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Abstract

Background: Drought is one of the most damaging climate-induced threats impacting the lives of many people every year. The purpose of this study was to determine farmer's drought coping strategies both proactive and reactive responses at household level based on the field survey in Raya Azebo and Raya Chercher districts, southern Tigray, Ethiopia. Agro–climatological based 246 households were sampled from the lowlands (36), midlands (202) and highlands (8). Multinomial logit model was used to identify best drought coping strategies.

Results: about 24.8% of female headed and 75.2% of male headed respondents have experienced mild to extremely severe drought in the last three decades. A significant association between the various drought severity and household heads (chi–square= 9.861, df=3, p–value< 0.05) observed.

Conclusions: this study concluded that collection and saving of pasture, soil and water conservation practices, and use of weather prediction information to adjust saving and farming system are best proactive drought coping strategies. Whereas, feeding of roasted cactus for livestock, borrowing loans for running small business, selling of household assets and reduction of food consumptions are the major reactive or off–farm drought coping strategies in the study area. If the responses of smallholder farmers are not well supported by the concerned bodies, the existing disaster preparedness and early warning systems in the area might be significantly affected and its impacts will be very serious on both the livelihood of local people and natural resources in the area.

Keywords: drought response, coping strategies, multinomial logit model, Southern Tigray

1. Introduction

Drought is one of the most devastating climate induced risks that affect the lives of many people annually (Gidey et al., 2018a, Velpuri et al., 2016, Wilhite et al., 2014). It is originated primarily from a precipitation deficiency and shortage of soil moisture due to the rising of surface and air temperature. For instance, droughts occurred across all parts of the world during the periods of 2001–2010 (Wilhite et al., 2014). This shock has been causes of a decline in agricultural production and productivity all over the world (Gidey et al., 2018b). However, the response of government and other concerned bodies have been poorly managed globally and this approach has been ineffective, and poorly coordinated (Wilhite et al., 2014). There have been also no rigorous attempts at the global level to initiate dialog on formulating and implementing national drought policies that include a basis for proactive, risk–based management to resolve drought impacts (Wilhite et al., 2014). As a result, the effects of drought in Africa are getting worst because most of the farmers are relying on rain–fed agriculture and limited capacity to cope–up with the impacts due to high levels of poverty, lack of skilled human resources and technologies. It is also highly anticipated that agricultural production and productivity of the continent to be more affected in the near future due to shortage of rainfall. In this paper, the term coping strategies referred to the short term responses to the adverse impacts of drought. The effect may differ in each agro–climatic zone (Mehar et al., 2016). At present, several parts of the sub–Saharan Africa have faced with a 10–40 % chance of failed seasons during the main cropping period (Shiferaw et al., 2014). For example, drought has severely affected maize crop which is one of the continent's most important crops (Wossen et al., 2017) and deteriorates a significant number of livestock. While agriculture has been the first and most affected sector, many other sectors have also practiced substantial decreases (e.g., energy production, tourism, and urban water supply) (Wilhite et al., 2014). Consequently, Agriculture in Africa (e.g., Greater Horn and Southern Africa) is highly sensitive to drought due to increasing climate variability and change (Shiferaw et al., 2014; Speranza, 2010, Thompson et al., 2010) e.g., erratic and highly variable rainfall both in amount and distribution. As a result, the water resources have been significantly affected in the area. Shiferaw et al. (2014) reported that the regions of Eastern and Southern Africa are primarily characterized by semi–arid and sub–humid climates with an extreme dry season. For example, the prolonged dry season has resulted in wide spread crop failure in 2013 and 2015 across Namibia (Wilhite et al., 2014) and Ethiopia. Twongyirwe et al. (2019) reported that drought induced food insecurity is a critical problem affecting about 6.3% of the households in Uganda. Speranza (2010) stated that there are also an extensive drought impacts not only on crops, but also on livestock in Kenya and 80 per cent of the area is arid and semi–arid, with pastoralism and agro–pastoralism being the dominant rural livelihoods. For decades, Ethiopia has been seriously affected by a prolonged drought due to climate change and variability, environmental degradation and other related factors. The changes in the climate have brought direct impacts on livelihood assets, health, food, and water security (Amsalu and Adem, 2009). As a result, the production and productivity of major crops such as teff, barley, maize, wheat, sorghum and others) yields have truncated. The economic and social growth of the country has also been greatly affected by this tragedy. Approximately 98% of farmland relies on rainfall and this has an immense effect on both agriculture and households food security (Dinku and Sharoff, 2013).

Tesfamariam et al. (2019) reported that during the 1984–1985 droughts, one of the most devastating drought periods in the country, the national GDP was dropped by 9.7%, while agricultural output was further declined by 21%. The Tigray National Regional State has been one of the most vulnerable regions of Ethiopia to drought. Gidey et al. (2018b) reported that the arid and semi–arid area of the region has been severely affected by the recurrent droughts due to late rainfall onset, early cessations, erratic and high dry spells. In the event of drought, there will be a possibility of losses of 21–100% during the main crop cycle in the region in general and the study area in particular. As a result, there may be minimal capacity for smallholder farmers to cope–up with the current climate fluctuations and potential changes. This challenge may also affect the natural resources due to rapid population growth (Gidey et al., 2018b). Therefore, the impacts of drought (e.g., economic, social and environment) seem to be increasing and it is a good indication of unsustainable resource use and growing (Wilhite et al., 2014). For instance, the lack of adequate rainfall or soil moisture affect crop production and productivity as a result the impacts of drought would be severe in the area because of the dependency on rainfall. Conversely, drought does not only affect crop production, but also livestock production and their products (e.g., milk) due to lack of fodder, diseases and water (Webb and Reardon, 1992). Speranza (2010) reported that production of milk decreased during the drought, putting an end to the market for livestock products. Kassie (2014) pointed out that loss of pasture and depletion of water sources, loss of vegetation cover, loss of livestock production, and resources depletion are good examples of drought impacts.

Drought stress can be characterized by the reduction of moisture level. During the acute drought period, various coping strategies have been adopted by the farmers (e.g., reducing food sales, reducing food intake, removing children from school and liquidating productive assets such as livestock, land, trees, among others) (Shiferaw et al., 2014). Therefore, there is no single solution to cope–up with drought as it takes an integrated strategy composed of several practices for exchanging knowledge, designing response strategies and implementing solutions (Macon et al., 2016). As a result, the ability to cope with drought varies widely from one country to another and from one area, community or population group to another (Wilhite et al., 2014). For instance, weather–index insurance (crop insurance), use of drought–tolerant crops, improved crop management practices, land preparation, soil and water conservation practices, and use of weather prediction information have been among the widely applied drought coping strategies in the study area. Crop diversification, changes in cropping pattern and calendar of planting, irrigation efficiency enhancement, water harvesting practices, livestock management, afforestation and agro–forestry practices strengthen drought coping strategies (Arragaw and Woldeamlak, 2017; Akinnagbe and Irohibe, 2014, Legesse et al.2013).

Menghistu et al. (2018) and Twongyirwe et al. (2019) pointed out that there is limited study on the socio–economic impacts of recurrent drought and coping strategies. For instance, Mohamed (2017) reported that most of the farmers have also used some coping strategies (e.g., selling of wood or charcoal, involving in small business activities (trading), and reduction of food consumption, livestock sales, and migration). The coping strategies, however, can differ from place to place based on the community's exposure to drought risk and socio–economic context. Hadgu et al. (2015) have used multinomial logit model to comprehend the best adaptation strategies and the findings indicates that farming in the midlands or Weyna–Dega declines irrigation by 23% as compared to Kola or lowland. Twongyirwe et al. (2019) noted that irrigation to reduce the risk of crop failure during periods of prolonged drought. However, the possibilities of applying crop varieties have increased by 37% than the farmers residing in the Kola or lowland. Selection of an improved crop varies may increase crop production and productivities and also diminish farmer's susceptibility to drought risks. In addition, household with poor resource endowments would face a higher risk of being food insecure (Twongyirwe et al., 2019). Besides, Gidey et al. (2018a) reported that the impact of drought could be reduced through involving the smallholder farmers in a wide range of on–farm and off–farm practices and/or drought coping strategies and mitigation programs. Therefore, it is highly important to address and focus on how the smallholder farmers of the study have been responded to drought and its implication. This study attempted to highlight drought coping strategies and responses at household level in Raya Azebo and Raya Chercher districts, Southern Tigray, Ethiopia.

2. Material and Methods

2.1 Study area

The study area is located in southern Tigray, Ethiopia. It constitutes both Raya Chercher and Raya Azebo districts. The total land mass of the area is 1777 sq km. About 58% of the areas rely in Raya Azebo and the remaining 42% is in Raya Chercher. Geographically, it is located at 39°40′0″ and 40°0′0″ longitude east and 12°20′0″ and 12°50′0″ latitude north (Figure 1). Gidey et al. (2018a) reported that the mean maximum and minimum temperatures were about 30.5 and 15.9 °C, respectively. The area receives an annual average rainfall of 558 mm (Gidey et al., 2018a). The minimum and maximum elevation value of the area ranges from 913 to 3110 mean above sea level (m.a.s.l). Both crop production and livestock rearing are the major livelihoods and main source of income of the community. The study area consists of three major lands cover types (e.g. cultivated land 1061 sq km (59.7%), shrub/bush land 519 sq km (29.2%) and barren lands or exposed rock surface 197 sq km (11.1%). The total population of the area both male and female is 192,287. The male population is roughly 93,948 (48.9%), while the female population is 98,338 (51.1%). The maximum, minimum and average family size of the study area is 13, 2, and 6.2, respectively.

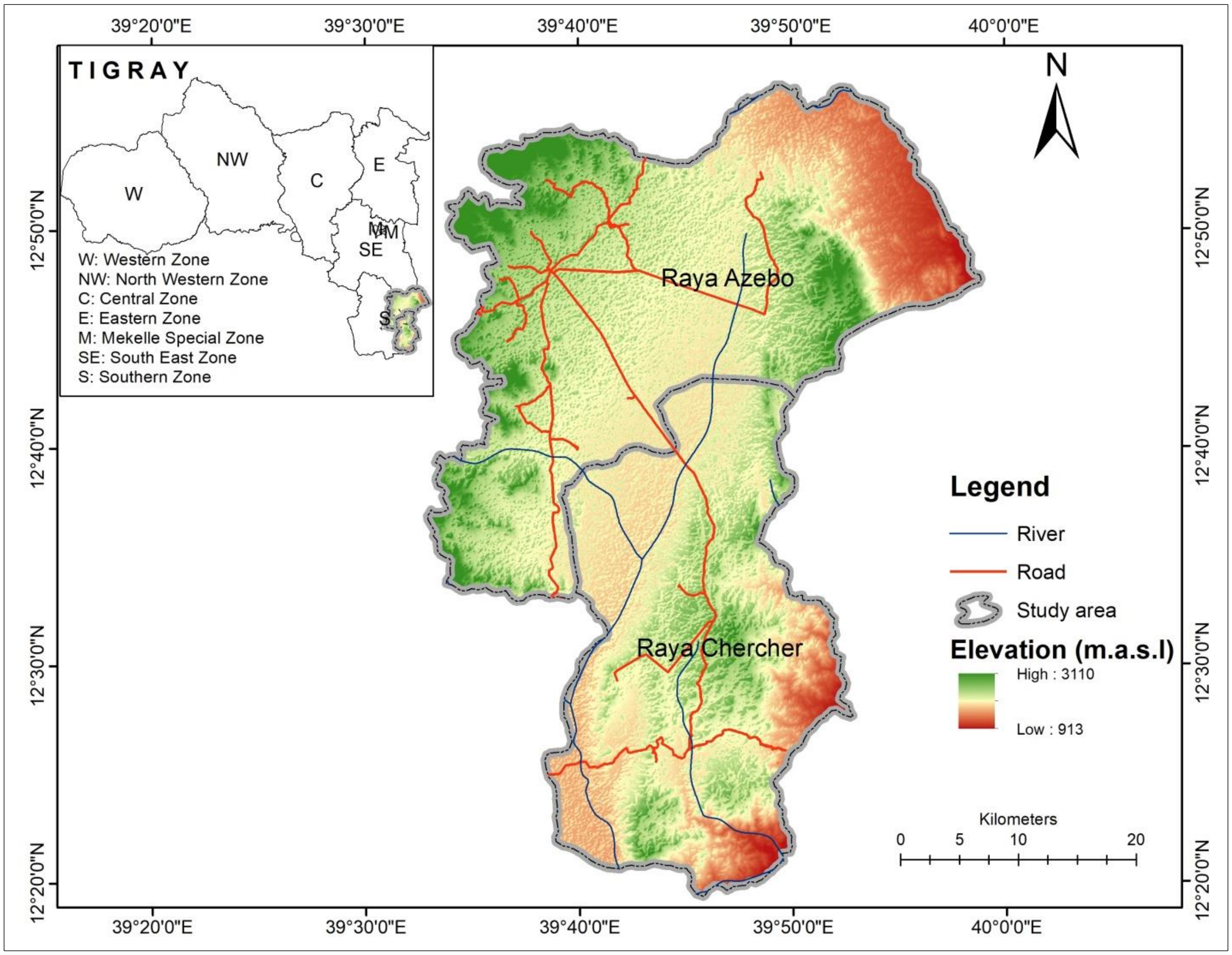

Figure 1. Map of the study area

2.2 Sampling procedure

A multistage sampling technique was applied to determine an appropriate sample size. Based on the Ethiopian Ministry of Agriculture and Rural Development agro–climatic zonation, the study area was stratified in to Kola or lowland (500–1500 m.a.s.l), Weyna–Dega or midland (1500–2300 m.a.s.l) and Dega or highland (2300–3200 m.a.s.l) (Table 1). A cluster sampling technique based on the homogeneity or agro–climatology similarity of the area was employed to determine the number of households residing in each similar agro–climatology zones and then the sample size was estimated based on Cochran (1963) as follows (Equation 1):

$$n = \frac{z^2(p)(q)}{(d^2)} \tag{1}$$

Where n = desired sample size, z = confidence level, 95per cent, p = proportion of the households to be included in the sample (20per cent), q = 1–0.2 i.e. 0.80, d = acceptable error 5 per cent.

The equation was used to sample 20 per cent of households (equation 1). A systematic random sampling method was then applied to proportionally sample after the total number of households residing in each of the similar agro–climatic zones were multiplied by the required sample size (i.e., 246) divided into the total number of households of the study area (i.e., 41,803) (Table 1).

Table 1. Sample size determination

Agro–climatological zone classification (ACZ)		Total Household (hh)		Collected sample size (n=246)		Total area coverage	
Values m.a.s.l)	ACZ	hh	%	N	%	Sq km	%
500–1500	Lowlands (Kola)	6109	14.6	36	15	454.5	25.6
1500–2300	Midlands (Weyna Dega)	34,324	82.1	202	82	1297.2	73
2300–3200	Highlands (Dega)	1370	3.3	8	3	24.8	1.4
	Total	41,803	100	246	100	1,777	100

2.3 Data collection

In this study, the socio–economic data were collected from 246 households. Each household took an average of one and half hours to respond to the semi–structured questions or the face–to–face interview. Besides, focus group discussion consisting of eight team members per group were conducted to comprehend how the farmers were responding to drought, its possible causes, coping strategies and impacts on the natural resources, livelihood and livestock. A total of eleven group members have been formulated to discuss openly. Furthermore, the field observation was undertaken by the researchers to observe and gather information pertaining to the biophysical and socioeconomic conditions of the study area. Moreover, earth observation (e.g., elevation, land cover, vegetation) at moderate spatial resolution have been obtained from Water and Land Resources Information System (WALRIS) archive at www.wlrc–eth.org the National Geospatial Database System, Ethiopia.

2.4 Data analysis

The socioeconomic datasets have been analyzed using descriptive and inferential statistical techniques to make estimations, decisions or predictions in Stata SE v13. A multinomial (polytomous) logit model (MNL) was applied to evaluate the best drought proactive and reactive coping strategies as well as responses. The MNL model the best model to predict discrete choices because of the computational drawbacks of the multinomial probit (MNP) model (Mohammed, 2007, Sosina et al. 2009). This model has been used in several studies to select best coping practice or choices for climate change adaptation (e.g., Hadgu et al., 2015) and others. This study employed a multinomial logit (MNL) model to examine the various drought coping strategies that influences the smallholder farmers of the study area. To describe the MNL model, assume Y represents the response random variable taking on the values {1, 2.., j} for choices j, a positive integer, and let X denote a set of explanatory variables. In this case, Y representing the coping strategies measure chosen by the household heads. Here, we assumed that each farmer household selected a set of categorical discrete, disjoint choices of drought coping strategies and these strategies are assumed to depend on one or more factors of X (e.g., Gender, Age, Family size, farm size etc…). The question shows how other variables changes in the factors of X that affects the response probabilities, $P(Y = j|X = x)$, for j=1, …. , J. Since the probabilities must sum to unity,$P(Y = j|X = x)$, is determined once we know the probabilities for j=1,2,…., J. Let X be a 1xK vector with first element unity, the MNL model has response probabilities given by:

$$\boldsymbol{P}(\boldsymbol{Y} = \boldsymbol{j}|\boldsymbol{X} = \boldsymbol{x}) = \frac{\boldsymbol{e^{x\beta_j}}}{1 + \sum_{\boldsymbol{k}=1}^{\boldsymbol{J}} \boldsymbol{e^{x\beta_k}}}, \qquad \boldsymbol{j} = 1, \ldots, \boldsymbol{J} \qquad [2]$$

Where β_j is K x 1 vector of coefficients, j=1, ….., J

The response variables Y's for the on–farm drought coping strategies are: (I) Selection of drought tolerant crops (II) Irrigation Construction of flood (III) Land preparation and use of compost (IV) Soil and Water Conservation and (V) Use of weather predictions information. In addition the response variables for the off–farm drought coping strategies are: (I) Looking for government support (II) Migration both animal and human (III) Borrow loans from microfinance t (IV) Selling of household assets (V) Daily Laborer (VI) Reduction of food consumption and (VII) Feeding of roosted cactuses. The unbiased and consistent parameter estimate of the model equation (2) requires the assumptions of Independence of Irrelevant Alternatives (IIA) to hold. In addition, the IIA assumption requires that the probability of using a certain coping strategies (e.g., Collection and saving of pastures) selected by a given household head needs to be independent from the probability of choosing another coping strategies (i.e., ${}^{P_j}\!/\!{}_{P_k}$ is independent of the remaining probabilities). The parameter estimates of the MNL model provide only the direction of the effect of the explanatory factor effects variables on the response variable, but estimates do not represent either the actual magnitude of change nor probabilities (Greene, 2003). To interpret the effects of explanatory variables on the probabilities, the marginal effect has been computed. Differentiating equation–2 partially with respect to the explanatory variables provides marginal effects of the explanatory variables as shown below:

$$\frac{\partial p_j}{\partial x_k} = P_j \left[\beta_{jk} - \sum_{j=1}^{j-1} P_j \beta_{jk} \right] \qquad [3]$$

The marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from their average (e.g., Proactive and reactive coping strategies or on–off response). The explanatory variables of the study were households socio–economic, environmental, and climatic and others, as hypothesized to have associations with the households' farmers coping strategies. Based on theory, empirical literature, and researcher's best knowledge of the contextual setting, nineteen explanatory variables (Table 2) were used to determine the best coping strategies to drought both for on and off–response farm activities. Following the model building, Variance Inflation Factor (VIF) and Contingency Coefficient (CC) were employed to detect multicollinearity for continuous variables and discrete variables, respectively. Breusch–Pagan test was conducted to assess the presence of heteroscedasticity or constancy of variance in the model. Finally, the model was tested for the validity of the Independence of Irrelevant Alternatives (IIA) assumptions by using Hausman's test. This test failed to reject the null hypothesis of independence of the drought coping strategies, suggesting that the multinomial logit (MNL) specification is appropriate to model drought coping strategies of smallholder farmers in the study area. MNL model specification was used by several researchers to model drought coping strategies of smallholder farmers in Africa (Temesgen et al. 2009; Hassan and Nhemachena, 2008). The response variables in the empirical estimation are coping strategies that are chosen by the household farmers during the field survey (Table 2). In this case, various best coping strategies were selected to examine farmer's response to drought incidence, coping and impacts on natural resources (e.g., vegetation cover status), agricultural productions (e.g., crop and livestock)

Table 2. Selected variables used for drought coping strategies and impact assessment

S.no	Selected variables	Category	Expected Sign for on–farm	Expected Sign for off–farm
1	Gender (Male and Female)	Dummy	+	+
2	Age (household head)	Continuous	+	+
4	Educational status (literate and illiterate)	Categorical	+	+
5	Family size	Continuous	+	+
6	Farm size	Continuous	+	–
7	Harvest times per annual	Categorical	+	–
8	Farming system use (summer, belg and irrigation)	Categorical	+	–
9	Production status (increased, decreased)	Categorical	+	+
10	Drought frequency (every year, once in every two years, once in every three years, once every four years)	Categorical	+	+
11	Drought severity (mild, moderate, severe, extremely severe)	Categorical	+	+
12	Drought causes (perceived by the household head such as lack of rainfall, high temperature, God	Categorical	+	+

	punishment)			
13	On farm drought response (coping) activities	Categorical	+	–
14	OFF farm drought response (coping) activities	Categorical	–	+
15	Effects of drought on natural resources	Categorical	+	+
16	Effects of drought on livestock	Categorical	+	+
17	Effects of drought on crop production	Categorical	+	+
18	Access to credit	Categorical	+	+
19	Access to early warning information	Categorical	+	+

3. Results and discussion

3.1 Household's characteristics

3.1.1 Age group of respondents by gender

The age of household head is one of the most essential variables that can influence selection of drought coping strategy. In the study area, the respondent's age ranges from 31 to 77 with an average age of 47. Figure 2 show that the respondents age group by gender. The results indicates that about 36% of the male headed households were in their middle age adults group, while 9% of the respondents were old adults of female headed households. whereas 6% of the respondents were elderly (Figure 2). Twongyirwe et al. (2019) reported that the age of household head is a proxy for farming experience, on the assumption that the household's knowledge of drought coping strategies and food security issues increase as the household head grows older and become more experienced.

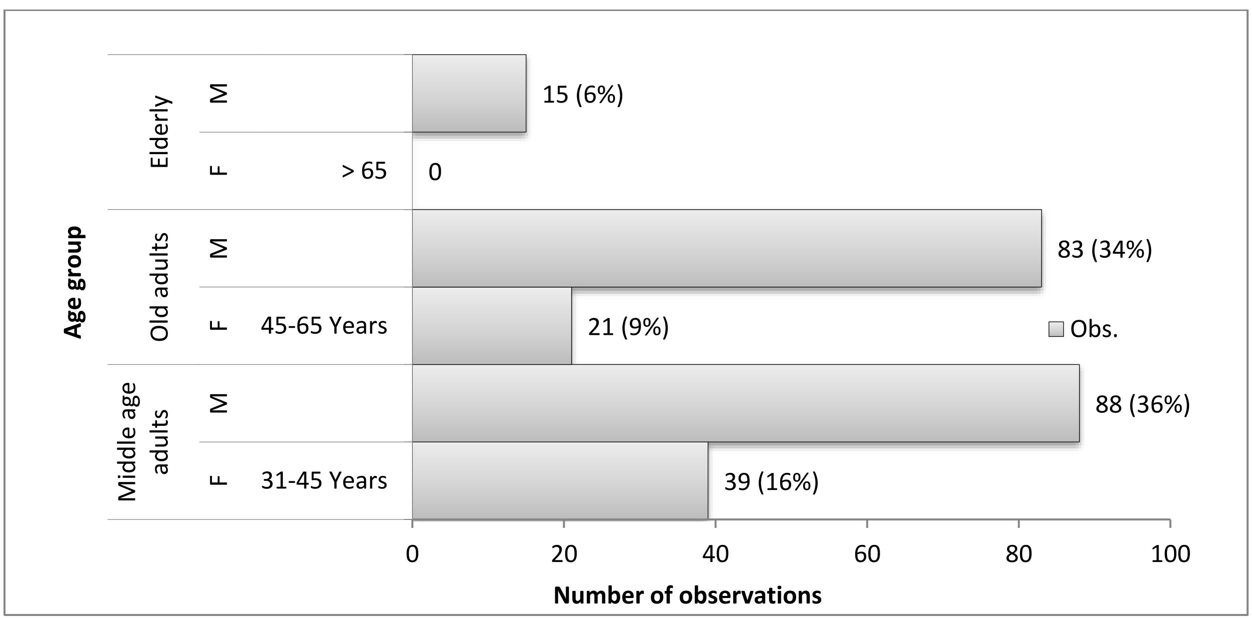

Figure 2. Household age group

3.1.2 Educational status at household level

Literacy is the most important factor or instrument for understanding facts (e.g., about drought) and changing our lifestyle and/or strengthening our resilience, coping and mitigation to various climate hazards. It is explained in terms of contribution on working efficiency, competency, income, adopting technologies and becoming visionary in creating conducive environment to educate dependents with long term target to ensure better living condition than illiterate ones (Twongyirwe et al., 2019). Studies indicate that the level of literacy could influence selection of drought coping strategies due to the behaviors of respondents. In the study area, about 61.4% of the respondents are illiterate, while 38.6% of the respondents are literate. An illiterate male headed household respondent which covers about 68.8% are higher than female headed households illiterate. The female headed illiterate household covers 31.4% (Table 3). Similarly, the literate male headed households covers only 88.4% and 11.6% female headed. Therefore, literate households can help to generate new ideas or methods towards understanding the causes of drought, and improving the coping strategies. Besides, literate households can reduce the chance of becoming food insecure (Twongyirwe et al., 2019).

Table 3. Literacy status of respondents at household level

Household head	Literacy status						chi–square	*P*–value
	Illiterate	Literate				Total		
		1–4	5–8	9–12	Others			
Female	48 (31.4%)	6 (12.8%)	2(5.4%)	3(33.3%)	0.0	11(11.6%)	1.82	0.401
Male	103 (68.2%)	41(87.2%)	35(94.6%)	6(66.7%)	2(100%)	84(88.4%)		
Total	151 (100%)	47(100%)	37(100%)	9(100%)	2(100%)	246(100%)		

3.1.3 Farm size at household level

Table 4 shows the farm size of female and male headed households. The results indicate that male headed households own a maximum of 3.5 ha, while females are own 2.5 ha. Mehar et al. (2016) pointed out that farm size is the most important proxy for determining farmer's economic status and coping strategies. The mean farm size owned by male headed household (0.93±0.74ha) was higher than female (0.54±0.75 ha) (Table 4). For example, in the study area, about 2.03 per cent of females and 6.5 per cent of male headed households are landless farmers. However, they are renting plots for cultivation from other farmers who have serious health problems and economic challenges such as access to get or own oxen or labor to cultivate the land on time. Similarly, Mehar et al. (2016) reported that farmers who have their own farm have a high probability of investing in coping strategies compared to landless farmers. Studies indicates that if the cultivated land size increases the possibility that the household gets more yield is also high during the wet season (Twongyirwe et al., 2019). In this case, the household may have better drought resilience mechanism. However, those households who live in the marginal areas and whose livelihoods are highly dependent on natural resources are more susceptible to drought because they have limited drought coping capacity (Amsalu and Adem, 2009).

Table 4. Comparison of farm size at household level

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Female	61	.5491803	.0569067	.4444558	.4353499	.6630108
Male	185	.932973	.0548457	.7459815	.8247658	1.04118
combined	246	.8378049	.0448072	.7027741	.7495483	.9260614
diff		-.3837926	.1010283		-.5827915	-.1847938

```
    diff = mean(Female) - mean(Male)                              t =  -3.7989
Ho: diff = 0                                     degrees of freedom =      244

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0001         Pr(|T| > |t|) = 0.0002          Pr(T > t) = 0.9999
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Furthermore, we compared the average farm size of male and female headed households for assessing the difference. The result revealed that (t= –3.8, t= 244, *p*–value<0.0001). Thus, there is a statistically significant average difference in the farm size between the male and female headed households in the study area. One of the possible reasons for the difference is that demographic composition of the respondents.

3.2 Drought status at household level

Understanding the status of drought at early stage and household level is imperative for formulating effective mitigation measures (Velpuri et al., 2016) and coping strategies. The mitigation measures help to reduce the adverse effects, especially for smallholder farmers who grow crops under unfavorable conditions, such as low and erratic precipitation and poor soils. In the study area, about 24.8% of female headed and 75.2% of male headed respondents have experienced mild to extremely severe drought in the last three decades (Table 5). The severity may vary depending on the households demand for water and other natural resources. The association between the various severity level in both of the household heads shows that there is significant association between the different drought severity levels and household heads (chi–square=9.861, df=3, *p*–value<0.05). Tembo et al (2018) reported that about 92% of the farmers in the south east of Tigray perceived that rainfall is significantly decreasing annually in the last three decades. This aggravates the incidence of drought and its impacts (e.g., both on natural resources, human and livestock).

Table 5. Drought severity at household level

Severity level	Household type		Total	chi–square	*P*–value
	Female headed	Male headed			
Mild	4 (1.63%)	8 (3.25%)	12 (4.88%)	9.8608	0.02
Moderate	20 (8.13%)	77 (31.30%)	97 (39.03%)		
Severe	31 (12.60%)	97 (39.43%)	128 (52.03%)		
Extremely severe	6 (2.44%)	3 (1.22%)	9 (3.66%)		
Total	61 (24.80%)	185 (75.20%)	246(100.00%)		

3.3 Smallholder farmers' drought coping strategies

Since 1983/85, the recurrent drought has regularly affected southern Tigray, particularly the natural resources (e.g., vegetation cover) and agricultural production and productivity (e.g., Maize, Teff) have declined both in Raya Azebo and Raya Chercher districts. This affects the education, health, and livelihoods that lead to food insecurity and poverty. The major triggering factors were the lack of optimum rainfall during the belg or additional rain season which usually starts from March–June and summer or the main rain season (July–early September). Macon et al. (2016) also reported that California has been severely affected by droughts due to high temperatures and dry summer seasons that have significantly affected the agricultural sector (e.g., seasonal declines in the quality of dryland forage). The change in rainfall patterns and wind erosion, increased salinization and decreased carbon mineralization aggravates the incidence of drought (Thomas, 2008). At present, numerous attempts have been made to establish coping strategies to overcome drought stress in the study area. Therefore, drought is one of the most important challenges to ensure food security in the study area. Both the proactive approach (preparing for possible drought) and the reactive approach (responding to drought) were essential components of coping strategies (Macon et al., 2016). The smallholder farmers of the study area have identified multiple strategies to cope–up with the impact of drought. The selected strategies have been based on the household heads farm size, family size, education, age; awareness and severity of drought, among others. However, the gender of respondents or household heads can influence the decision to select best drought coping strategies because they have different roles (Mehar et al., 2016). Teshager et al. (2019) have also observed similar findings in the Upper Blue Nile Basin, Ethiopia.

Table 6 shows best on–farm drought coping strategies estimated using the MNL model that the smallholder farmers of the study area frequently used to cope–up with drought. Results of the multinomial logit (MNL) model indicates that age of the household head, which represents experience, affecting the coping to drought positively and significantly in strategies number II and V (p–value<5%). The relative risk ratio, which is the exponent of the coefficient of the estimate (e^{β}) shows that a change in the age of the household head result in a 3.5 and a 2.4 higher probability of choosing strategy number II and V as compared to the base choice strategy (i.e., land preparation and use of compost (manure). The marginal effect of the age estimate shows that the probability of choosing strategy number II and V increased by 0.04% and decreased by 0.17%, respectively, as compared to choosing the base choice strategy. Likewise, households family size, which usually represents the size of the family living within the family affecting the coping to drought positively and significantly both strategies numbers IV and V (p–value<10%). The relative risk estimate of the family size estimate shows that a unit change in the family size of the household result in a 4 and 6.4 higher likelihood of choosing strategy number IV and V, respectively, as compared to the choice of the base outcome. The average marginal effect of the family size estimate also shows that the likelihood of choosing strategy number IV and V decreased by 0.06% and increased by 0.04%, respectively, as compared to the base outcome. Besides, farm size of the household which represents the share of cultivated land measured affecting the coping to drought positively and significantly the strategy number II (p–value<10%). The relative risk estimate shows that a unit change in farm size of the household in choosing coping strategy II produces to have the same effect on coping to drought as compared to the base outcome. The average marginal effect of the estimate of the farm size indicates that the probability of choosing strategy number II decreased by 6.63% as compared to the base outcome. Furthermore, soil and water conservation which represents the involvement of the farmers in preserving the cultivated land of the area under study affecting the coping to drought positively and significantly the choice of strategy II (*p*–value<1%). The average marginal effect of the estimate shows that the probability of choosing strategy number II increases by 5.4% as compared to the base outcome. Moreover, the effects of drought on production, measured both in terms of complete loss, partial loss and pest and disease, the result indicates that complete loss is found to have significant effect in choosing the coping strategy number II (*p*–value<5%). The marginal effect of this estimate also shows that the probability of choosing strategy number II increases by 18.1% as compared to the base outcome. Moreover, Access to accurate weather information reduces the impacts of drought on both humans and livestock as ranchers can prepare for potential emergencies and serve as a valuable source of knowledge for researchers, land managers and policymakers. This may support to improve the existing response capacity to drought in the form of preparedness strategies when drought strikes (Speranza, 2010). However, the farmers of the study area are not getting timely information about the future drought due to lack of scientific drought monitoring and early warning systems. Now–a–days, high–quality information sources (e.g., weather forecast information) and peer–to–peer knowledge sharing on incoming drought risk improves the ability to respond to drought (Macon et al., 2016; Wilhite et al., 2014). Therefore, the community of the study area should get timely information to strengthen their coping strategies and reduce the impact felt from drought.

Table 6. Best proactive drought coping strategies and on–farm response in the study area

Proactive drought coping strategies and on–farm response	Selection of drought tolerant crops (**I**)			Collection and saving of pastures (**II**)			Construction of flood diversion channels for irrigation usage (**III**)			Soil and Water Conservation (SWC) to enhance soil moisture availability and health (**IV**)			Use of weather prediction information to adjust saving and farming system (**V**)		
	dydx	Coef	*p* –value	Dydx	coef	*p* –value	dydx	coef	*p* –value	dydx	coef	*p* –value	dydx	coef	*p* –value
Household type (Gender) (reff: Female Headed)															
Male Headed	–0.039	–0.01	0.99	–0.063	0.27	0.75	–0.0059	–0.25	0.81	0.108	0.72	0.36	0.0019	0.69	0.49
Age (household)	0.0004	–0.01	0.76	–0.000463	0.22	**0.036****	0.00017	0.01	0.86	0.0015	–0.02	0.62	–0.0017	–0.13	**.021****
Family size	–0.0056	0.22	0.30	0.0044	–0.30	0.409	–0.0029	0.29	0.28	–0.00601	0.31	**.088***	0.0047	0.62	**.015****
Farm size	–0.0022	–0.01	0.99	–0.0663	–3.02	**0.074***	–0.00023	–1.30	0.17	0.0629	0.11	0.83	0.0051	0.36	0.62
Farming system use (reff: Rain–fed or Main rain season)															
Both Belg and Irrigation	–0.039	–1.56	0.17	–0.081	–1.12	0.25	0.0076	0.39	0.73	0.1098	–0.50	0.56	0.0002	–0.63	0.61
Drought frequency (reff: Once every year)															
Once in very two years	0.0124	0.46	0.67	–0.082	–0.17	0.86	–0.0075	–0.59	0.62	0.0914	0.39	0.68	–0.0131	–0.48	0.70
Once in every three years	–0.0109	1.37	0.31	0.044	1.77	0.15	–0.0264	1.08	0.47	0.0011	1.60	0.18	–0.00747	1.24	0.41
Once in every four years	0.0073	17	1	0.071	17	1	–0.0332	18	1	–0.045	17	1	–0.0033	17	1
Perceived cause of droughts by the households head (reff: High Temperature)															
Deforestation due to lack of	–0.011	–0.81	0.50	0.125	0.08	0.94	0.0077	0.00	0.99	–0.088	–0.70	0.49	–0.0299	–1.71	0.28
God punishment	–0.016	0.57	0.60	0.041	1.23	0.23	–0.00616	1.85	0.11	0.0001	0.97	0.33	–0.024	0.14	0.91
Investors because they destroy potential cactus	–0.050	0.00	1.00	–0.136	0.0	1.00	0.9900	0.0	1.00	–0.7554	0.00	1.00	–0.0441	0.00	1.00
Pests and diseases (crop)	–0.05	16.83	1.00	0.734	18.27	1.00	–0.0099	2.07	1.00	–0.7554	–0.83	1.00	0.0097	16.61	1.00
Soil and water conservation practices	0.025	0.36	0.80	0.054	10.07	**0.001******	–0.0017	0.04	0.98	–0.0181	0.16	0.90	–0.0441	0.00	0.99
Lack of rainfall	0.01		0.333	0.247	–1.40	0.498	–	0.79	0.33	–	–	0.42	–	–	0.59
Effects of drought on natural resources: (reff: Drying water resources)															
Loss of Vegetation	–0.009	1.04	0.41	0.053	1.51	0.20	–0.0177	16.33	1.00	–0.0614	1.12	0.29	0.0321	17.19	0.99
Effects of drought on crop production (reff: Pest and disease)															
No yield (complete loss)	–0.04	1.13	0.39	0.1815	2.92	**.026****	–0.0312	16.99	1.00	–0.0964	1.48	0.18	–0.018	0.83	0.56
Yield reduction (partial loss)	–0.092	–0.58	0.74	–0.010	1.29	0.43	–0.0299	16.79	1.00	0.1529	1.65	0.22	–0.026	–0.04	0.98
Effects of drought on livestock (reff: mortality)															
Acute diseases (sever)	–0.062	0.45	0.75	0.169	2.00	0.14	–0.0234	1.04	0.54	–0.0388	1.39	0.26	–0.0436	–1.19	0.48
No production (e.g., no milk, no fertility)	0.016	16.62	0.996	–0.236	0.60	1.00	0.0310	14.6677	0.996	0.211	16.774	0.996	0.04256	17.11	1.00
Starvation due to lack of pasture (forage)	–0.053	–0.15	0.89	0.1064	1.01	0.35	–0.0147	–0.20	0.88	–0.0024	0.63	0.50	–0.0342	–0.66	0.60
Access to credit (Loan) (reff: No)															
Yes	–0.0152	–0.12	0.87	–0.0916	–0.31	0.63	–0.00131	–0.29	0.73	0.1057	0.29	0.63	0.003	0.35	0.66
Access to drought early warning information (reff: No)															
yes	0.029	1.05	0.18	–0.025	0.41	0.57	–0.0051	0.48	0.60	0.0094	0.55	0.42	–0.00916	–0.04	0.97
Drought severity level (reff: Mild)															
Moderate	0.204	0.38	1.0	0.0731	0.0	1.00	0.0158	0.0	1.00	–0.2814	0.0	1.00	–0.0053	0.0	1.00
Severe	0.211	0.34	1.0	0.1125	0.0	1.00	0.0171	0.0	1.00	–0.3359	0.0	1.00	–0.0015	0.0	1.00
Extremely severe	0.000	0.0	1.00	0.0930	0.0	1.00	0.0287	0.0	1.00	–0.2274	0.0	1.00	0.1131	0.0	1.00

Mean dependent var.: 3.756
Pseudo r–squared : 0.277
Chi–square: 204.879
Akaike crit. (AIC): 805.906

SD dependent var.: 1.658
Number of obs.: 246
Prob > chi2: 0.000
Bayesian crit. (BIC) 1279.125
*** $p<.01$, ** $p<.05$, * $p<.1$

dydx: Marginal effect
coef.: Coefficient
Base outcome category: **Land preparation and use of compost (manure) to improve soil fertility**

In addition, Table 7 shows that the MNL model estimates for the off–farm coping strategy activities. The result reveals that male headed household, affects the choice of coping to drought positively and significantly for strategy number V (*p*–value<10%). The relative risk ratio of the estimate indicates that a male headed household have a 3.5 times higher in favoring the choice for strategy number V as compared to the base choice strategy (i.e., migration to adjacent and remote areas). The marginal effect estimate of the male headed households shows that the probability of choosing strategy V increases by 0.77% as compared to choosing the base outcome strategy. Beside, age of the household head, affecting the coping to drought positively and significantly the choice of the coping strategy number I (*p*–value<5%) and its relative risk estimate indicates that the odds of choosing this strategy number I is same as compared to the base strategy. The marginal effect of the estimate of age shows that the likelihood of choosing strategy number I increased by 0.7% as compared to choosing base outcome strategy. Moreover, the family size of the household affecting the coping to drought strategy number III, positively and significantly (*p*–value<10%) and strategy number V (*p*–value<5%). The relative risk of the estimate indicates that a unit change in size of the family have a 1.3 times higher effects in choosing strategy number III and a 0.63 times less effect as compared to the base outcome. The marginal effect of the estimate for the family size tells us that the probability of choosing strategy number III is less likely to be selected as compared to the base outcome. This fact is true for all factors that have significant influence on strategy number III.

On the other hand, farm size affects the choice of strategy number I affecting the coping to drought positively and significantly (*p*–value<10%) and strategy number IV (*p*–value<1%). The relative risk estimate of the farm size shows that a unit change in farm size has a 0.45 and 0.31 times higher in selecting strategy number I and IV, respectively as compared to the base outcome. The marginal effect of the estimate shows that the probability of choosing strategy IV decreases by 9.7% and increases by 5.6% for strategy number I as compared to the base outcome. Moreover, the sub–category of belg and irrigation affects the choice of the strategy number II positively and significantly (*p*–value<5%). The relative risk of the estimate indicates that a unit change of the farming system use of belg and irrigation by the farmers have a 16.6 times higher in choosing strategy I as compared to the base outcome. The marginal effect of the estimate shows that the probability of adopting strategy II decreases by 3.6% as compared to the base outcome. Furthermore, the effect of drought on crop production of complete loss affects the farmers choice of strategies I and V (*p*–value<5%). The relative risk of the estimate indicates that a change in the estimate changes the choice of strategy I and V by 5.5% and 5%, respectively as compared to the base outcome. The average marginal effect of the model, it is found out that in the present study the likelihood of choosing strategy number I and strategy number V would decrease (increase) the probability of selecting strategy I by 9.8% as compared to the base outcome.

Similarly, partial loss of the effect of drought on crop production affects the choice of the strategy numbers I and V (*p*–value<2%). The relative risk of the estimate shows that a change in the estimate changes the choice of the strategy I and V by 3.4% and 2%, respectively as compared to the base outcome. The average marginal effect reveals that the probability of adopting strategy I and V would decrease the probability of selecting these two strategies as compared to the bases outcome. In addition, the effect of the drought on livestock, result indicates that it affects positively and significantly for the choice of the strategy number I and V (*p*–value<5%). The relative risk of the estimate of the factor changes the farmer's choice in strategies number I and V by 10.23 and 6.43, respectively compared to the base outcome. The average marginal effect of the estimate reveals that the probability of making a choice for the strategy number I and IV would decrease (increase), respectively as compared to the base outcome. Finally, access to credit affects the selection of strategy number II positively and significantly (*p*–value<10%). The relative risk of the estimate shows that a change in the estimate would result in a change by about 7% in selecting strategy II as compared to the base outcome. The average marginal effect result reveals that the probability of choosing strategy II increases by 0.1% as compared to the base outcome.

Table 7. Best reactive drought coping strategies and off–farm response in the study area

Reactive drought coping strategies and off–response	Feeding of roosted cactuses for their livestock (**I**)			Borrow loans from microfinance to begin small business (petty trading) (**II**)			Selling of household assets (e.g., livestock) for buying grains (**III**)			Food for work (as daily labor) (**IV**)			Reduction of food consumption both in quality and quantity (**V**)		
	dydx	Coef	*p* –value	dydx.	coef	*p* –value	dydx.	coef	*p* –value	dydx.	coef	*p* –value	dydx.	coef	*p* –value
Household type (Gender) (Reff: Female Headed)															
Male Headed	0.052	1.10	0.13	–0.0435	1.18	0.45	0.000	–0.17	0.77	0.052	0.63	0.32	0.0077	1.67	.056*
Age (household)	0.0007	0.08	.021**	–0.006	0.07	0.20	0.000	0.03	0.40	0.009	0.10	.003***	–0.0007	–0.03	0.56
Family size	–0.0011	0.05	0.75	–0.015	–0.03	0.93	–0.000	0.27	.064*	0.012	0.20	0.18	–0.005	–0.47	.045**
Farm size	0.0527	–0.81	.087*	0.080	–0.46	0.58	0.000	–0.94	.032**	–0.097	–1.18	.005***	0.005	–0.13	0.82
Farming system use (reff: Rain–fed or Main rain season)															
Both belg and irrigation	–0.1047	1.01	0.22	–0.036	2.81	.019**	0.000	–0.20	0.82	0.137	0.90	0.25	–0.002	0.07	0.95
Drought frequency (reff: –Once every year)															
Once in very two years	0.088	–0.45	0.64	0.060	–1.75	0.22	–0.000	–1.21	0.16	–0.047	–0.90	0.29	–0.004	–1.14	0.32
Once in every three years	0.088	–0.31	0.76	0.040	–1.60	0.33	–0.000	–0.57	0.54	–0.157	–1.24	0.20	–0.004	–0.94	0.45
Once in every four years	0.079	–1.26	0.50	0.047	0.00	1.00	–0.000	–0.82	0.58	0.037	–0.50	0.73	–0.002	–0.80	0.69
Perceived cause of droughts by the households head (reff: High Temperature)															
Deforestation	–0.056	–0.63	0.60	–0.026	1.58	0.39	0.000	0.93	0.33	–0.037	0.12	0.91	–0.009	–1.11	0.48
God punishment	–0.0301	–0.24	0.74	0.003	0.80	0.48	0.000	0.00	1.00	0.064	0.24	0.70	–0.006	–0.67	0.46
Investors because they destroy potential cactus	–0.095	21.15	1.00	–0.091	13.11	1.00	–0.000	0.52	1.00	–0.198	0.02	1.00	–0.012	–1.12	1.00
Pests and diseases (crop)	–0.095	0.00	1.00	0.187	0.00	1.00	–0.000	0.00	1.00	0.254	–0.29	0.86	–0.012	0.00	1.00
Soil and water conservation practices	0.171	0.58	0.58	–0.029	0.00	1.00	–0.000	0.07	0.94	0.055	0.63	0.51	–0.007	–0.61	0.66
Lack of rainfall	0.022	1.82245032	0.052*	0.037	–	–	–	–	–	–	–	–	–	–	–
Effects of drought on natural resources: (reff: Drying water resources)															
Loss of vegetation	0.0294	0.00	0.99	0.245	0.00	0.99	–0.000	0.00	0.99	–0.254	0.00	0.99	–0.0039	0.00	0.99
Effects of drought on crop production (reff: Pest and disease)															
No yield (complete loss)	–0.098	–2.90	0.006***	0.013	–1.609	0.42	–0.000	0.08	0.94	0.028	–0.04	0.97	–0.0999	–2.94	.025**
Yield reduction (partial loss)	–0.1639	–3.38	0.001***	0.146	0.00	0.99	0.000	–0.62	0.63	–0.017	–1.13	0.43	–0.0991	–4.07	.017 **
Effects of drought on livestock (reff: mortality)															
Acute diseases (sever)	–0.075	1.03	0.39	–0.084	15.17	0.99	0.000	0.16	0.87	0.204	1.11	0.26	–0.0155	–0.06	0.96
No production (e.g., no milk, no fertility)	–0.029	–0.64	0.68	0.047	–1.55	1.00	–4.46	0.48	0.66	–0.241	0.00	0.99	–0.0361	0.00	1.00
Starvation due to lack of pasture (forage)	–0.057	2.33	.021**	–0.158	16.45	0.99	0.000	1.08	0.18	0.169	1.86	.033**	–0.026	0.03	0.98
Access to credit (Loan) (reff: No)															
Yes	0.004	–0.360	0.506	0.001	1.842	.097*	0.000	0.039	0.935	–0.056	0.226	0.647	0.0035	0.433	0.528
Drought severity level (reff: Mild)															
Moderate	0.1089	–0.81	0.46	–0.011	13.79	1.00	0.000	1.29	0.32	–0.094	–0.28	0.79	0.0180	14.56	1.00
Severe	0.0598	–0.28	0.79	–0.042	14.84	1.00	0.000	1.61	0.21	–0.059	0.21	0.84	0.0344	15.54	1.00
Extremely severe	–0.0824	0.87	0.57	–0.026	16.10	1.00	0.000	0.08	0.97	–0.223	–1.14	0.51	0.000	–1.07	1.00

Mean dependent var.	4.23	SD dependent var.	1.89
Pseudo r–squared	0.21	Number of obs.	246
Chi–square	187.03	Prob > chi2	0.009
Akaike crit. (AIC)	1004.52	Bayesian crit. (BIC)	1530.32

dydx: marginal effect
coef.: Coefficient
Base outcome category: Migration (both animal and human) to adjacent and remote areas

***** p<.01, ** p<.05, * p<.1***

Wossen et al. (2017) pointed out that crop failures caused by drought could affect labor supply. Similar practices have also been observed in Raya Azebo and Raya Chercher as most of the farmers wish to migrate during the drought episodes to save their lives and livestock. This attitude can severely affect the agricultural sector and most of the households depend themselves on governments aid. Providing drought relief may decrease self–reliance and rise dependency on government and donor organizations (Wilhite et al., 2014), however, technological support may advance the farmers drought coping strategy and farming system. Therefore, the attitude of ranchers must be changed to build self–resilience and improve their drought coping. Besides, there is a need of coordinated national drought policy that includes comprehensive monitoring, early warning and information systems, impact assessment procedures, risk management measures, drought preparedness plans, and emergency response programs to respond to drought effectively (Wilhite et al., 2014).

Similarly, Macon et al. (2016) stated that the recurrent droughts pose a risk to health both economically and in rangeland. In the study area, a number of smallholder farmers sell their crop and buy livestock assets as a form of savings or insurances during the non–drought period. This practice may give relief to the households to cope–up with drought. However, during the periods of dry season and drought, most of the farmers reduce their food intake and sell their livestock at lower price due to lack of fodder and livestock diseases. For instance, diarrhea and mumps, skin infections, trypanosomiasis, worms and parasites, coughs and lung infections were some of the major diseases observed in the study area. Mehar et al. (2016) and Speranza (2010) were also reported similar cases in Bihar, India and Kenya. This entails a substantial decrease in the existing production systems. It will also increase the livestock deaths, poor fertility and breeding, flea infestations and retarded growth (Speranza, 2010). Therefore, drought risk reduction policies and effective measures should be developed to diminish the impacts associated with droughts in the study area. Moreover, access to irrigation is an important strategy to reduce the vulnerability of agriculture to climate risks such as drought. Therefore, the farmers of Raya Azebo and Raya Chercher should have equitable access to irrigation to enhance their strategies for coping with drought.

4 Conclusions

This study evaluated farmer's drought coping strategies (both proactive and reactive) responses at household level based on the field survey using multinomial logit model in the southern zone of Tigray, Ethiopia. The mean farm size owned by male headed household respondents (0.93±0.74ha) were higher than female (0.54±0.75 ha) respondents. This indicates that there was a significant difference ($t = -3.8$, $t = 244$, p–value<0.0001) in the farm size between the male and female headed households due to demographic composition of the respondents in the area. About 24.8% of female headed and 75.2% of male headed respondents have experienced mild to extremely severe drought in the last three decades. As a result, significant association between the different drought severity and household heads (chi–square=9.861, df=3, p–value<0.05) observed. Moreover, the study identified best proactive (on–farm) drought coping strategies such as collection and saving of pasture, soil and water conservation practices, and use of weather prediction information to adjust saving and farming system. In addition, feeding of roasted cactus for livestock, borrowing loans for running small business, selling of household assets such as livestock, food for work (Productive Safety–Net Programme), and reduction of food consumption both in quantity and quality were identified as reactive or off–farm drought coping strategies in the study area. The smallholder farmers of the study area should work more on crop rotation or diversification, soil and water conservation and irrigation along with the stress resistant varieties to improve soil health and existing production and productivity of the area. This result may give good insights to improve the current disaster preparedness and early warning systems monitoring and evaluation in the area. Besides, it helps to develop impact based drought mitigation measures to save the lives of local community and their livestock assets to improve the production and productivity of the area.

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Ethics approval and consent to participate

The authors abide by the rules and regulations of research ethics and confirmed that there is no ethical conflict in this manuscript as well research.

Consent for publication

All authors have read the manuscript carefully and agreed to submit for publication.

Competing interests

We declare that there is no competing interest.

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Figures

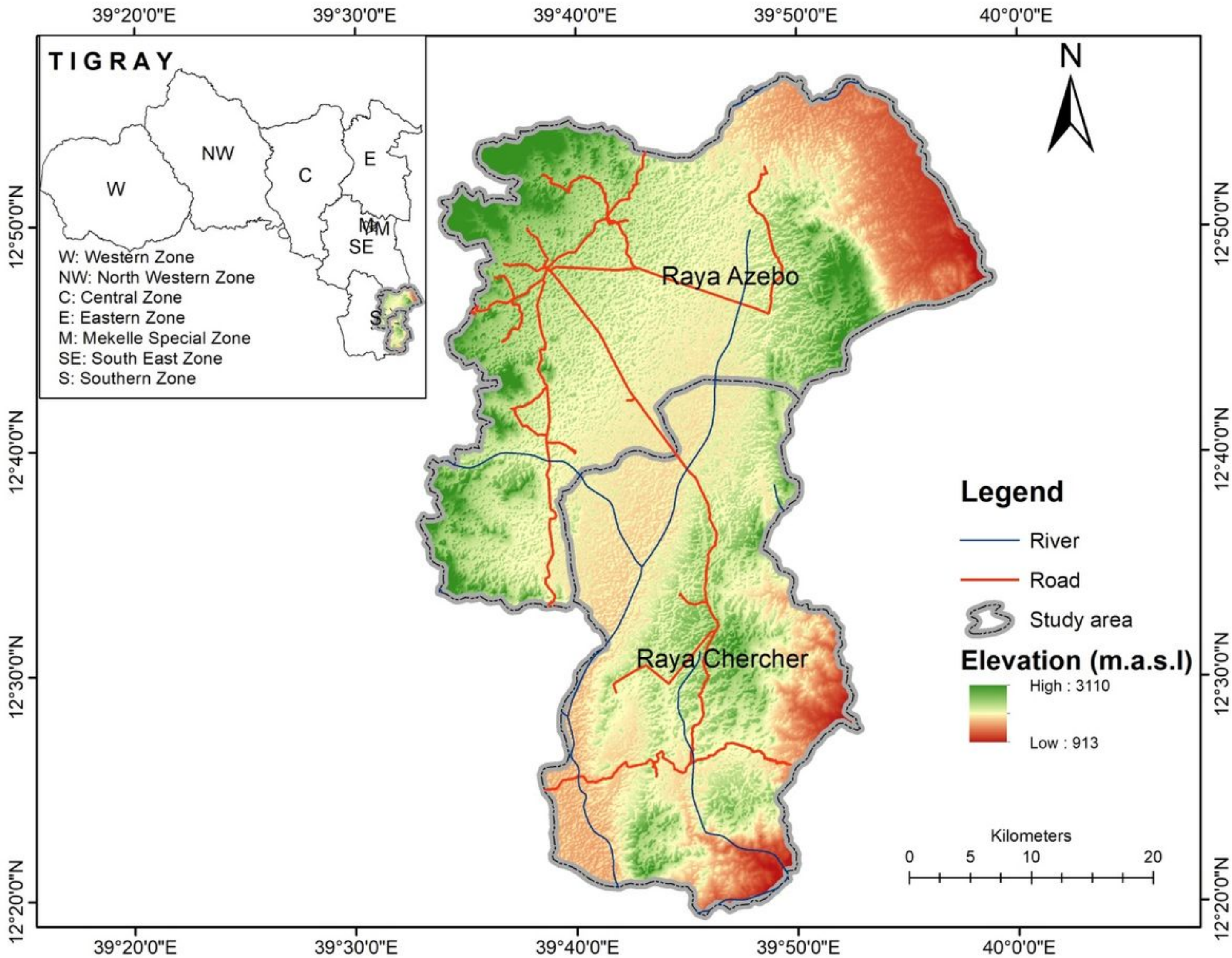

Figure 1

Map of the study area Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

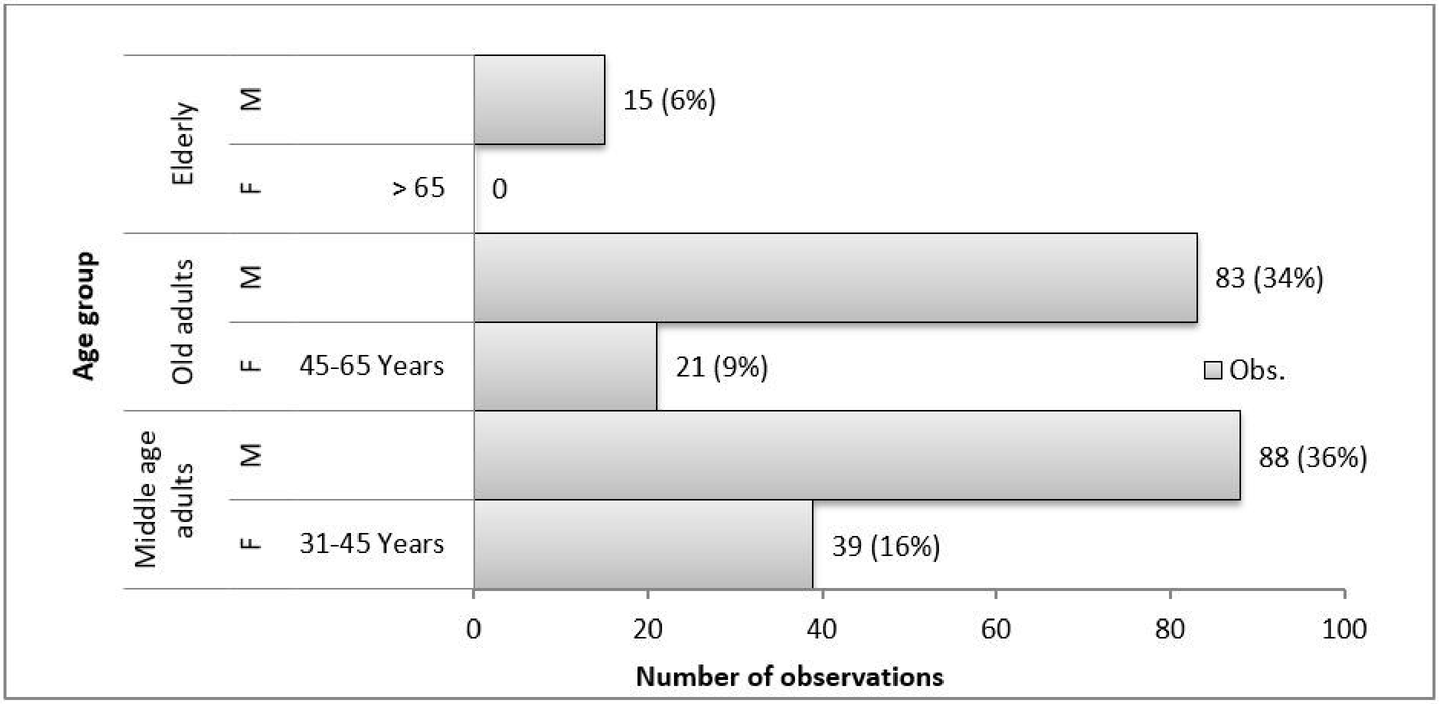

Figure 2

Household age group