Livelihood zone-based perception and adaptation strategies of rural households' to rainfall and temperature variability in the Northeastern Highlands of Ethiopia

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Abstract

Background

Appraising of rural households' perception and observed rainfall and temperature variability is a vital stage in devising operational adaptation strategies. Therefore, this study aims to examine the rural households' perception and adaptation strategies to climate variability induced vulnerability in Northeastern Highlands of Ethiopia across the livelihood zones. A total of 361 sample households were selected using proportional probability sampling techniques. Data sources such as survey questionnaire, interview and focus group discussion were used to collect the necessary information. Historical rainfall and temperature data from CenTrends Great Horn of Africa v1 and CRU_TS 4.0 were also used. Precipitation Concentration Index (PCI) and Standardized Anomaly Index (SAI) model were employed to analyze the data. Descriptive statistical tools for frequency and percentage were also used.

Results

The result showed that rainfall and temperature variability induced vulnerability were well perceived by rural households' though varied across the livelihood zones. This was also similarly shown by Precipitation concentration index and standardized anomaly index at the annual, *Kiremt* and *Belg* seasons in the observed rainfall and temperature information. In response to rainfall and temperature variability induced vulnerability, rural households have engaged in a range of adaptation measures. These include the different biophysical soil and water conservation measures; crop and livestock diversification by planting and rearing variety of crop and livestock; changing crop planting and harvesting dates according to the changing pattern of rainfall. However, the executed adaptation strategies are insufficient as compared to the imposed vulnerability challenges by climate variability. There is also a great gap between rural households' climate variability perception and level of actual adaptation response measures. Because the result revealed that the presence of various impediments deterred the available and implemented adaptation response measures to climate variability induced vulnerability.

Conclusion

Even if rural households perceiving and practicing adaptation measures to climate variability induced vulnerability, still different impediments weaken the actual adaptation responses. Therefore, these demands the government, communities, and other stakeholders at different level in designing integrated and distinct livelihood zone-based adaptation strategies to reduce households' crop-livestock mixed agriculture from climate calamity vulnerability.

Introduction

Climate variability and extremes are the biggest global challenge threating the biophysical systems, agriculture, and socioeconomic well-being of the poor primarily in developing countries (Parry et al., 2005). Even in the future, climate change will have all embracing impacts on socioeconomic and related sectors such as water resources, agriculture and terrestrial ecosystems (UNFCCC, 2007). Of the sectors, agriculture is one of the most vulnerable to climate variability and extremes with the horrible consequences for the economy and food security that endanger the stability of developing countries (Mbilinyi et al., 2013). Agriculture and food security are of critical issues under climate variability stresses specifically climate has threatened agriculture in many African countries (IPCC, 2007). Certainly, climate variability and extremes impact on the environment affects the sustainability of rural households' livelihoods unless the necessary adaptive measures taken (IPCC, 2013; 2014; EPCC, 2015). Hence, to limit the cost of climate change on agriculture sector adaptation strategies become a response option (IPCC, 2014). However, local level climate variability perception by the farming community is the first step in adaptation process (Deressa et al., 2011). Therefore, deal with rural households' perception of climate variability and associated impediments to adaptation are vital before understanding their adaption measures (Pickson & He, 2021; Le Dang et al., 2014). Bewket (2012), Tiwari et al. (2014) argued that knowing the perception of rural farming households about climate variability and extremes facilitate the adaptation process. Adapting to climate change involves taking the appropriate adjustments measures to limit the impact of climate change on the agricultural sector (UNFCCC, 2007; World Bank, 2011).

In history, agriculturalists have continuously endeavored to adapt the changing climate condition in the agricultural sector. But, in some cases the effort of adaptation measures becomes ineffective (EPCC, 2015). Agricultural producers may respond to the threats posed by climate variability and extremes using different adaptation options such as risk management, technology, diversification, and biophysical conservation practices (IPCC, 2007). For successful crop-livestock management, adaptation response to climate change through climate forecast information may be advantageous (Tripathi & Mishra, 2017; Thornton et al., 201; Hellmuth et al., 2007). Change of cropping pattern and calendar of planting according to weather forecast information may be able to reduce crop production risks due to climate variability (Akinnagbe & Irohibe, 2014).

Diversification as adaptation response may be of different types. According to Thornton et al. (2013), agricultural diversification happens when more species of plant varieties or livestock breeds are practiced by a given farming household. Mixed cropping is also another way of crop diversification with varying attributes in terms of maturity periods, drought tolerance, input requirements and product end users (e.g. maize as food and sunflower for cash) (Akinnagbe & Irohibe, 2014). As adaptation response measures, grow and reproduce livestock that able to tolerate the challenging conditions of poor nutrition, parasites and diseases. Such measures could be distinguishing and improving local breeds that have adapted to local climatic stress and feed sources (Hoffmann, 2008). Livestock management systems are also adaptation strategies which include a lower number but more efficient productive livestock and changes livestock herd composition (Batima, 2006). Non-agricultural livelihood income diversification (labor work in a city, engaged in shopping, or processing agriculture products) may also happen as adaptation strategies to climate change vulnerability. Hence, agricultural and non-agricultural livelihood diversification may be exceedingly pertinent options to the farming households' as adaptation strategies to climate change vulnerability (Thornton et al., 2013).

The biophysical conservation is another adaptation strategy comprising soil and water conservation practices as a key aspect of the economic and environmental sustainability of all types of agricultural systems (López-Vicente & Wu, 2019). According to Mosissa (2019), biophysical practices for soil and water conservation enable to control land degradation and enhance productivity. WASWC (2005) itemized the biophysical conservation that includes agronomic, vegetative and structural land use management measures. However, there are different sources of adaptation response measure impediments comprising lack of information on adaptation options, scarcity of land, financial shortage, limited access to improved inputs, poor market and irrigation accesses (Deressa et al., 2009; Gebrehiwot & Veen, 2013). Technological limit is also another setback to abjure climate shocks (O'Brien, 2017).

A considerable number of studies in Ethiopia (Cherinet & Mekonen, 2019; Teklewold et al., 2019; Gezie, 2019; Mihiretu et al., 2019; Mekonnen et al., 2017; Assaye, 2016; Deressa et al., 2011; Deressa et al., 2009) have been indicated on the perception and adaptation actions by the farming communities to climate variability induced vulnerability. So far, studies on rural households' perception, adaptation strategies and impediments to climate variability induced vulnerability have been almost exclusively limited on agro-ecological zone or administrative Districts. However, this study was based on livelihood-zones that households share similar livelihood patterns (access to the same set of food and cash income sources, and similar market opportunities). Therefore, this study was aimed to investigate rural households' perception, adaptation responses and impediments to climate variability and extreme induced vulnerability across the livelihood-zones in the northeastern highlands of Ethiopia.

Materials And Methods

Description of the study area

This study was carry out across the six livelihood zones. namely, Abay-Beshilo Basin (ABB), South Wollo and Oromia eastern lowland sorghum and cattle (SWS), Chefa Valley (CHV), *Meher-Belg*, *Belg*, and *Meher* (USAID, 2009) in South Wollo Zone of Ethiopia, located between $10^{0}10'$N and $11^{0}41'$N latitudes and $38^{0}28'$E and $40^{0}5'$E longitudes (Fig.1). The total area of the Zone is about 17705.73km^2, which is divided into 19 rural districts and 4 administrative towns (ANRSPC, 2017).

Fig.1:

The rainfall amount and patterns have been defined by the annual, *belg* and *kiremt* seasons rainfall variability in space and time (Segele et al., 2015; Segele et al., 2009; Korecha & Barnston, 2006; Segele & Lamb, 2005). The region under study is known as *Kiremt* dominant bimodal rainfall peaks: *Kiremt* and *Belg* (Segele et al., 2015). The long-term average annual rainfall and temperature (minimum and maximum) in the northeastern highland of Ethiopia was indicated (Fig.2). Based on this long-term data, the average rainfall amount recorded ranges from the lowest value (15.13 and 18.04mm) in December and January to the highest value (264.78 and 270.50mm) in July and August. The highest peak rainfall of *Belg* season (Feb-to-May) in the study was observed in April while the highest *Kiremt* season (June-to-September) was indicated in July and August. The mean, maximum and minimum temperature also varies from the highest temperature values of 19.22, 26.6 and 11.82^{0}C in June to the lowest values of 14.68, 22.93 and 6.43^{0}C in December respectively. In the central part, where South Wollo is located, the rainfall has a bimodal regime small rainfall (*Belg* rainy season) observed from February to May while the highest rainfall (*Kiremt* rainy season) from June to September (Fig.2).

The traditional farming system both the rearing of animals and the growing of crops is the dominant economic activities in the livelihood zones of the study area. The existence of diverse agro-ecology enables farm households to grow varieties of crops and rearing of animals as means of livelihood (source cash and consumption) options (ANRSPC, 2017; SWAD, 2018). The agricultural activities are mainly rain-fed as a livelihood for the small holder farmers. The agricultural livelihood activities of the study for crop production follow *Kiremt* (big rainy season) and *Belg* rainfall, but vary between the livelihood zones. The old-style subsistence farming (a mix of both crop production and rearing of livestock) was the primary form of livelihood activities in all livelihood zones of the study area. The dominant crops cultivated across the study livelihood zones include barley, sorghum, *teff,* wheat, maize, lentils, faba beans, and haricot beans. Cattle, goats, sheep, and equines are the major livestock kept in widely different types of environment (Lawrence et al., 2010; USAID, 2009). However, the contribution of livestock in the livelihood of people was highly limited by internal and external livestock diseases and parasites (USAID, 2009; Little et al., 2006).

Fig.2:

Sampling techniques and sample size

This research employed a multistage and mixed sampling approach to obtain comprehensive information. In view of that stratified and proportional probability sampling techniques were used to select the study *kebeles* (the lowest administrative division) and participants from each livelihood zones. Above all, the study area was firstly stratified in to six (6) livelihood zones: Abay-Beshilo Basin (ABB), South Wollo and Oromia eastern lowland sorghum and cattle (SWS), Chefa Valley (CHV), *Meher-Belg*, *Belg*, and *Meher* based on USAID (2009) classification. Secondly, identified *kebeles* inclusively found within their respective livelihood zone and then simple random sampling technique was employed to select six (6), one *kebele* from each livelihood zone. Thirdly, the samples HHs were selected using simple random sampling procedures. In the case of finite population, the size of the sample may be estimated based on either our experience or personal judgment or the result of a pilot study or past data (Kothari, 2004). This study acknowledges previous studies of Ekise et al. (2013), Berlie (2013) and Barlett et al. (2001). Accordingly, the formula below was used to calculate the sample size as (Eq. 1):

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

Where: n = the sample size; N = total number of households which is the; p = 0.5 the sample proportion reliability and q = 1-p; e = 5% the margin of error/acceptable error considered; Z = 1.96 is the critical value for a 95% confidence interval.

Hence, 361 sample households were drawn using proportional simple random sampling techniques from a total of 6,018 household population. The selected *kebeles* were *Yewotet, Galemot, Mosebit, Tossa-felana, Ancharo* and *Arejio* from the livelihood zones of ABB, *Meher, Belg, Meher-Belg*, CHV and SWS respectively. The respective numbers of samples proportional to the size of the population in each *kebele* were 34, 81, 52, 95, 51 and 48 from ABB, *Meher, Belg, Meher-Belg*, CHV and SWS livelihood zones.

Data sources and collection techniques

This study was based on the qualitative and quantitative data from primary and secondary data sources. Historical monthly rainfall and temperature data were obtained from CenTrends Greater Horn of Africa precipitation v1 and Climate Research Unit (CRU) TS Version 4.01 respectively. Monthly rainfall data were obtained from CenTrends Greater Horn of Africa precipitation v1 while temperature data obtained from CRU_TS Version 4.01. Both the CenTrends and CRU data were obtained from KNMI climate explorer (https://climexp.knmi.nl/start.cgi). Moreover, data were also collected from survey questionnaire, key informant interview and Focus Group Discussion (FGD). Using survey questionnaire, data were collected from HH heads using semi-structured interview schedule. The qualitative information from FGD and key informant interview were also conducted to complement the survey. Key informants and FGD participants selection were carried out those knowledgeable people who have valuable viewpoints about local facts, thoughts and opinions related to community livelihood vulnerability. The selected key-informants and focus group discussants were with the purpose that they have more credibility and better acquaintance to provide constructive information. The interview Key informants include officials/experts at Zonal and district level, *kebele* development agent workers and community leaders. The interview guide questions were prepared prior to the interviewing to frame the interview focused on the objectives of the study. The interview guide questions were also unstructured that allow flexibility for interviewees to talk freely and to phrase the questions as they wish. The FGD was also carried out with participants by developing generic questions related to the topic being discussed and arranging assistances. The recruited participants in FGD integrated household farmers, local community leaders and development agent workers. The FGD was handled using developed unstructured generic questions related to the topic being discussed as a memory guide and arranging assistances. One FGD was conducted from each selected livelihood *kebele*.

Data analysis techniques

Precipitation Concentration Index (PCI) and Standardized Anomaly Index (SAI) model were employed to analyze the spatiotemporal variability and trends of rainfall and temperature in the study area as shown in the succeeding discussions. The analysis of temporal rainfall variability was computed using the Precipitation Concentration Index (PCI) as:

Precipitation Concentration Index (PCI) was employed to show the concentration of annual and seasonal rainfall.

$$PCIAnnual = \frac{\sum_{i=1}^{12} pi^2}{\left(\sum_{i=1}^{12} pi\right)2} * 100(2)$$

$$PCISeasonal = \frac{\sum_{i=1}^{4} pi^2}{\left(\sum_{i=1}^{4} pi\right)2} * 33.3(3)$$

Where: pi is the monthly rainfall in i th month
For this study, the annual and seasonal concentration of rainfall was calculated using PCI. Studies in De Luis et al. (2011), Valli & Krishna (2013), Al-Shamari (2016) categorized that PCI < 10 show a uniform rainfall

distribution (low rainfall concentration), between 11 and 15 illustrates a moderate rainfall concentration, 16 to 20 signifies irregular distribution and greater than 20 shows very high concentration of rainfall.

Standardized Anomaly Index (SAI) Model

The standardized anomaly index of rainfall and temperature were computed and used to assess the temporal pattern in climate variability studies of rainfall and temperature across the study region. Annual average rainfall and annual mean minimum, maximum and average temperature series were analyzed for fluctuation using Standardized Anomaly Index (SAI) which is a commonly used index for regional climate change studies (Koudahe et al., 2017; Babatolu & Akinnubi, 2013). Either rainfall or temperature is expressed as a standardized departure xi from the long-term mean (i.e. the mean of the base period), calculated as

$$SAI = \frac{pt - p_m}{\sigma} \quad (4)$$

Where: *SAI* = standardized rainfall/temperature anomaly; *Pt* = annual rainfall and temperature in year t; *Pm* = long-term mean annual rainfall and temperature over a given observation periods; *σ* = standard deviation of annual mean rainfall and temperature over the observation periods.

The survey data collected for the study were examined using statistical tools for frequency and percentage. Moreover, after the analysis of indices and modeling data related to the perception and observed climate variability as well as adaptation measures of study, profiles were illustrated using tables, figures, and graphs Non-numeric qualitative data obtained from focus group discussion, key informant interview were also analyzed using content analysis and then integrated with survey results.

Results And Discussions

Socio-demographic characteristics of sample households

Socio-demographic characteristics of the study population have implications on livelihood vulnerability and adaptation measures to climate variability and extremes. Table 1, Fig.3, 4 and 5 shows the socio-demographic characteristics of sampled households in terms of age and sex composition, marital status, household size and education level. Age (Fig.3) portrays farming experience, local climate variability perception and adaptation measures of the rural community. Through experience, farmers perceive and understand the challenges of climate variability and extremes, and implementation of various adaptation measures to reduce livelihood vulnerability to climate variability and extremes and associated risks. Therefore, the age structures of the surveyed households were examined. Hence, in terms of age category, the majority of respondents (73.67 %) were aged between 20–49 years. The remaining 22.87% and 3.47% of the respondents were belonged to 50 - 64 and ≥ 65 years of age respectively. In view of that, Deressa et al. (2011), Ishaya & Abaje (2008), Maddison (2006) exhibited that the higher the age of the farming households represents their experience in farming sector and the more likely to perceive climate variability and related induced vulnerability.

Fig.3:

The survey result indicates that, 329 (91.13%) males and 32 (8.87%) females were involved in the study across the livelihood zones out of the total 361 sampled households. Deal with marital status (Table 1), the majority 303 (83.82 %) of the surveyed households were married. The rest (6.57%, 4.65% and 4.97%) surveyed households were divorced, widowed and single respectively. This shows that the realities of rural households are taking the responsibility of farming activities after they married. Similarly, Soyebo et al. (2005) confirmed that much of rural agricultural livelihood is practiced by married people. On the sex category, 91.13% of the respondents were male headed household heads. This also supports the rural agricultural activities area engaged by married households where the male is the head.

Table 1

As presented in Fig.4, about 63% of the respondents across the entire livelihood zones had a household size between four and seven while 22.68% had ≤ 3 household size. Conversely, 14.4% of the respondents had ≥ 8 household size. The presence of large family size is responsible to increase events of climate variability and extremes through farmland fragmentation, decline in cultivated area per household size and resources degradation.

Fig.4:

Education can encourage people to change their attitudes and behavior; it also helps them to make informed decisions. Education is crucial to promote climate action. It helps people understand and address the impacts of the climate crisis, empowering them with the knowledge, skills, values and attitudes needed to act as agents of change. Accordingly (Fig.5), about 77% of the respondents did not attend any formal education. When this value is disaggregated, 52.13% were totally illiterate with no education of any kind and 24.92% were able to read and write. The households who attended primary and secondary schools constitute 15.35% and 7.6% respectively. From this result it is evident that there is high illiteracy rate which limits the rural farming households' access to different information sources and in turn results in unwillingness to utilize new technologies in their agricultural practices. Such perspectives also revealed by Deressa et al. (2011), Maddison, (2006) as the farming households' level of education increase their awareness and access to information on climate variability and induced vulnerability.

Fig.5:

Rural Households' perception and observed rainfall variability

According to Le Dang et al. (2014), Raworth (2007), preparedness regarding the adversative situation of climate variability and extremes, has been shown to correspond the perceptions/awareness levels of affected farming households. To convey adaptation action, local communities have to realize first their vulnerability from the induced calamity effect of climate variability and extremes. Therefore, it is imperative to have some understanding of the people inhabiting in the study area about climate variability and extreme event perception. Respondents were inquired about their perception related to the local variability and pattern of rainfall, changes in temperature and incidence of drought frequency over the past 20 years across the livelihood zones (Fig.6). The survey result reveals that a large number of the farming communities have perceived certain form of changes in climate variability and extreme events. Accordingly, 75.2% of the communities perceived that a decreasing trends of rainfall during therainy seasons. Household respondents in the livelihood zone of *Belg* perceived the highest proportion (87%) of decreasing in rainfall. Only small proportions of the respondents (13.2%, 7.2% and 3.8%) were perceived an increase, no change and do not know respectively. Changes in the shift of rainfall calendar in terms of late onset and early cessation were also noticed by the majority of the household respondents across all the livelihood zones. However, late onset and early cessation of rainfall differed among livelihood zones. For instance, late onset of rainfall ranged from 97.5% (in *Belg*) to 65.9% (in *Meher*) livelihood zones while perceived of early cessation rainfall ranged from 92.6% (in SWS) to 63.7% (in *Meher-Belg*) livelihood zones. Similar study result reports in different parts of Ethiopia and other countries (Simotwo et al., 2018; Weldegebriel & Prowse, 2017; Habtemariam et al., 2016; Ndamani & Watanabe, 2015; Deressa et al., 2011) were also ascertained that the farming households perceived rainfall variability and decreasing trend in amount.

Fig.6:

Historical observed rainfall data was also used to substantiate rural households' perceptions regarding the seasonal changes, anomalies and trend of precipitation in the area under study. Hence, the results of the seasonal changes, anomalies and trend of precipitation were revealed (Table 2, 3 and Fig.7). As it was exhibited in Table 2, the annual PCI in the period between 1900-2014 showed that rainfall was largely characterized by high irregular distribution ranged from 16% - 20% (77.4% of the observation years) and very high irregular distribution >20 (14.8% of the years) with a certain moderate rainfall concentration about only 7.8% of the years. Studied results of (Asfaw et al., 2018; Ayalew et al*.,* 2012; Bewket, 2009; Bewket & Conway, 2007) revealed similar conclusions to the occurrences of irregular annual rainfall distribution. Almost 92.2 % of the years in *Kiremt* season belongs to moderate rainfall concentration while 41% and 55.5% of the years correspond to low and moderate rainfall variability pattern of *Belg* season respectively.

Table 2

Significant variation in rainfall concentration has been also observed at the annual and seasonal time scales between the recent (1981-2014) period and the first eighty years (1900-1980). It was denoted in table 4, increasing of the very high irregularity of rainfall concentration was shown in the recent period (1981-2014) with about 27% of the observation year as compared to the period of 1900-1980 with about 10% of the observation years. Nevertheless, decreasing of the high irregularity of rainfall concentration observed in the recent period (1981-2014) with about 59% of the observation years than the first eighty years (1900-1980) with 85% of the observation years.

A considerable amount of rainfall reduction had been observed in the annual mean, as well as *Belg* and *Kiremt* seasons (Table 3). The mean annual total as well as *Kiremt* and *Belg* seasons rainfall amount for the period of 1900-1940 was found to be 1020.35 mm, 701.34 mm and 242.02 mm respectively. However, these amounts were decreased by 47.24 mm, 40.67 mm, and 19.87 mm for mean annual as well as *kiremt* and *belg* seasons espectively between the recent period (1981-2014) and the first four decades (1900-1940). Therefore, much of the declined (86%) in the annual rainfall amount contributed from kiremt season. Similar finding of Asfaw et al. (2018) in Woleka sub-basin of south Wollo indicated that mean annual and *kiremt* season rainfall decreased radically to 101.2mm and 92.6mm respectively although the minimal change of rainfall (6mm) observed in *belg* season between the periods of 1901-1940 and 1981-2013.

Table 3

As shown in Fig.7, the higher negative rainfall anomalies were observed for *belg* (51%), *kiremt* (47%) and annual (52%) negative anomalies. The study also investigated that the annual negative anomalies much higher for the recent period of 1981-2014 (62%) than the period of 1900-1980 which was 39%. Likewise, *kiremt*and (*belg)* seasons proportion of negative anomalies for the recent period (1981-2014) were 56% and (53%) higher than the 1900-1980 period, which was 41% and (50%). Results of these rainfall anomalies agreed with the works of Bewket (2009) and Bewket & Conway (2007) for the period of 1961-2003 with negative anomalies ranging from 39%-53% in drought-prone areas of Amhara Region. Similarly, Ayalew et al. (2012) investigate a negative anomalies ranging from 46%-66% for the period of 1979-2008 in the Amhara Region as well as Urgessa (2013) calculates negative anomalies ranging from 33.3%-84.75% for the period of 1952-2012 in the arid and semi-arid parts of Ethiopia. Moreover, of all the observation years, 1984, 1987, 1999, 2009 and 2013 were found to be the highest negative rainfall anomalies (the lowest rainfall amount) ever recorded at annual as well as *kiremt* and *belg* seasons in the study region in the recent period of 1981-2014. Similar findings of Viste et al. (2012), (Conway (2000) distinguished the observed years of 1984, 1987, 1999, 2009 as the lowest rainfall amount of years in most parts of Ethiopia.

Fig.7:

Rural Households' perception and observed temperature variability

Time-to-time increasing of the local temperature perception was reported (Table 4) by 87.5% of the respondents, but varied across the livelihood zones that ranged from 93.7% (in *Belg*) to 77.9% (in CHV). Insignificant proportions of the respondents (3.25%) were conversely perceived a decrease in temperature changes. The rest perceptions of no change and do not know in temperature changes accounts about 3.43% and 5.82% respectively. Experience about drought perception and frequency of drought occurrence across the livelihood zones were also reported by the respondents. On average, each study livelihood zones experience drought by about 79.17% of respondents and 6.18 times drought frequency occurrences over the past 20 years. This might be associated with increased temperature and decreased in rainfall over the livelihood zones. Similarly, research findings of elsewhere in Ethiopia (Cherinet & Mekonnen, 2019; Mekonnen et al., 2017; Weldegebriel & Prowse, 2017; Habtemariam et al., 2016; Deressa et al., 2011) were reported that the farming communities perceived increasing of temperature.

Table 4

Historical observed temperature datawas also used to validate rural households' perceptions pertaining to the anomalies and trend of temperature in the area under study. Hence, the results of temperature anomalies and trends were revealed (Fig.8).The standardized anomalies (Fig.8) showed that inter-annual variability of temperature had been observed for the annual average, maximum and minimum over the period of 1901-2016.

However, the annual average, maximum and minimum temperature anomalies had been increased positively almost continually after 1990 which supports the theory of global warming trends of the 20th century. For instance, almost the 1980s onwards for minimum temperature and the 1990s onwards for annual average and maximum temperature has shown positive anomalies. Moreover, of the total number of observations in the recent period of 1981-2016, the highest proportion of positive anomaly (about 78%) was observed in the minimum temperature as compared to that of the maximum (about 56%) and average temperature (50%). On the other hand, in the period of 1901-1980, the overall increased proportion of positive anomalies found to be about 39%, 38% and 41% for annual average, minimum and maximum temperature.

Fig.8

Information obtained from Focus Group Discussion (FGD) and Key Informant (KI) interview corroborated that similar sympathetic was noted on the variability pattern of rainfall and increasing temperature across the livelihood zones. Perceived change in the variation of temperature and rainfall characterized by FG discussants and key informants was in terms of the variation and declined in rainfall amount, discontinuous in distribution and erratic in its onset and ending. Sometimes anticipated rainfall brought about substantial losses (quality and quantity) due to damages on matured crops during the harvesting period as reported by the respondents. Therefore, increased exposure risk owing to rainfall variability and changes in temperature within the study households across the livelihoods was observed. The frequent variation in rainfall and increasing temperature worsen the vulnerability of the rural households' with the influences on poor performance in agriculture and food security outcomes. Information obtained from the KI interview and FGD, different exposure hazards to vulnerability were reported at each livelihood zones. For instance, the manifestations of climate change exposure and observed impact on farmers' agricultural practices were erratic rains to SWS, *Meher* and ABB livelihood zones; frost and hail storms to *Meher* and *Belg* livelihood zones; and flood to SWS while malaria to ABB. Crop pest infestations, livestock diseases, shortage of rainfall were reported as the common hazards to vulnerability across the livelihood zones. Basically, rural households' perception in rainfall variability, changing in temperature, and frequent drought occurrence were substantiated with the observed meteorological records of the study area in Mekonen & Berlie (2020; 2021); Mekonen et al. (2020). Similar findings in the perception of rainfall variability and extreme events, increased the frequency and severity of natural shocks in recent years in different parts of Ethiopia has been reported by Tessema & Simane (2019); Asfaw et al. (2018); Teshome & Baye (2018); Teshome (2016a; 2016b); Mahoo et al. (2013); Berlie (2013).

Box.1: Perceived climate variability and extreme events.
A Key Informant was an elderly (about 63 years old) man from *Belg* livelihood zone. He has grown and lived in the area and shared what he perceived about climate variability and extreme induced vulnerability as:
... our livelihood activities have been compromised by the defies of natural hazard in the form of deficit and unpredictability of rainfall, increased temperature and frequent drought occurrences. For instance, increased rainfall variability and shift in the seasonal rainfall calendar in terms of late onset and early cessation perceived over the past 20 years in the area. Even now and in the future we have worried of such unreliable and unpredictable nature of rainfall will continue. These uncertainty influences our decision on when and what crops to plant. i.e crop production activities in terms of the timely ploughing, planting and harvesting are seriously affected that subsequently exposed us to livelihood vulnerability. Temperature also perceived as increasing over the years. The manifestation of increased temperature was observed as: ***(i).*** *the incidence of disease and pest increased that subsequently decreased the level of crop and livestock productions and productivity.* ***(ii).*** *the shift in the cultivation zone of crops like Teff (Eragrostis abyssinica), Noug (Guizotia abyssinica) and maize (Zea mays) have now started growing at the margin area that were not cultivated previously.*

Households’ adaptation strategies to climate variability induced vulnerability

Rural households verified that the greatest influences on the rain-fed agricultural production are result from increasing temperature, rainfall variability in terms of changes in the seasonal pattern of rainfall and prolonged incidences of drought. The farming households have various notions on how to prepare for climate variability and extremes induced vulnerability and to move out of destitution. Equally, the farming households of South Wollo, Northeastern Highlands of Ethiopia undertake various adaptation strategies to tackle the long-term impacts of climate variability and extreme events across the livelihood zones. The adaptation techniques were identified by querying the rural households about the actions they take against the adverse influences of climate variability and extremes induced vulnerability. Local level adaptation strategies practiced in the study livelihood zones comprises natural resource management, and crop and livestock productions.

The rain-fed agricultural sector in Ethiopia is highly vulnerable to rainfall variability, increasing temperature and land degradation (Tesfaye et al., 2017). However, agricultural livelihood sources management practices may perhaps increase agricultural production and reduce productionrisk also tends to support climate change adaptation (Bryan et al., 2013).The responses toclimate variability and extremes induced vulnerabilityare using the practices of natural resource management which includes soil and water conservation. Therefore, the adaptation response measures of soil and water resources conservation practices were implemented at the household’s level against the changing local climatic and environmental degradation.In the Ethiopian highlands terracing is widely used, just as grass stripping, soil bunds, stone bunds and alley cropping (Hurni et al., 2010).The commonly behaved conservation measures of soil and water resources in the study livelihood zones includes contour plowing, soil and stone bunds, check dam, hillside terracing, planting trees, crop rotation, and mixedintercropping. However, adaptation responses to avert climate variability and extremes induced vulnerability vary among the livelihood zones (Fig.9). Contour plowing and crop rotation are common practices adaptation intervention practice by almost all rural households for the changing climate variability and extremes across the livelihood zones. The survey result revealed that households involved in adaptation strategies of building soil and stone bunds, check dams, hillside terracing and planting trees accounts about 46.02%, 25.62%, 51.67% and 53.72% of the total respondents respectively. Mixed intercropping farming system is important to control weeds, pests and disease, improves soil fertility,greater use of environmental resourcesand increases agricultural production (Bayu et al., 2007; Mousavi & Eskandari, 2011).

However, the practice of mixed intercropping farming system as adaptation strategy by households' in the study livelihood zones only accounts about 20.33%. *Teff* with sunflower, Sorghum with bean, are some of the mixed intercropping farming practiced in ABB, *Meher* and SWS livelihood zones.Equally, at community level, households' were involved in the physical and biological soil and water conservation measures such asbuilding soil and stone bunds,afforestation/reforestation activities. For instance, 83.7% and 83.2% of respondents were participated in the adaptation measures ofbuilding soil and stone bunds,and afforestation/reforestation activities implemented at the community level.Households' involvement in building soil and stone bunds, check dams and planting trees adaptation measures were basically organized and implemented by government intervention at the District and *Kebele* levels as scheduled adaptation strategy. The Ethiopian Government has initiated a massive community-based soil water conservation program in the last two decades, and this has become effective in conserving soil and water and improving livelihoods particularly in the northern part of the country (Tesfaye et al., 2017). Large efforts have been made to conserve soil and water through a range of techniques including stone bunds, soil bunds, and check dams (Alemayehu et al., 2009; Nyssen et al., 2009).There has been a long tradition of building soil and water conservation structures e.g. stone and soil bunds via the local agricultural offices as food for work in Ethiopia (Rosell, 2014).Di Falco & Bulte(2013) also reported that tree planting, soil bunds, cultivation of hedges,contour plowing, irrigation, and water harvesting are common climate variability and extremes adaptation strategies relevant in Ethiopia.

According to the information obtained from Zonal and Districts' key informant interview, stone and soil bunds were constructed along the contour and become stable with vegetative measures, such as grass and animal fodder trees. These bunds reduce the rate of runoff and soil erosion, retain water behind the bund and help water permeation. Moreover, from the viewpoint of climate variability and extreme events adaptation, practices of stone and soil bunds protect the rural households' livelihoods source (land) from the impact of heavy rainfall. Even, in drought years, the improved retention and infiltration of water into the soil, increasing the amount of water available to plants and guaranteeing from failure of agricultural crops at early stage and anticipated yield loss.

Fig.9:

The practices of livelihood crop and livestock productions are also observed from the survey result as an adaptation strategy against the impact of climate variability and extremes by certain proportion of households across the livelihood zones. The most important responses of crop productions as adaptation strategy include crop diversification, farming early maturing crop varieties, farming drought tolerant crop varieties, planting Chat/eucalyptus tree and adjusting crop planting calendar. These adaptation measures taken by rural households were varied across the livelihood zones (Fig.10). The response of crop diversification as adaptation strategy accounts about 67.7% of the total respondents. The most common diversified livelihood crops cultivated include sorghum, *teff,* wheat, maize, barley, haricot and faba beans, and lentils but vary among the livelihood zones. For instance, as the information obtained from key informant interview of Zonal agricultural expert, ABB, *Meher-Belg*, CHV and SWS livelihood zones mainly diversified their crop production engaged in the cultivation of sorghum, *teff* and maize. Barley, faba beans, and lentils were the major crops cultivated in *Belg* livelihood zone. Likewise, wheat, *teff*, vetch and red sorghum crops are grown in *Meher* livelihood zone.

Planting chat (*Catha edulis*) and eucalyptus tree (64.9% of the total respondents) were also important adaptive measures against the impact of climate variability and extremes. Farming early-maturing crop varieties, farming drought tolerant crop varieties and adjusting crop planting calendar as adaptation strategy in response to the deficit of rainfall, and the changing onset and cessation of rainfall were reported by 37.38%, 34.17% and 76.22% respondents respectively. These strategies are also justified by the fact that most focus group discussants of rural households have experienced crop failure due to severe terminal moisture stress in the past 20 years. Accordingly, comparable adaptation strategies such as planting different and early mature crop varieties, adjustment in planting calendar were reported by focus group discussants across the livelihood zones. These farming strategies can help to minimize the vulnerability of rural households to the changing rainfall patterns and drought or low rainfall on farming activities. Focus group discussants particularly reported that rural households' adaptation response through the adjustment in planting calendar was aims at changing the dates of the farming activities to coincide with the rainy season. Hence, farmers largely change activities of land preparation and crop sowing dates either forward or backward based on previous calendar. Because of ambiguities related to climate variability and extremes, farmers have to start land preparation activities earlier to be ready in case earlier onset of the rainy season. Trusting on personal experience, majority of the farming households designed their agricultural calendar by themselves. Similarly, (Deressa et al., 2008; Lobell et al., 2008; Berlie, 2013; Asrat & Simane, 2017; Tessema & Simane, 2019) reported that the practices of crop diversification, adjusting crop planting calendar, using improved inputs (farming early maturing and drought tolerant crops) were adaptation responses to climate variability and extremes vulnerability. FAO (2009) also reported that these adaptation measures believed to reduce the rural households' vulnerability to climate variability and extremes such as seasonal shifts in the timing of rainfall and prolonged drought.

Fig.10:

Livestock production is another livelihoods opportunity to rural households as adaptation strategy against climate variability and extremes vulnerability across the livelihood zones (Fig.11). The survey result showed that livestock diversification as adaptation measure accounts about 69.72% of the total respondents. The reported livestock diversification practiced by the respondents as adaptive strategies include the rearing of cattle, sheep, goats, equines, and chickens but differs among the livelihood zones. Reducing the number of livestock kept, sale of some livestock before the incidence of long dry season and changing types of livestock kept were reported actions carried out by 53.47%, 50.23% and 28.28% respectively as responses to livelihood vulnerability to climate variability and extremes. Practices of keeping improved livestock breads and engaged in planting improved livestock feeds as adaptation strategy against livelihoods vulnerability to climate variability and extremes were very small proportion, which accounts about 0.80% and 4.87% respectively.

Similar studies of Bewket (2012), Bryan et al. (2011), Deressa et al. (2010), FAO (2009) have reported that livestock production widely used as adaptation strategies to climate variability and extremes vulnerability in different parts of Ethiopia and Africa.

Fig.11:

Income diversification was also another adaptation strategy against climate variability and extremes induced vulnerability across the study livelihood zones. Accordingly, the reported income diversification includes sales of crop and livestock, sales of firewood/charcoal and construction materials, safety net program, agricultural labor, and employment in Towns (Fig.12). The survey result showed that the majority of rural households' income (79.4% of respondents) obtained from sales of crop and livestock. Income from sales of firewood/charcoal and construction materials (45.3% of respondents) also plays a substantial proportion with beat differences across the livelihood zones. Labor related income sources such as involving in productive safety net program, agricultural labor, and employment in Towns were reported by 17.1%, 32.8% and 23.1% respondents respectively as adaptation strategies in response to livelihoods vulnerability. Similarly, Ellis (2000), Chavas & Di Falco (2012), Berlie (2013) showed that components such as sales of crop and livestock, wages, remittances and payments in-kind (e.g. food) are popular climate related risk adaptation strategies in Ethiopia and other developing countries.

However, impediments of adaptation measures to climate variability and extremes were reported from survey and focus group discussants. During FGDs, farming households raised the issue of free grazing livestock for poor physical and biological soil and water conservation measures. Rural households did not implementing restricted/controlled livestock grazing due to stocked crop residues and hay were not enough coupled with recurrent drought until the next harvest season. Hence, following harvest all cropland become open to free grazing until the next growing season. Therefore, this free grazing practice has a destructive effect on the conservation efforts, as trampling livestock often damage physical conservation structures such as stone terraces and stone/soil bunds. The vegetative cover/biological means of conservation is also grazed and damaged. Focus group discussants were also most frequently and largely discourse the lack of knowledge, inadequate information and limited technical support, inadequate access to improved crop varieties, lack of financial capital and lack of modern equipment as impediments to carry out effective adaptation strategies to climate variability and extreme induced vulnerability across the livelihood zones. The survey result also showed similar adaptation impediments as reported by almost all rural households for the changing climate variability and extremes across the livelihood zones.

Fig.12:

Conclusion

Vulnerability assessment is a vital juncture in designing operational adaptation strategies. A significant number of the farming households have perceived their vulnerability from the climate variability. Therefore, rural households have engaged in a range of adaptation measures. Various adaptation strategies such as biophysical soil and water conservation, crop and livestock diversification by planting and rearing variety of crop and livestock, and changing crop planting and harvesting dates according to the changing pattern of rainfall were implemented. However, there is a great gap between the actual executed adaptation strategies and rural households' level of perception. Executed adaptation strategies are insufficient as compared to the imposed vulnerability challenges by climate variability. The practice of free grazing impacted the effort of sustainable physical and biological soil and water conservation measures. Moreover, households shortfall on weather forecast information, inadequate application of improved farm inputs such as early-maturing and drought resistant crop varieties. All these demands the government, communities, and other stakeholders at different level could be implemented by designing distinctive integrated livelihood zone-based adaptation strategies to reduce the vulnerability of crop-livestock mixed agricultural system livelihoods from climate calamity.

Abbreviations

ABB: Abay-Beshilo Basin; ANRSPC: Amhara National Regional State Plan Commission; CHV: Chefa Valley; EPCC: Ethiopian Panel on Climate Change; FAO: Food and Agricultural Organization; IPCC: Intergovernmental Panel on Climate Change; KNMI: The Royal Netherlands Meteorological Institute; PCI: Precipitation Concentration Index; SAI: Standardized Anomaly Index; SWAD: South Wollo Agricultural department: SWS: South Wollo and Oromia eastern lowland Sorghum and cattle; UNFCCC: United Nations Framework Convention on Climate Change; USAID: United States Agency for International Development; WASWC: World Association of Soil and Water Conservation.

Declarations

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Not applicable

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Tables

Table 1

Sex and marital status characteristics of sample households by livelihood zones (%).

Category		Livelihood zones						Total (%)
		ABB	Meher	Belg	Meher-Belg	CHV	SWS	
Sex	Male	91.7	89.2	93.2	90.5	90.3	91.9	91.13
	Female	8.3	10.8	6.8	9.5	9.7	8.1	8.87
Marital status	Single	3.3	4.4	6.7	6.1	3.7	5.6	4.97
	Married	84.4	87.6	83.3	81.1	84.4	82.1	83.82
	Divorced	7.8	4.4	4.9	5.6	8.5	8.2	6.57
	Widowed	4.5	3.6	5.1	7.2	3.4	4.1	4.65

Table 2

Annual and seasonal Precipitation Concentration Index (PCI)

PCI Index (%)	Observed PCI at Annual, Kiremt and Belg (%)								
	1900-1980			1981-2014			1900-2014		
	Annual	*Kiremt*	*Belg*	Annual	*Kiremt*	*Belg*	Annual	*Kiremt*	*Belg*
<10	-	8.6	50.6	-	6	17.6	-	7.8	41
10-15	5	91.4	47	15	94	76.5	7.8	92.2	55.5
16-20	85	-	2.5	59	-	6	77.4	-	3.5
>20	10	-	-	27	-	-	14.8	-	-

Table 3

Mean change of *Belg, Kiremt* and annual rainfall (1900-2014).

Seasons	Mean			Mean Change
	1900-1940	1941-1980	1981-2014	1900-2014
Belg	242.02	225.70	222.15	19.87
Kiremt	701.34	691.29	660.67	40.67
Annual	1020.35	1004.64	973.11	47.24

Table 4

of Rural households' perception of local temperature change and drought incidence (%)

Change factors	Livelihood zones						Total
	ABB	Meher	Belg	Meher-Belg	CHV	SWS	
Temperature:							
Increasing	86.6	90.3	93.7	87.1	77.9	89.4	87.50
Decreasing	3. 4	0	1.4	3.3	6.8	4.6	3.25
No change	2.8	3.6	2.4	4.6	4.7	2.5	3.43
Don't know	7.2	6.1	2.5	5.0	10.6	3.5	5.82
Drought:							
Drought Experience	75.3	78.2	93.7	86.9	69.9	71	79.17
Drought Frequency (Years)	5.3	6	7.4	5.8	6.7	5.9	6.18

Figures

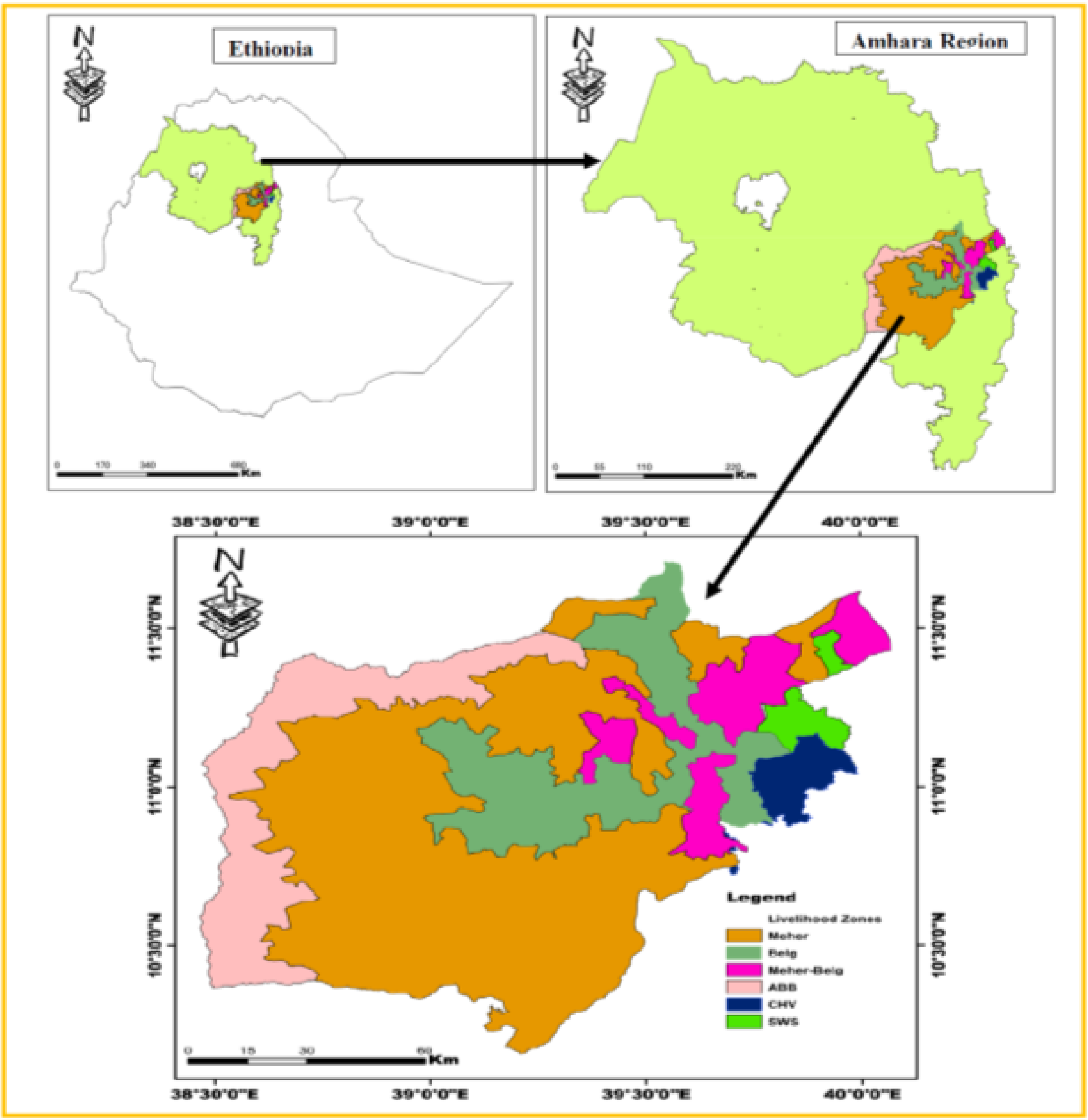

Figure 1

Geographic location and livelihood zones of South Wollo, northeastern highlands of Ethiopia

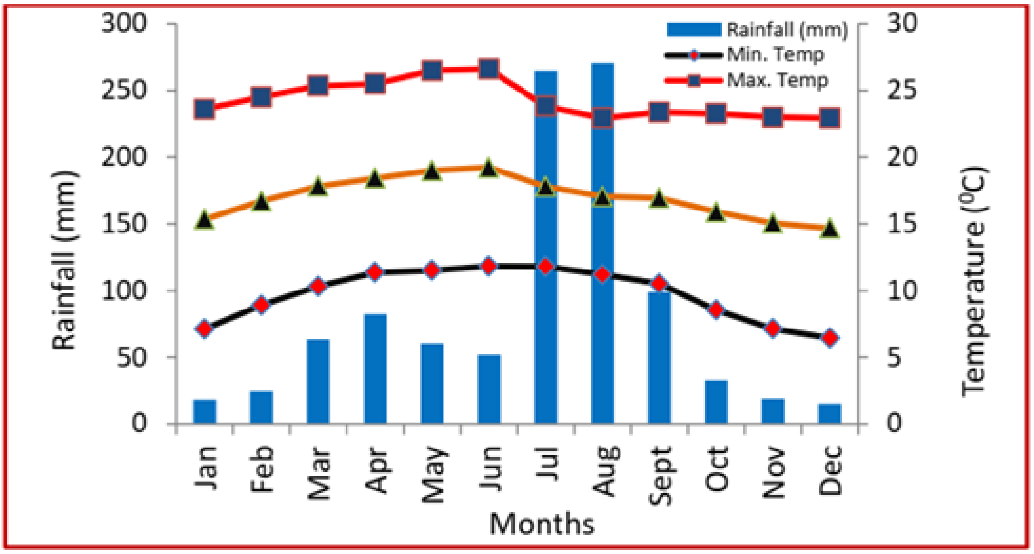

Figure 2

Monthly average rainfall and temperature of the study area, Northeastern highlands of Ethiopia

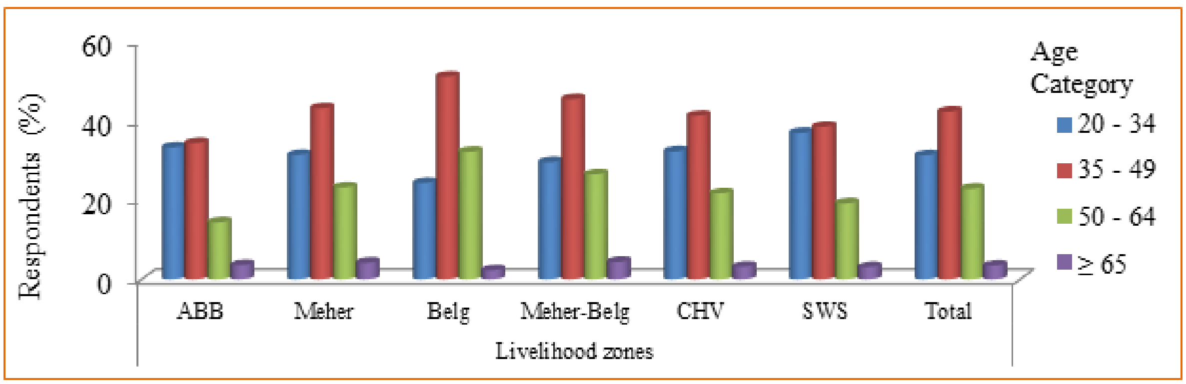

Figure 3

Age categories of respondents across the livelihood zones

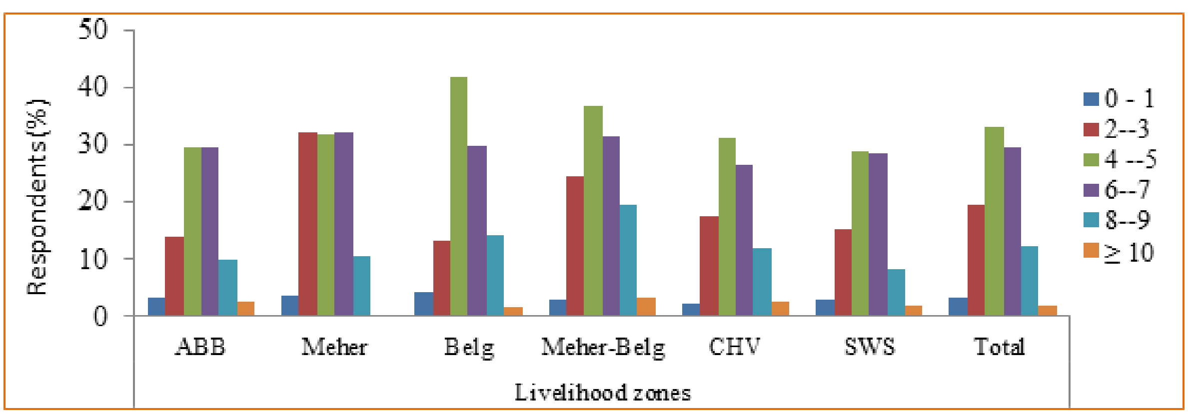

Figure 4

Family size of respondents across the livelihood zones

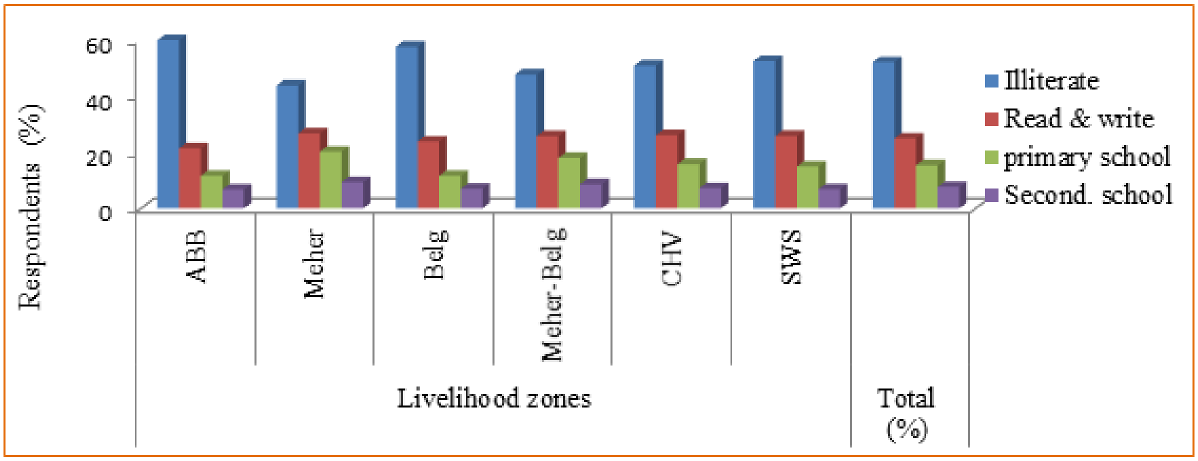

Figure 5

Educational level of respondents across the livelihood zones

Figure 6

Perceptions of rural households' on local climate (rainfall) changes across the livelihood zones

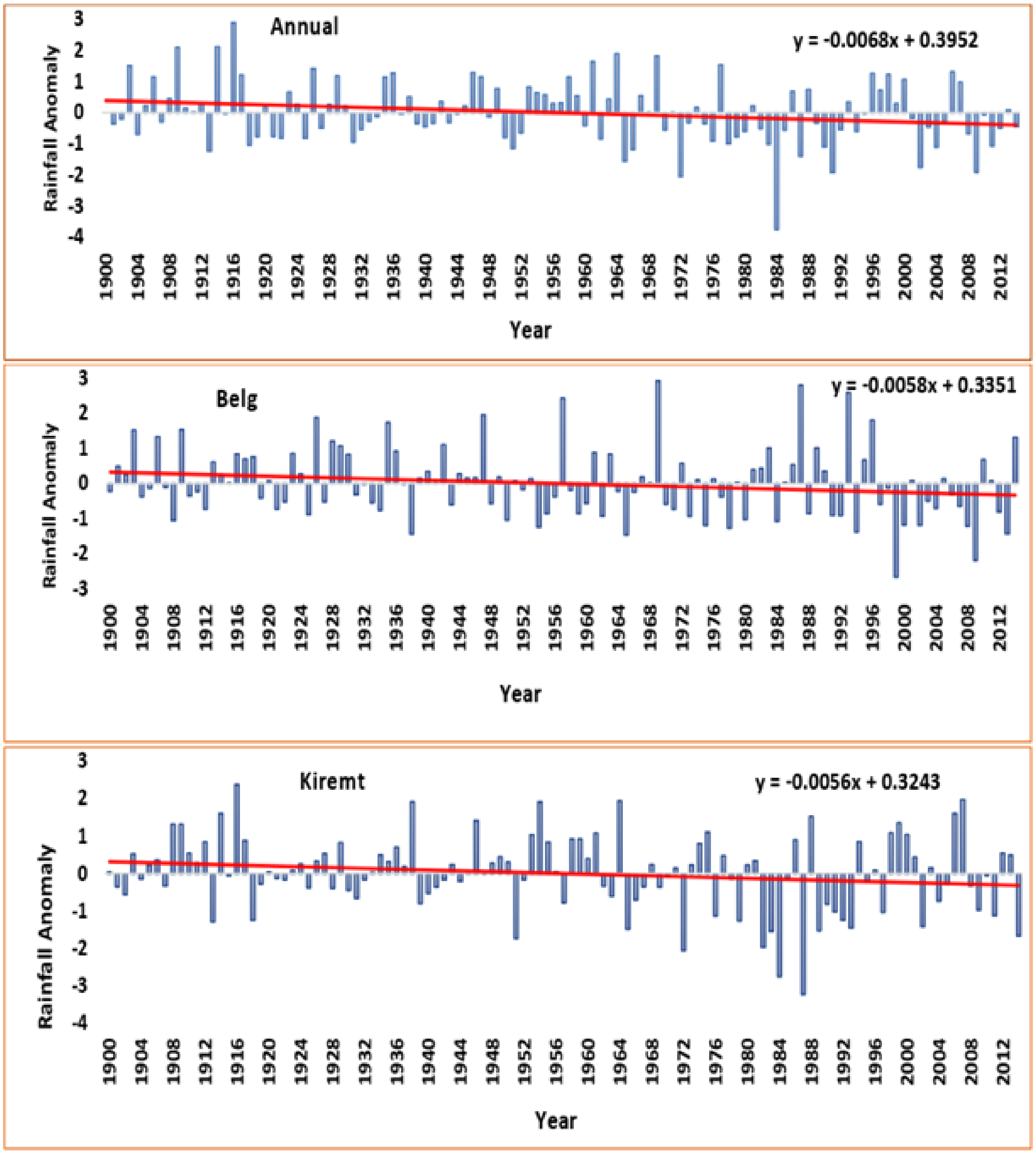

Figure 7

Temporal anomalies of annual, belg and kiremt rainfall (1900-2014).

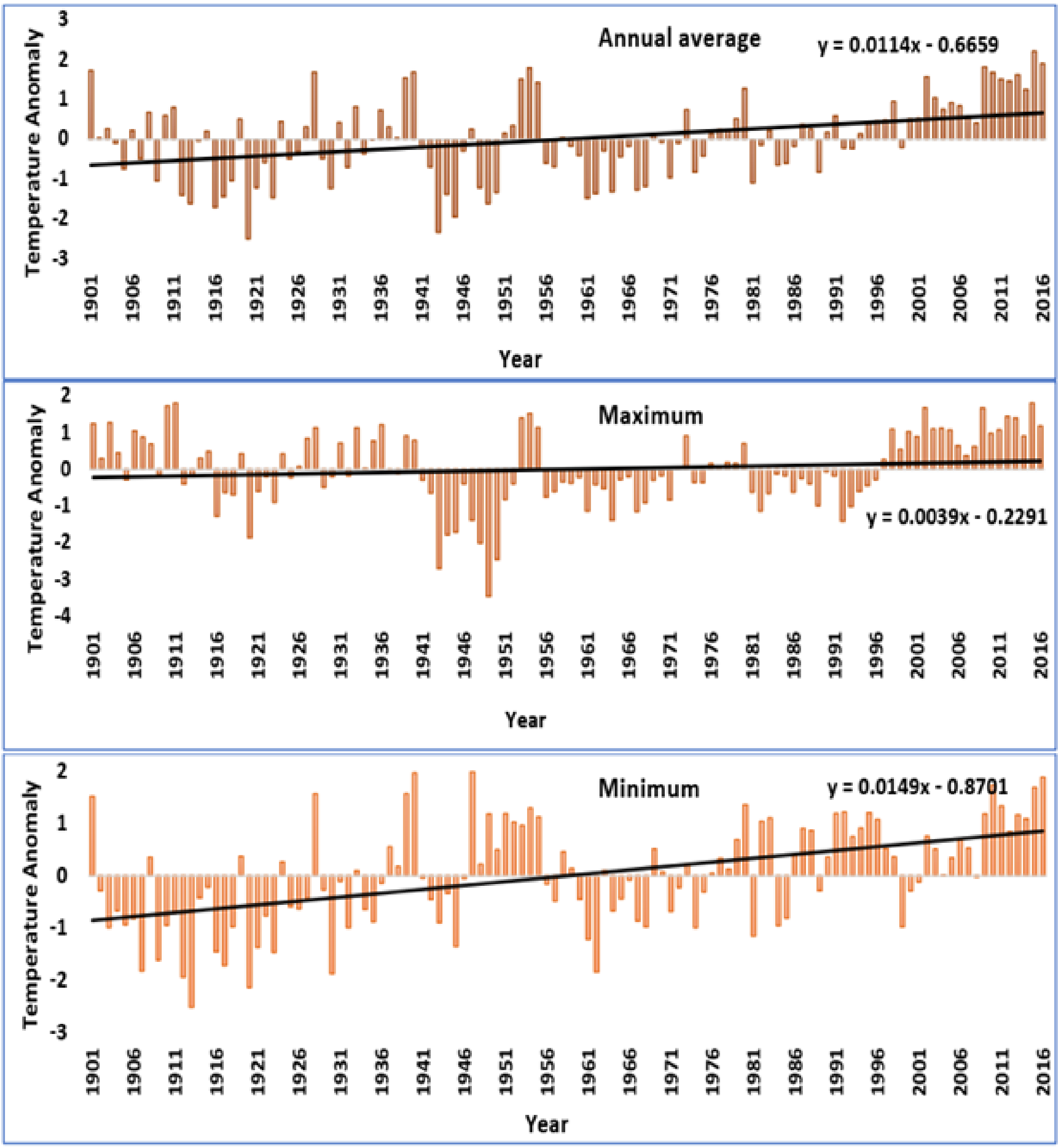

Figure 8

Temporal anomalies of minimum, maximum and annual average temperature (1901-2016).

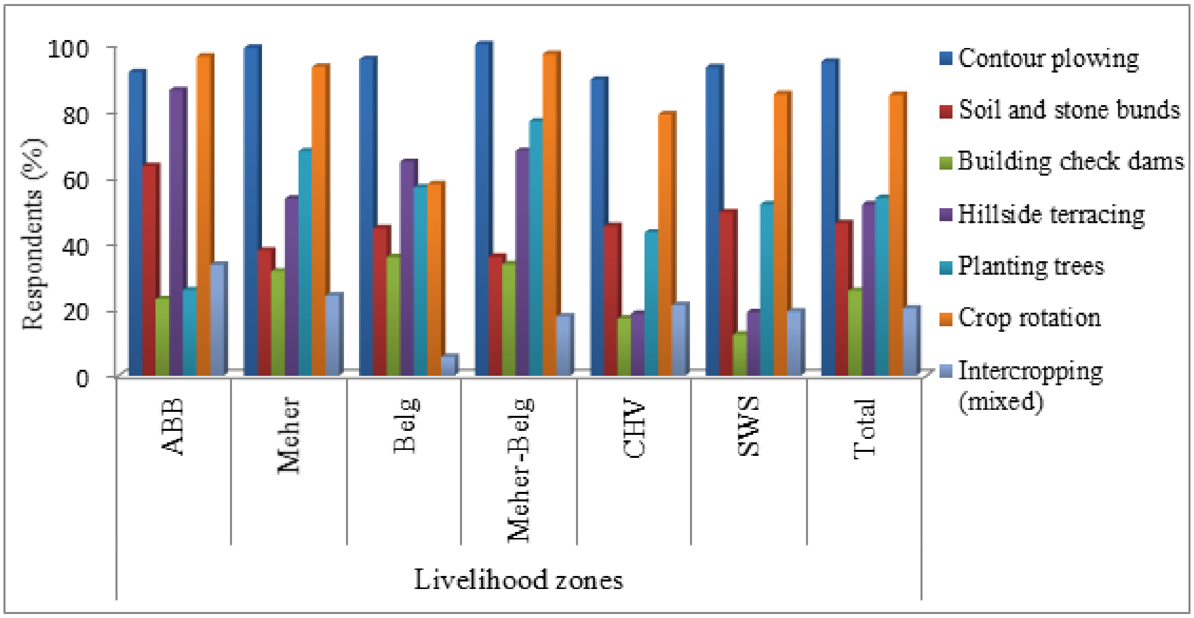

Figure 9

Farm level physical and biological adaptive strategies to local climate variability induced vulnerability

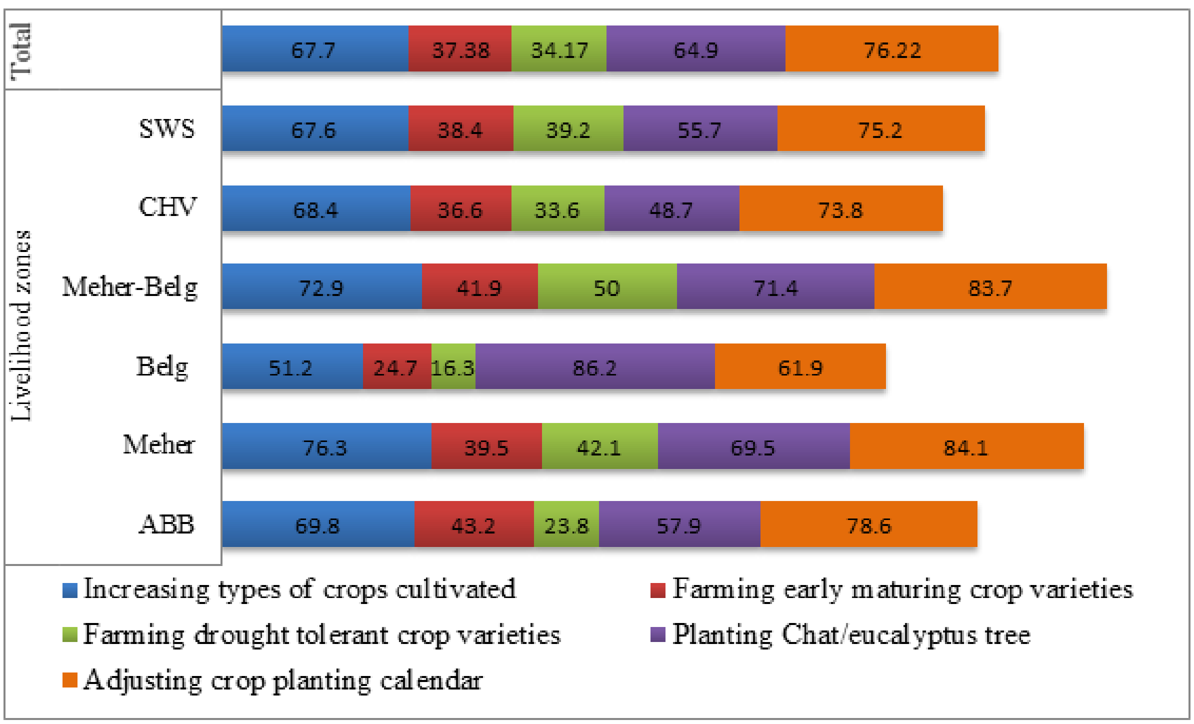

Figure 10

Crops as adaptation strategies against climate variability induced vulnerability across the livelihood zones (respondents in %).

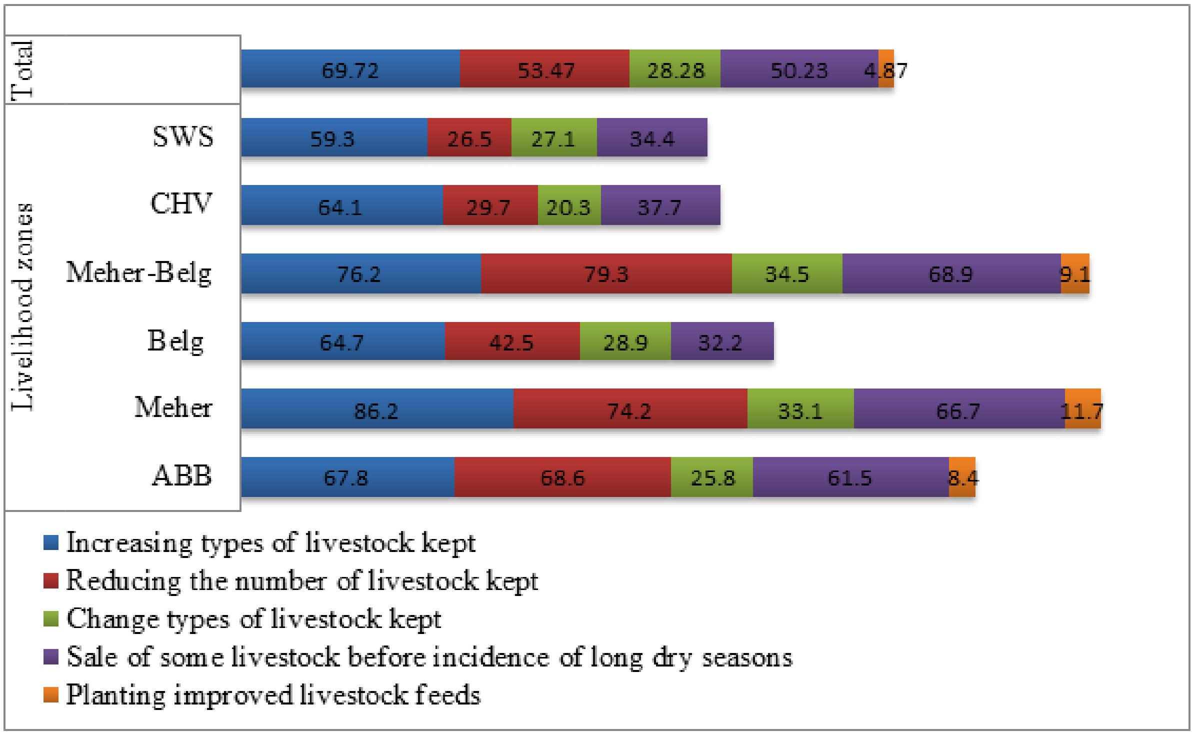

Figure 11

Livestock as adaptation strategies against climate variability induced vulnerability across the livelihood zones (respondents in %).

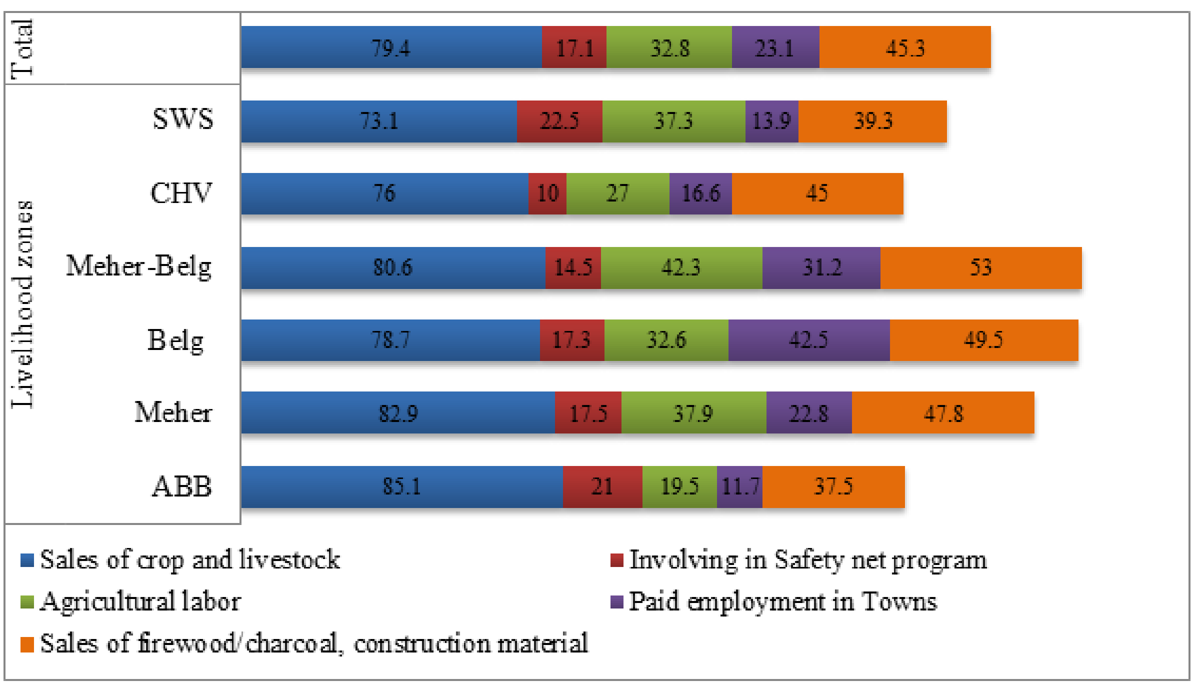

Figure 12

Income diversification as adaptation strategies against climate variability induced vulnerability across the livelihood zones (respondents in %).