

Farmers' Perceptions and Adaptation to Climate Variability and Climate Change in the Central Rift Valley of Ethiopia

Hirut Getachew¹ and Kindie Tesfaye²

¹*Department of Plant Science, Ambo University, P O BOX 19, Ambo, Ethiopia, E-mail: hirut_ge@yahoo.com*

²*Haramaya University, P O Box 134, Dire Dawa, Ethiopia, E-mail: hankid27@yahoo.com*

Abstract

Agriculture is one sector that is most vulnerable to the impacts of climate change. The impact of climate change is severe in Africa where agriculture is the main source of daily subsistence and adaptive capacity is low. This study was conducted to understand historical climate trends, perception of smallholder farmers on climate change and their current adaptation mechanisms at four sites (Meki, Melkassa, Miesso and Ziway) in Central Rift Valley of Ethiopia. The study involved analysis of historical climate data and survey using semi-structured questionnaires. The results showed the existence of high interannual rainfall variability within season and sites. The number of rainy days exhibited a declining trend at Meki in both *belg* (FMAM) and *kiremt* (JJAS) seasons, and increasing trend at Melkassa in the *belg* (FMAM) season. While an increasing trend was observed at Miesso and Ziway in the *kiremt* (JJAS) season and no change in trend during the *belg* (FMAM) season at both sites. The minimum and maximum temperature showed increasing trend at Miesso and Ziway, whereas no change was observed at Melkassa. As opposed to the cessation of the rainfall, onset date of rainfall was highly variable at all sites. Farmers had a good perception on climate change and most believed that the environment has changed over the years due to various human activities. Erratic distribution, reduction in amount, late onset and early withdrawal of the rain and increased heat were major problems mentioned as the reasons for frequent crop failures in the respective areas. Most of the farmers cope with the impacts of climate change through various adaptation strategies such as growing short maturing varieties, adopting recently released varieties, application of fertilizers and irrigation to increase yield per unit area, and to some extent looking for off-farm part time activities among others.

Key words: Climate variability, Climate change, Perception, Adaptation, Rift valley, Ethiopia

Introduction

Agriculture is the source of livelihood to the majority of Ethiopian population and the base of the national economy. It employs more than 80 percent of the labor force and accounts for 45 percent of the GDP and accounts for 85 percent of the export revenue (MoFED, 2006). However, Ethiopian agriculture is dominated by small-scale and subsistence farming systems and it is heavily dependent on rainfall, as irrigation is currently applied to only 3% of arable land. Thus, the dependency of farmers on rain fed agriculture has made the country's economy extremely vulnerable to the aberrations of weather and climate (Kidane *et al.*, 2006).

A recent vulnerability and poverty mapping study in Africa (Orindi *et al.*, 2006; Stige *et al.*, 2006) put Ethiopia as one of the most vulnerable countries to climate change with the least capacity to respond. Rainfall variability and associated drought have been major causes of the country's food shortages and famine. Nationally, the link between drought and crop production is widely recognized, but little is known about how climate change is affecting crop production and what strategies households are employing (Mahmud *et al.*, 2008).

The Ethiopian Central Rift Valley (CRV) is one of the regions in the country which is affected by climate

variability and change. It covers a variety of agroecologies characterized by extensive areas of low rainfall and limited areas receiving adequate rainfall. The rainfall pattern in the CRV is bi-modal in nature and largely influenced by the annual oscillation of the inter-tropical convergence zone, which results in warm, wet summers (with most of the rainfall occurring from June to September) and dry, cold and windy winters. The main rainy season accounts for 70-90% of the total annual rainfall. Minor rain events, originating from moist south-easterly winds, occur between March and May (Hengsdijk and Jansen, 2006).

Crop production in semi-arid regions is largely determined by climatic and soil factors. Among the climatic factors, the distribution and amount of rainfall affect the agricultural systems of the CRV. Therefore, rainfall is considered as the limiting factor in these areas and many of the farm decisions are made based on the time of onset of rainfall. The onset and distribution of rainfall governs crop yields and determines the choice of the crops to be grown (Stelio, 2004). The cultivated land in the CRV is mostly located in the valley floor and the major field crops grown includes; teff, barley, maize, sorghum, lentils, chickpeas and field peas. The most important vegetables that are grown under irrigation include the common bean, tomato, onion, cabbage and broccoli (Moti, 2002). In general, the inter-annual and inter-seasonal climate variability coupled with

climate change is the main cause of fluctuating annual production with occasional drastic reduction of crop yields in the region. However, there is dearth of information on the degree of climate variability and change, perceptions of farmers towards climate variability and change and current adaptation strategies in the CRV. Therefore, this study was undertaken to analyze risks of climate in crop production and how farmers perceive climate variability and change and how they are adapting to the changes in the study area.

Materials and Methodology

Description of the study area

The areas covered by this study were Meki (latitude $8^{\circ} 15' N$, longitudes $38^{\circ} 82' E$ and altitude 1400 m.a.s.l), Melkassa (latitude $8^{\circ} 4' N$, longitude $39^{\circ} 32' E$ and altitude 1550 m.a.s.l), Miesso (latitude $9^{\circ} 23' N$, longitude $40^{\circ} 75' E$ and altitude 1400 m.a.s.l) and Ziway (latitude $7^{\circ} 93' N$, longitudes $38^{\circ} 72' E$ and altitude 1640 m.a.s.l) which are all located in the Central Rift Valley of Ethiopia. The choice of the districts was based on data availability, farming system and representativeness of agroecological settings in the Central Rift Valley (Fig 1).

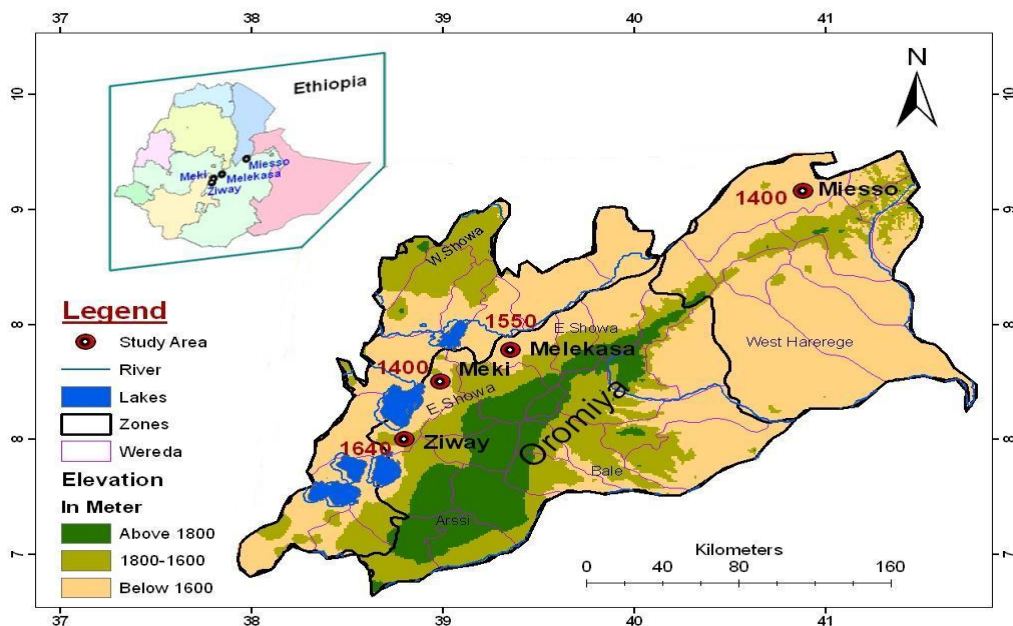


Figure 1. Location map of the study areas

Climate change and variability analysis

Secondary data obtained from National Meteorological Agency was used for climate change and

variability analysis. The data base period for all the study sites is shown in Table 1.

Table 1. Database period for rainfall and temperature

District	Rainfall		Maximum and Minimum Temperatures	
	Database period	No. of years	Database period	No. of years
Meki	1966-2009	41	NA	NA
Melkassa	1977-2009	33	1977-2009	33
Mieso	1974-2009	36	1990-2009	20
Ziway	1970-2009	40	1970-2009	40

NA: Data not available

Rainfall and temperature variability and change analysis

The annual and seasonal pattern of rainfall and temperature were examined for each district by processing daily rainfall and temperature data using INSTAT version 3.36 (Stern *et al.*, 2006). The rainfall and temperature variability at each site were determined by calculating mean, standard deviation and coefficient of variation (CV). The CV was calculated as the ratio of the standard deviation to the mean rainfall in a given period. The standardized anomaly (Z) for rainfall and temperature was calculated as:

$$Z = \frac{x - \bar{X}}{S}$$

Where x = annual total rainfall or annual mean temperature

\bar{X} = long term mean

S = standard deviation of the entire series

Onset and cessation of rain, probability of dry spell and length of growing season analysis

The onset of rain (a successful planting date) was defined as the first occasion after first of March when the rainfall accumulated in 3 consecutive days is at least 20 mm and no dry spell of more than 7 days in the next 30-days (Sivakumar, 1988; Kindie and Walker, 2004). To analyze the onset of rain and dry spells, a first order Markov chain model was fitted to get more than 30 years of data for each site using INSTAT version 3.36. The daily rainfall data was processed to give maximum dry spell lengths in the next 30 day periods starting from the onset of rain for each site. Probabilities of the maximum dry spell lengths

exceeding 5, 7, 10, 15 and 20 days over the next 30 days from planting were calculated to get an overview of the drought at the study area for the whole year. The end of the rainy season (defined as the occurrence of a day after first September when the soil water drops to 10 mm m⁻¹) was determined by using the water balance dialogue in INSTAT climatic guide (Stern *et al.*, 2006). Then the length of growing period of the study areas was determined as the difference between the onset date and end date (Stern *et al.*, 2006; Kindie and Walker, 2004).

Survey sampling procedures

A multi-stage purposive sampling procedure was followed to select East Shewa and West Hararghe, administrative zones. These zones were selected on the basis of their vulnerability to climate variability and change. Once the zones were selected, the same procedure and selection criteria were used to select the study districts Meki, Melkassa, Miesso and Ziway. Peasant associations (PAs) were selected using purposive sampling procedure based on their vulnerability to climate change using

the information obtained from district Bureau of Agriculture and Rural Development. Following the selection of the PAs, 50 sample farmers were randomly selected in each of the four districts on the basis of probability proportional to size of the household

Data analysis

The data were coded and entered into SPSS Version 16 computer software and descriptive statistics was generated and interpreted.

Results and Discussion

Climate Variability and Change Analysis

Rainfall variability and change

The long-term rainfall data for the four sites are presented in Table 2. The mean annual rainfall of the study areas ranged from 719 mm (Miesso) to 791 mm (Melkassa) and slightly varied from district to district with a standard deviation ranging from 167 (Melkassa) to 191mm (Miesso) and CV ranging from 21(Melkassa) to 27 % (Miesso). This indicates that the rainfall at Miesso is more variable than the other sites.

Table 2. Long-term annual rainfall statistics of four meteorological stations in the Central Rift Valley of Ethiopia

Characteristics	Weather Station			
	Meki	Melkassa	Miesso	Ziway
Mean (mm)	729	791	719	742
Standard deviation (mm)	179	167	191	168
CV (%)	25	21	27	23

CV = coefficient of variability

A time series bar chart indicated high inter-annual rainfall variability among the districts (Figure 2). The annual total rainfall ranged from 281-1131mm at Meki, 425-1234 mm at Melkassa, 271-1111 mm at Mieso and 314-1042 mm at Ziway (Figure 2). These annual rainfall figures indicate that Melkassa

has greater annual total rainfall than the rest of the sites studied. The highest and lowest total annual rainfall years were 1983 and 1995 at Meki, 2007 and 1989 at Melkassa, 1996 and 1986 at Mieso and 2008 and 1970 at Ziway, respectively (Figure 2).

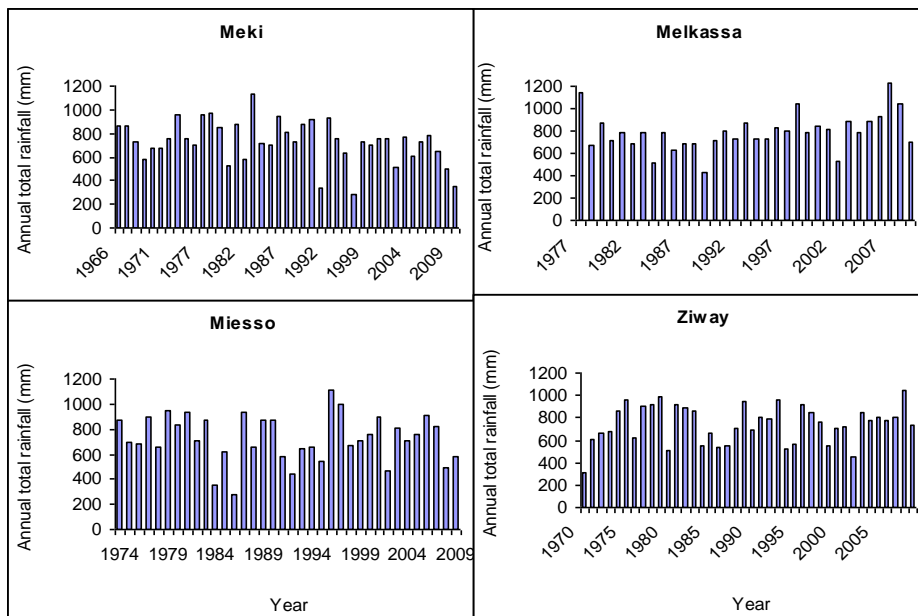


Figure 2. Long-term inter-annual variability of rainfall at four sites in the Central Rift Valley of Ethiopia.

The standardized rainfall anomaly gives a clear picture of average (normal), above average (wet) and below average (dry) years (Figure 3). As it can be seen from Figure 3, the four stations had experienced both dry and wet years over the last 33 (Melkassa) and 41 years at (Meki). For instance Meki had experienced dry conditions in 1991, 1995 and 2009 whereas it enjoyed wet conditions in 1983. The years that gave above average rainfall at Melkassa were 1977 and 2007 as opposed to 1989 when dry

conditions prevailed. Mieso experienced dry conditions in 1984 and 1986 and wet condition in 1996. The years that dry and wet conditions prevailed in Ziway were 1970 and 2008, respectively (Figure 3).

Moreover, the linear trend line for Meki clearly demonstrated a general declining tendency in rainfall since 1966, whereas increasing trend was observed for Melkassa. On the other hand, there was little or no change in

rainfall trend at Mieso and Ziway (Figure 3).

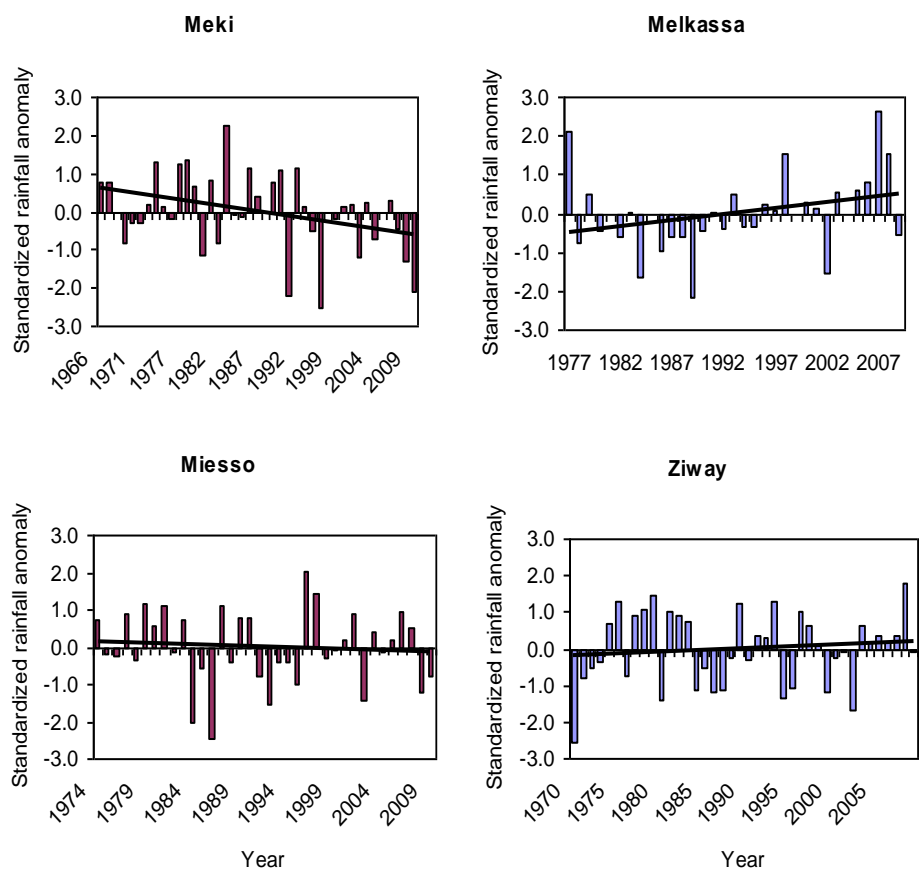


Figure 3. Rainfall variability and trend as expressed by standardized rainfall anomaly at four sites in the Central Rift Valley of Ethiopia

Table 3. Seasonal rainfall distribution and its statistical attributes at four sites in the Central Rift Valley of Ethiopia

Site	Rainfall statistics								
	Season	Minimum	Percentile			Maximum	Mean	SD (±)	CV (%)
			25	50	75				
Meki	FMAM	71.2	150.7	187.5	266.4	510.4	213.9	95.2	44.5
	JJAS	90.6	409.3	464.9	551.3	658.8	468.2	119.4	25.5
	OND	0.0	6.6	22.7	58.7	262.6	42.9	55.7	129.7
Melkassa	FMAM	23.0	115.1	197.6	260.5	323.6	185.1	83.2	45.0
	JJAS	289.2	435.3	526.1	584.1	704.3	515.8	107.3	20.8
	OND	0.6	13.0	45.1	135.1	314.2	71.0	74.4	104.9
Miesso	FMAM	0.0	163.2	237.7	306.4	530.8	248.6	115.8	46.6
	JJAS	184.5	288.5	396.4	479.8	648.1	395.3	116.3	29.4
	OND	0.0	18.8	42.1	112.4	435.1	70.46	85.1	120.8
Ziway	FMAM	75.1	162.9	245.7	302.8	394.9	232.7	96.3	41.4
	JJAS	112.3	390.4	445.9	502.7	788.6	443.5	122.0	27.5
	OND	0.0	5.9	23.4	71.1	289.2	47.5	60.1	126.6

The bimodal pattern of the rainfall in the study sites is presented in Table 3. The first rainy season (*Belg*) extends from end of February to May (FMAM) while the second (*Kiremt*) extends from June to September (JJAS). The long-term minimum FMAM season rainfall total ranges from 0 mm (Miesso) to 75.1 mm (Ziway) while the long-term maximum rainfall ranges from 323 mm (Melkassa) to 531 mm (Miesso). In one out of four years the FMAM season rainfall ranges from 115.1 mm (Melkassa) to 163.2 mm (Miesso) with an upper quartile value of 260.5mm (Melkassa) to 306.4 mm (Miesso). The median and average seasonal rainfall for *belg* season ranges from 187.5 mm (Meki) to 245.7 mm (Ziway) and 185.1 mm (Melkassa) to 248.6 mm (Miesso), respectively.

The *belg* (FMAM) exhibited higher rainfall variability (41-47%) as compared to the *kiremt* rainfall variability (21-29%) at the four sites (Table 3). The analysis also showed that the *belg* rainfall was more variable at Miesso, while it was less variable at Ziway. Miesso also had the most variable *kiremt* rainfall, while Melkassa had the least variable one. Even if the study areas are located in close proximity to each other, they differed in the amount of seasonal rainfall distribution receive and the degree of variability of seasonal rainfall. On the other hand, the dry season of the study area (*Bega*) extends from October to December (OND). The long term minimum season rainfall total is 0 mm in all sites and the maximum seasonal rainfall total ranges from 262 mm (Meki) to

435mm (Miesso). The *Bega* rainfall exhibits the highest rainfall variability (105-130%) at four sites as compared to *Belg* and *Kiremt* season, even if the season was dry under normal condition (Table 3).

The seasonal rainfall analysis on the number of rainy days is presented in

Figure 4. Number of rainy days showed a declining trend in both the *belg* and *kiremt* seasons at Meki followed by the *belg* season at Melkassa. On the other hand, the number of rainy days showed an increasing trend in the *kiremt* season at Melkassa, Miesso and Ziway.

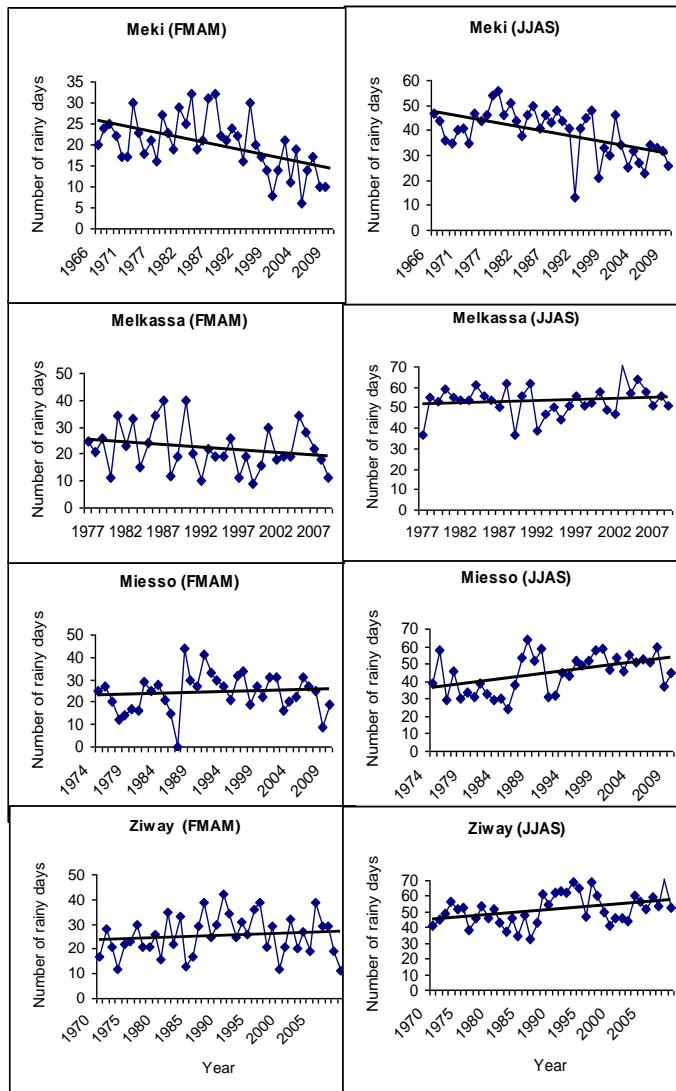


Figure 4. Variability and Trend of number of rainy days in *belg* (FMAM) and *kiremt* (JJAS) seasons at four sites in the Central Rift Valley of Ethiopia.

Onset and cessation of rainfall, length of growing season and dry spell risk analysis

The analysis of rainfall for agricultural purposes must include information on the trends or changes in precipitation; the start, end and length of the rainy season; and the distribution of rainfall amounts through the year, and the risk of dry spells (Stelio, 2004). The cumulative probabilities of onset and end date, and length of growing period of the study areas are presented in Figure 5 and 6 respectively. The variability of onset date for the four districts was higher as compared to end date and length of growing period. At Meki, the rain starts before May 10 (131 DOY) in 20% of the time, before June 21 (173 DOY) 50 % of the time and before July 6 (188 DOY) 80% of the time. In the case of Melkassa, the rain starts earlier than May 11 (132 DOY) in one out of five years , earlier than June 25 (177 DOY) 50% of the time and 80% of the time (in four out of five years time) it starts before July 9 (191 DOY). On the other hand, at Mieso, the rain starts earlier than March 18 (78 DOY) 20% of the time indicating that planting earlier than 18 March is possible only once in every five years time in Mieso. The chance of planting before June 3 (155 DOY) and July 10 (192 DOY) at

Mieso is 50 and 80%, respectively. The chances of effective planting before April 19 (110 DOY), June 14 (166 DOY) and June 24 (176 DOY) at Ziway were 20, 50 and 80%, respectively (Figure 5). A further note could also be made from Figure 5 that rainfall duration is dependent mainly on the onset date. In 50-80% of the time, the rain ends in all districts in the month of September, except Meki where it extends up to the month of October in 80% of the time.

The median (50%) length of the growing period was found to be 101, 88, 118 and 104 days at Meki, Melkassa, Mieso and Ziway. In 80% of the years, the length of the growing period did not exceed 138, 121, 175 and 141days at Meki, Melkassa, Mieso and Ziway, respectively (Figure 6).

Overall, except for the rainfall onset date of the season, the four stations bear similar patterns for the end date and length of growing period. Culturally, the first planting time in the study area is in the month of March in Mieso, but the probability of having rainfall onset in the beginning of this month is less than 10% in all the other three sites except Mieso.

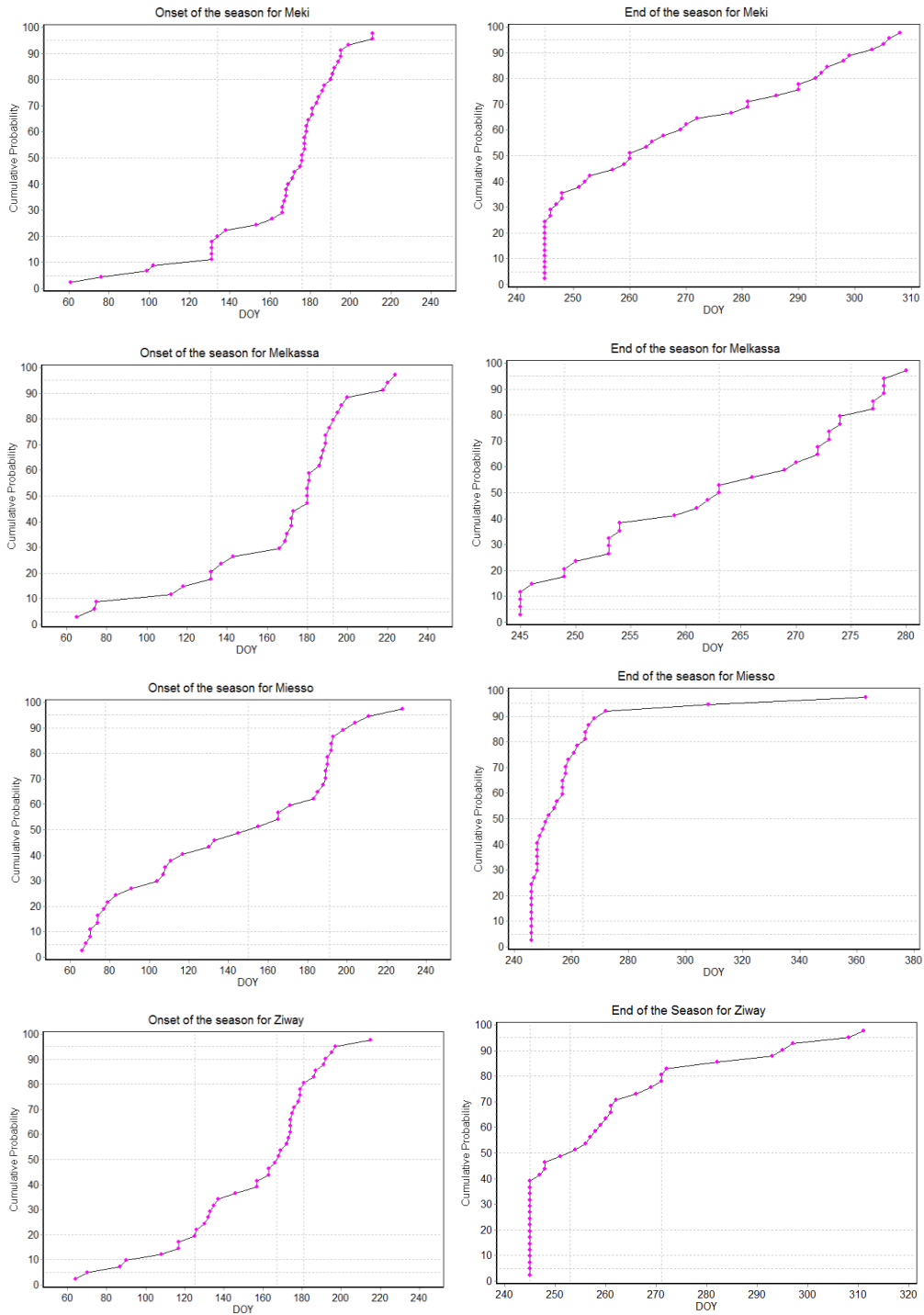


Figure 5. Cumulative probability of onset and end of rainy season at four sites in the Central Rift Valley of Ethiopia.

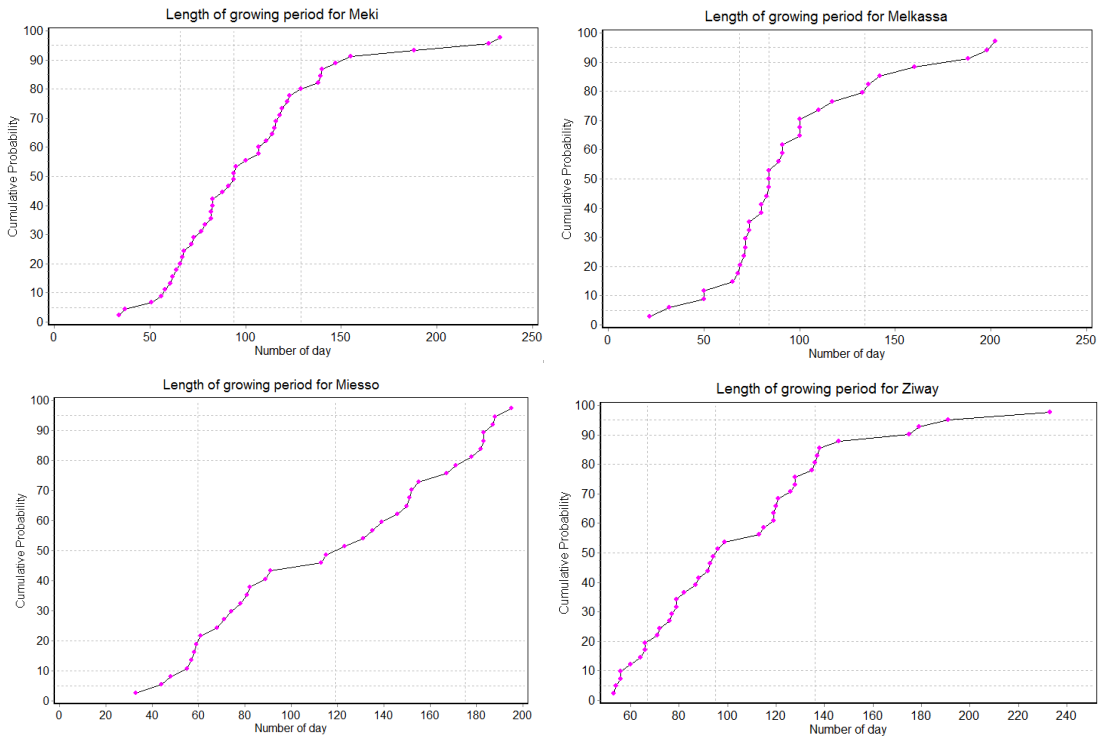


Figure 6. Cumulative probability of length of growing season at four sites in the Central Rift Valley of Ethiopia.

The ‘parabolic-type’ curves explained that the probability of dry spells longer than 20 days from March to September is less than 10% in all districts, whereas it showed a certain degree of upward slope in April and May and descends down to zero from the middle of June to middle of July. The probability of dry spells more than 15 days is less than 10% for Miesso and less than 20% for the rest of districts in March. The dry spell graphs showed a variation across sites in the probability of dry spells longer than 10 days (Figure 7).

Moreover, the probability of 5 days of dry spell curves stayed at 100% during the earlier and later months in the growing season. All the dry spell length probability curves converge to their minimum only during the peak rain period (July and August) for all districts and turn upward again around September, indicating the end of the growing season (Figure 7).

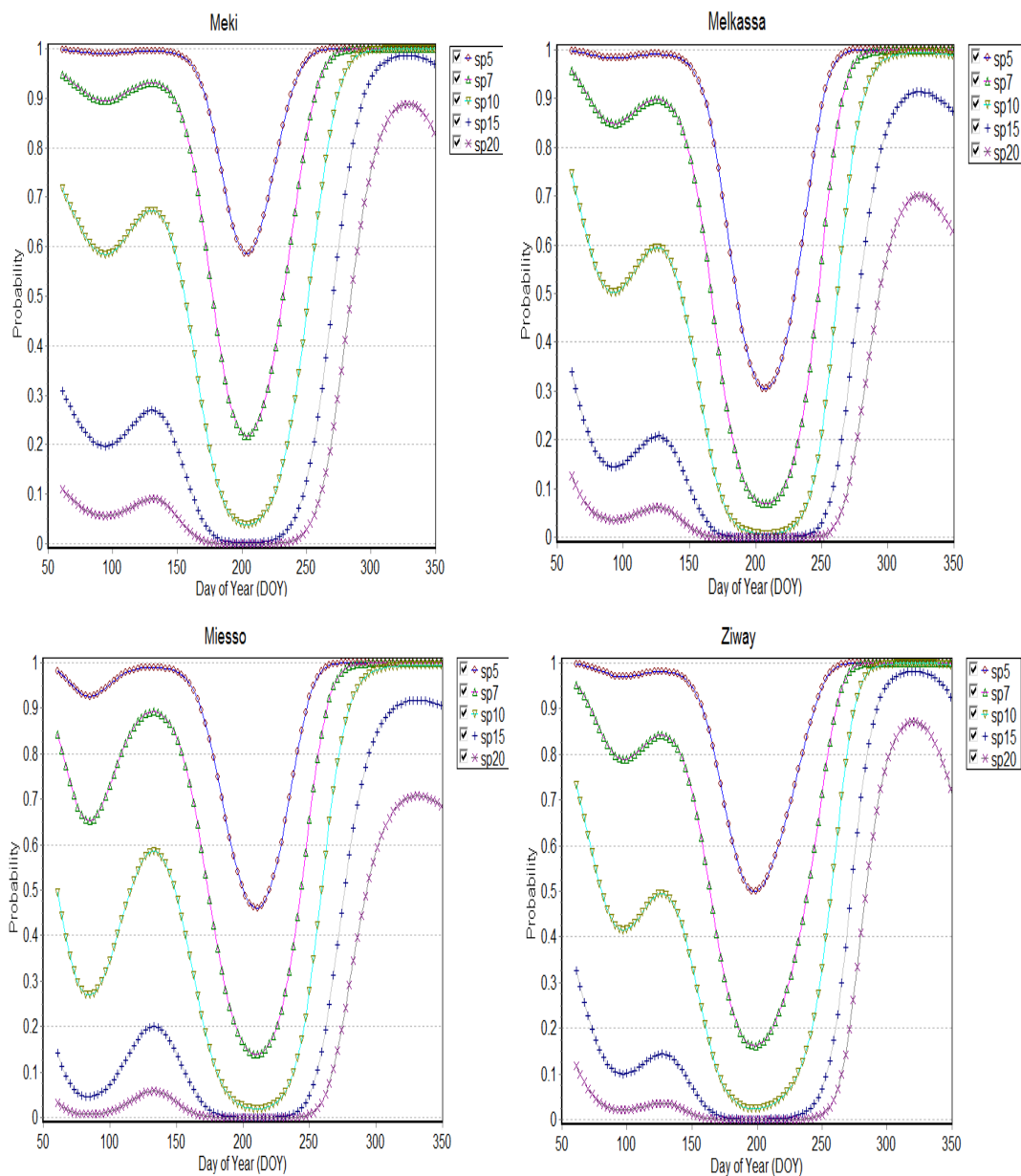


Figure 7. Probability of dry spells longer than 5, 7, 10, 15 and 20 days at four sites in the Central Rift Valley of Ethiopia.

Temperature variability and change

The mean annual maximum temperature at the three sites (Melkassa, Miesso and Ziway) ranged from 26.8-30.6 °C, while the mean minimum ranged from 13.7-15.0

°C (Table 4). The minimum temperature showed a higher variability than the mean maximum temperature at all the sites (Table 4).

Table 4. Mean maximum and minimum temperatures at three sites in the Central Rift Valley of Ethiopia

Temperature	Sites		
	Melkassa	Miesso	Ziway
Maximum temperature			
Mean (°C)	28.6	30.6	26.8
Standard deviation (°C)	0.5	0.6	1.2
CV (%)	1.8	1.9	4.5
Minimum temperature			
Mean (°C)	14.1	15.0	13.7
Standard deviation (°C)	1.5	0.6	1.4
CV (%)	10.6	3.7	10.1

CV = coefficient of variability

The maximum temperature indicated a clear increasing trend at Miesso and Ziway but it remained static at Melkassa. On the other hand, the minimum temperature showed a slight increasing trend at Miesso and Ziway, but showed a clear decreasing trend at Melkassa (Figure 8).

temperatures particularly at Miesso and Ziway and increase in maximum temperature at melkassa indicate a clear warming of the atmosphere in the regions. An increase in maximum and minimum temperatures is taken as a good indicator of global warming in a given area (IPCC, 2001).

The increasing trend of both mean maximum and minimum

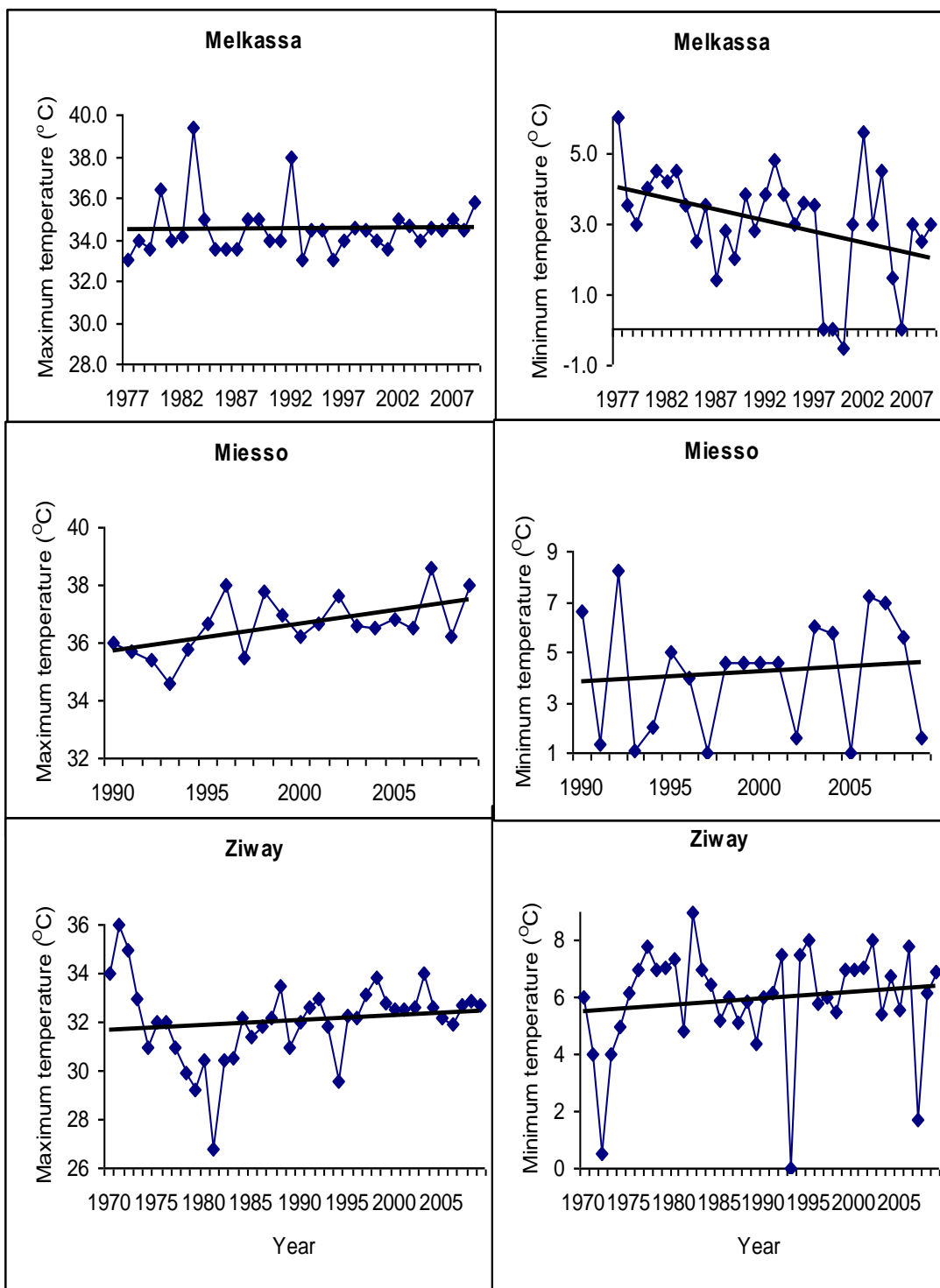


Figure 8.. Annual maximum and minimum temperature variability and trend at three sites in the Central Rift Valley of Ethiopia.

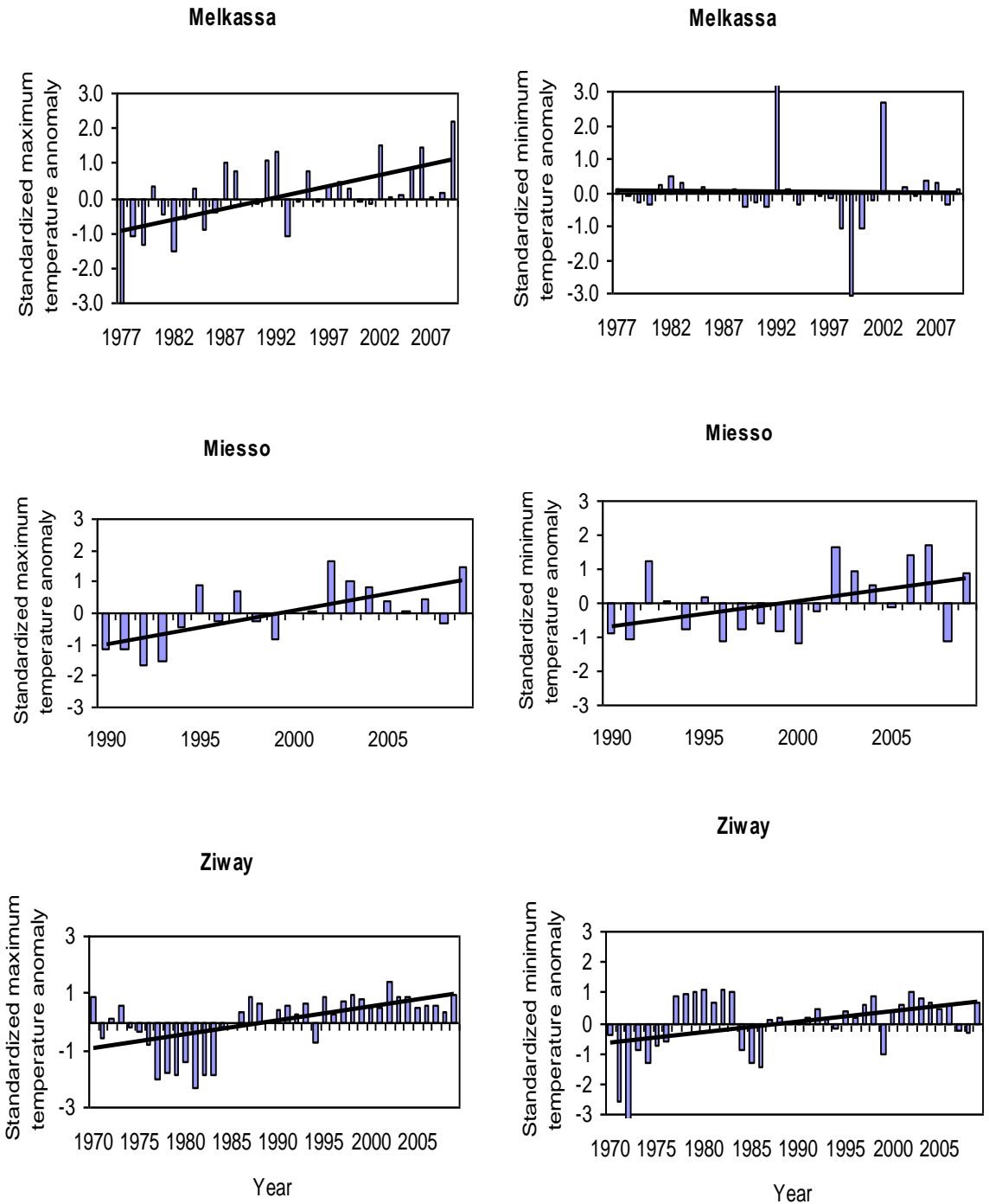


Figure 9. Annual mean maximum and minimum temperature variability and trend at three sites in the Central Rift Valley of Ethiopia.

Farmers' perceptions to climate variability and climate changes

Almost all respondents at the three sites and more than 85% of the respondents at Ziway felt a reduction of rainfall amount in their respective areas over the last few decades (Table 5). Respondents who perceived late start of the rains ranged from 50%

(Ziway) to 94% (Miesso) while the percentage of respondents who perceived early withdrawal of the rainfall ranged from 8% (Meki) to 66% (Miesso). About 30% (Miesso) to 72% (Melkassa) of the respondents believed erratic distribution of rainfall during the rainy seasons (Table 5).

Table 5. Climate related changes perceived by respondents (n=200) at four sites in the Central Rift Valley of Ethiopia

Perception with respect to climate change	Respondent (%)				
	Meki	Melkassa	Miesso	Ziway	Average
Reduction of rainfall amount	98	100	100	86	96
Late start of the rain	66	56	94	50	67
Early withdrawal of the rain	8	54	66	28	39
Erratic rainfall distribution during the rainy season	40	72	30	70	53
Increased frequency of drought	6	0	40	8	14
Increased Temperature	40	42	60	30	43
Increased frequency of flood	4	2	4	8	5
Farmers call the above changes as:					
Climate change	98	82	48	90	80
Climate variability	0	6	0	12	5
Natural phenomena	0	0	2	12	4
God punishment	2	12	52	8	19

Percent above hundred indicate multiple responses

On the other hand, only 40% of the respondents at Miesso and less than 10% of the respondents at the three other sites perceived increased frequency of drought in the last few decades. On average, only 5% of the total respondents perceived an increase in the frequency of flood in the study sites (Table 5). Most of the respondents at Miesso and more than

one-third of the respondents at Meki, Ziway and Melkassa felt an increase in heating of the air (Table 5). More than 80% of the respondents at Meki, Ziway and Melkassa believed that the changes in rainfall and temperature were due to climate change while about 52% of the respondents at Miesso believed that the changes were a result of God's punishment (Table

5). This perception of the farmers completely agrees with the long-term maximum and minimum temperatures trends and late onset date observed in the respective sites. Moreover, farmers' perception in agreement with rainfall variability and trend analysis observed in Meki station while completely disagree with that of Melkassa station.

Farmers' adaptation mechanisms to climate change

Vulnerability to climate change can be reduced through enhancing adaptive capacity and/or reducing sensitivity/exposure to climate related hazards. Adaptation is processes through which societies make themselves better able to cope with an uncertain future. Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes. Based on the results indicated in Table 6, farmers in the studied sites have been undertaking different adaptation measures to overcome challenges

faced in crop production in the study areas.

The adaptation measures include growing short and long maturing varieties, drought tolerant varieties, use of recently released varieties, application of fertilizers, water harvesting, use of irrigation, request for food aid and seeking part time jobs (Table 6). The use of recently released varieties is the most commonly used method in the study area (41%) particularly in Meki and Miesso whereas requesting for food and seeking part time jobs are least practiced among the major adaptation methods identified in the study areas. Greater use of the recently released varieties as an adaptation method could be associated with frequent access to new varieties like Melkassa-6Q, Melkassa-7 and Melkassa-5 (Maize varieties), 87BK-4122, RED SWAZI and MACIA (sorghum varieties) and GEMECHIS/DZ-Cr-387 (teff varieties) from Melkassa Agricultural Research Center (MARC).

Table 6. Climate change adaptation mechanisms practiced by farmers (n= 200) in four districts in the Central Rift Valley of Ethiopia

Adaptation	Respondents (%)				
	Meki	Melkassa	Miesso	Ziway	Total
Growing short maturing varieties	14	54	34	48	38
Growing long-maturing varieties	4	8	2	32	12
Growing drought tolerant varieties	0	0	22	2	6
Growing recently released varieties	56	16	56	34	41
Application of fertilizers	44	22	16	18	25
Water harvesting	6	0	18	4	7
Use of full or supplemental irrigation	20	32	0	18	18
Requesting for food aid	0	8	6	4	5
Seeking part time jobs	4	4	0	10	5

Percent above hundred indicate multiple responses

These adaptation measures mentioned by the farmers in the CRV are similar to the other findings reported to better suit drier conditions, including irrigation, crop diversification, and changing planting dates by Deressa *et al.* (2009) in Ethiopia, Maddison (2006) and Nhemachena and Hassan (2007) in South Africa, Bradshaw *et al.* (2004) in Canada, and Kurukulasuriya and Mendelsohn (2008) in Africa.

Conclusion

There was high inter-annual rainfall variability within the four districts. All districts experienced both very dry and very wet years in their meteorological record history. The trend line analysis exhibited a decreasing tendency of rainfall at Meki and an increasing tendency at Melkassa. There was no change in annual rainfall trend at Miesso and

Ziway. The *belg* (FMAM) season had high rainfall variability than the *kiremt* season (JJAS) at the four study sites. Meki exhibited a dramatic decline in the trend of number of rainy days in both seasons, while a slight declining trend was observed in the *belg* season at Melkassa. On the other hand, a reasonable increment had been observed at Miesso and Ziway in the *kiremt* season, while there was no change in the trend of rainy days in the *belg* season at both sites.

Onset, cessation, dry spell and length of growing season analyses have shown that except the onset date of the rainfall season, the districts have similar patterns on the end date and length of growing period.

The long-term temperature analysis showed an alarming increase in both maximum and minimum temperatures at Miesso followed by

Ziway. However, no change was observed in minimum temperature at Melkassa although the maximum temperature exhibited an upward trend.

Farmers have a good perception on climate change and most of them believed that the environment has been changing over the years due to deforestation. Erratic distribution, reduction in amount, late onset and early withdrawal of the rainfall and increased heat were the major problems mentioned as reasons for frequent crop failures over the areas and this has grave implications for all communities in the districts.

Farmers in the study areas are growing recently released varieties, short maturing varieties and application of fertilizer as adaptation strategies to overcome challenges faced due to climate change. Moreover, use of full or supplemental irrigation, growing long-maturing, drought tolerant crop varieties were also used as adaptation mechanism for the current climate variability and change related risks in the study areas.

The current study clearly indicated high inter-annual rainfall variability in the study areas and the associated climate risks. This calls for consideration climate in local, regional and national plans in order to reduce the effects of climate related risks and developing strategies to increase

adaptation to the current and projected climate change scenarios.

References

- Bradshaw, B., Dolan, H., and Smit, B. 2004. Farm-level adaptation to climatic variability and change in the Canadian prairies. *Climatic Change*, 67: 119-141.
- Deressa, T., Hassan, R., Ringler, C., Alemu, T., and Yusuf, M. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 10: 1-8. www.elsevier.com/locate/gloenvcha
- Kidane, G., Abebe, T. and Tibebe, D. 2006. Estimating crop water use and simulating yield reduction for maize and sorghum in Adama and Mieso districts using the cropwat model. CEEPA Discussion Paper No. 31. Centre for Environmental Economics and Policy in Africa. University of Pretoria, Pretoria, South Africa.
- Kindie, T. and Walker, S. 2004. Matching of crop and environment for optimal water use: the case of Ethiopia. *Physics and Chemistry of the Earth*, 29: 1061-1067.
- Kurukulasuriya, P. and Mendelsohn, R. 2008. A Ricardian analysis of the impact of climate change on African cropland. *African Journal of Agricultural and Resource Economics* 2 (1): 1-23.
- Hengsdijk, H. and Jansen H. 2006. Agricultural development in the Central Ethiopian Rift Valley: A desk-study on water-related issues and knowledge to support a policy dialogue. Plant Research International

- B.V., Wageningen, the Netherlands. pp. 25.
- Intergovernmental Panel on Climate Change (IPCC) 2001. Climate Change Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report. Cambridge University Press, Cambridge.
- Maddison, D., 2006. The perception and adaptation to climate change in Africa. Centre for Environmental Economics and Policy in Africa. Discussion paper No. 10, University of Pretoria, South Africa.
- Mahmud, Y., Salvatore, D., Temesgen, D., Claudia, R., and Gunnar, K. 2008. The impact of climate change and adaptation on food production in low-income countries evidence from the Nile Basin, Ethiopia. International food policy research institute (IFPRI) Discussion Paper No. 00828. Washington, DC.
- Ministry of Finance and Economic Development (MoFED) 2006. Survey of the Ethiopian economy. Addis Ababa, Ethiopia.
- Moti, J. 2002. Inter locked markets and intensity of input use in vegetable production: A case around Lake Ziway, Oromiya region, Ethiopia. MSc thesis Wageningen University, Netherland.
- Nhemachena, C., Hassan, R. 2007. Micro-level analysis of farmers' adaptation to climate change in South Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute, Washington DC, USA.
- Orindi, V., Ochieng, A., Otiende, B., Bhadwal, S., Anantram, K., Nair, S., Kumar V., and Kelkar, U. 2006. Mapping Climate Vulnerability and Poverty in Africa. pp.1-127. In: P.K. Thornton, P.G. Jones, T. Owiyo, R.L. Kruska, M. Herrero, P. Kristjanson, A. Notenbaert, N. Bekele and A. Omolo. Report to the Department for International Development, International Livestock Research Institute (ILRI), Nairobi, Kenya.
- Sivakumar, M.V.K. 1988. Predicting rainy season potential from the onset of rains in southern Sahelian and Sudanian climatic zones of West Africa. *Agriculture Forecast Meteorology*, 42: 295-305.
- Stelio, P. 2004. Trends of precipitation in Cyprus rainfall analysis for Agricultural Planning. Meteorological Service, 1418 Nicosia, Cyprus.
- Stern, R., Rijks, D., Dale, I., and Knock, J. 2006. Instat climatic guide. United Kingdom, England.
- Stige, L., Stave, J., Chan, K., Ciannelli, L., Pattorelli, N., Glantz, M., Herren H., and Stenseth, N. 2006. The Effect of Climate Variation on Agro-Pastoral Production in Africa. pp 3049-3053. Proceedings of the National Academy of Sciences of the United State of America.