevant to each agro-climatic zones of Northwest Ethiopia. Post-hoc Mann-Whitney U pair-wise comparisons were performed to indicate the direction of the effect, where there was a statistically significant difference between groups. Households were grouped based on the following characteristics: 1) ago-climatic locations of the households, 2) size of the household, 3) number of females in the household, 4) number of males in the household, 5) head of household's age. The test results showed significant differences in household adaptive capacity between the three agro-climatic zones, Chi Square (346) = 119.51, p=0.000. Post-hoc Mann-Whitney U pair-wise comparison tests indicate statistically significant differences in adaptive capacity between households in *Janamora* (highland agro-climatic zone), *Misrak Belessa* (lowland agro-climatic zone) and *Simada* (midland agro-climatic zone). It was found that households in *Simada* (midland agro-climatic zone) having significantly higher adaptive capacity than households in highland and lowland agro-climatic zones.

The Kruskal-Wallis test was also conducted to evaluate whether the adaptive capacity of rural farm households differ as a function of the age of the head of household. Households with an 'adult' head of household (p=0.033) and with a 'senior' head of household (p=0.007) had significantly higher adaptive capacity scores than households with a 'young' head of household in all the three agro-climatic zones of North-west Ethiopia. In terms of households size, the test result indicate that medium sized households (p=0.001) had significantly higher adaptive capacity scores than 'small' households. The findings further elucidated that there is also a significant difference in household adaptive capacity based on the number of males in the house and for number of females in the house (p=0.002).

Conclusion

This study highlights how adaptive capacity of rural farm households varies across the different agro-climatic zones, and also how it varies by household demographic characteristics. This research has shown that in rural Northwest Ethiopia, household adaptive capacity significantly differed when households were grouped by agro-climatic zones, household size, and age of the head of household. It also showed that households located in the midland agro-climatic zone, small size households, and households with a young head of household had lower adaptive capacity than their counterparts. Although farmers living in lowland agro-climatic zones had the lowest adaptive capacity in Northwest parts of the country, the analysis shows that highland agro-climatic zone had also experience low to moderate adaptive system. Our results demonstrate a strong need for policy intervention in the northwestern part of Ethiopia, where there is a higher vulnerability to climate change, than anywhere else in the country. Policy makers could focus on building adaptive capacity in the lowland agro climatic zone, an area that is lacking adequate infrastructure, social capital, access to information, and others.

Table 8. Sub-components with strong correlation from the three agro-climatic zones (R^2>0.80).

R^2 value	Sub-component	Major component
0.924	Distance to the nearest Drinking Water Source	Physical capital
0.909	Households own asset that allows them to have up-to-date information (Mobile, Network, TV, Radio)	Information
0.892	Distance to the nearest Health Facility	Physical capital
0.871	HHs family member with off farm employment	Financial capital
0.863	Distance to the nearest Primary School	Physical capital
0.855	HHs with access to credit to any financial institutions	Financial capital
0.851	Access to Agricultural inputs	Technological capital
0.836	Households where head of households has attended school	Human capital
0.804	HHs who do not receive any kind of support/help from neighbours/relatives	Social capital

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