Analysis of maize yield responses to climate in the arid and semi arid lands of lower eastern Kenya

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ABSTRACT

Climate is key determinant of crop yields under rain fed conditions in Kenya's dry lands as well as other parts of the country. Climate variability and change has had adverse effect on maize yields and food supply in ASALs. The objective of the study was to analyze the response of maize yields to changing climate in the arid and semi arid districts of lower Eastern Kenya. This study was based on the desire to understand the impact of climate variability/change on maize yields with an aim to provide strategies for adaption. Longitudinal survey and evaluation research designs were used in the study. Purposive and cluster sampling techniques were employed to select the study samples. The study utilized maize and climate time series datasets of lower eastern Kenya's four ASALs districts covering the thirty year period of 1979-2009. Both primary and secondary datasets were utilized. Primary data was collected by the use of questionnaires, key informant interviews and focus group discussions. Secondary data for maize yields was collected from the Ministry of Agriculture which were analyzed by use of INSTAT and SPSS statistical packages. Climate data were collected from KMD and KEFRI and analyzed to determine trends and patterns over the period. Responses of maize yields to climate were sought through Z-scores, tend analysis and descriptive. The findings revealed that there has been wide variability in climate in lower eastern Kenya. From climate variability analysis, the results show adverse effects on maize production and thus food security. The results indicated that there is enormous negative impact of climate on maize yields in the four ASAL districts of lower Eastern Kenya. Trend analysis revealed that maize yields are alarmingly declining at high levels in Machakos district (22.5 Kg/acre pa) followed by Kitui (12.0 Kg/acre pa), Mwingi (7.3 Kgs/acre pa) and lastly Makueni 8.7 Kg/acre pa). The maize yields Z-values were predominately negative in the period 1994-2008. Rainfall trend analysis revealed that four of the six weather stations were declining at alarming rate (0.6-15.5 mm pa). Evidently there was upward warming of annual and seasonal temperature at rate of 0.03 ^{0}C pa. These findings are startling but are crucial in planning appropriate adaptation mechanisms by government, researchers and other development workers in lower Eastern Kenya in support of enhancing resilience of maize production and food security. They will also be used by farmers to monitor climate risks and forecast maize production under rain-fed conditions in lower Eastern Kenya's dry lands.

Key words: Food security; crop yields; Arid and semi arid lands, climate change adaption, climate variability and change

1.0 INTRODUCTION

Agriculture is one of the key socio economic activities substantially affected by climate variability and change globally. The impact of weather and climate variability and change is more dramatic in the arid and semi arid lands (ASALs) which cover about 40 per cent of the earth's surface, are inhabited by approximately 20 per cent of world population and provide 10 % of the world's meat supply (Sivakumar *et al.,* 2005). Africa's ASALs comprise 66% of total land area and harbor approximately 200 million people (Sivakumar *et al.,* 2005). In Kenya, the ASALs occupy more than 80% of the country are home to about 10 million people and approximately 70% of the national livestock herd (GOK, 2009a). They are frequently inflicted by drought resulting to widespread food insecurity and poverty. Climate change and variability is expected to contribute to increased drought episodes, food insecurity and poverty (IPCC, 2007).

Maize is arguably the most important food crop in Kenya. Climate change and variability has had disastrous consequences in maize production. The climate change induced droughts of 1982, 1992, 2000, 2003, 2007 and 2009 wreaked havoc on maize production and food security in Kenya (GOK, 2009). In Kenya's ASALs often crop yields such as maize, beans and sorghum vary according to seasonal and annual climate of the area (Jaetzold, 2007). ASALs in Kenya are particularly vulnerable to climate variability and change due to the dependence on rain fed subsistence farming, widespread poverty, diseases, rising human population and low adaptive capacity (Nyandiko *et al.,* 2012). The ASALs in Kenya support about 10 million human population, 60% of livestock, and the largest population of wildlife (GOK, 2008). Major droughts such as those that occurred in the 1980s and 1990s inflicted major blows on dry land livelihoods. They droughts directly impacted on over 10 million people living in the ASALs (ILRI, 2010). Drought episodes in addition to occasional flash floods erode the assets of poor communities, reduce crop yields, undermine livelihood strategies and enormously contribute to a downward spiral of increasing poverty and food insecurity (ILRI, 2010). Analysis of climate and maize yields can provide critical information to farmers and other stakeholders on adaptation mechanisms to forestall climate change in Kenya's ASALs.

2.0 MATERIALS AND METHODS

This study was carried out in the four ASAL districts of lower Eastern Kenya. The study districts were Makueni, Machokos, Kitui and Mwingi. The altitude of the area varies from 600m to 1,100m above sea level (Jaetzold, 2007). The mean annual rainfall, evaporation and temperatures are in the order of 600mm, 1,150mm and 28^{0}C respectively. According to the 2009 population census the population was projected to be 3,037,373 people in 2010. The districts lie with latitudes--- and longitude----.

Climate data

Rainfall, temperature and evaporation records from six weather stations were analyzed to determine trends and patterns. The six weather stations that supplied climate data were Machakos (Ktumani), Makindu, Kibwezi, Kitui, Mwingi and Mutomo for the period 1979-2009. The climate data was supplied by Kenya Meteorological Department (KMD).

Determination of annual and seasonal trends and patterns of rainfall

Seasonal and annual trends were computed from daily data and trend and patterns determined by means of graphs and trend lines. The trend line equation y = ax +b was used to describe the changes in rainfall where 'y' represents the rainfall amount in millimeters, 'a' represents the slope hence the rate of change of rainfall over the period and 'b' represents the intercept on y-axis.

Determination of annual and seasonal trends and patterns of temperature

Seasonal and annual trends of temperature were computed from daily data and trend and patterns determined by means of graphs and trend lines. The trend line equation y = ax +b was used to describe the changes in temperature where 'y' represents the temperature amount in ^{0}C, 'a' represents the slope hence the rate of change of temperature over the period and 'b' represents the intercept on y-axis.

Determination of annual and seasonal trend and patterns of evaporation

Seasonal and annual trends were computed from daily data and trend and patterns determined by means of graphs and trend lines. The trend line equation y = ax +b was used to describe the changes in potential evaporation where 'y' represents the evaporation amount in millimeters, 'a' represents the slope hence the rate of change of evaporation over the period and 'b' represents the intercept on y-axis.

Determination of maize yield responses to climate

Maize yield data was obtained from Ministry Agriculture records for the period 1979-2009 fro the four ASAL districts of lower Eastern. However, Makueni and Mwingi districts the maize records were for the period 1993-20009. Z-scores and trend lines were used to determine maize yield response to rainfall, temperature and evaporation. Additional correlation and regression analysis ware used to further examine relationships between the climate and maize yields.

3.0 RESULTS

Annual and seasonal rainfall trends and patterns

High variabilities exist in seasonal and annual rainfall amounts in all the weather stations with some years receiving over 1000 mm and others receiving below 250 mm. Makindu had the highest mean annual rainfall (594.6 mm) while Mutomo had the highest (mean =808.0mm). Trend analysis of seasonal and annual rainfall showed most of the stations had a negative trend except Mwingi and Mutomo stations (Table 1). Evidently the rate of rainfall decline in the selected weather stations has been dramatic. The Machakos annual rainfall is declining at the rate of up 1.4 mm pa, Makindu is declining at rate of up to 5.6 mm pa, Kitui is declining at rate of up to 15mm pa and Kibwezi station and surroung areas are declining up to 2.3 mm pa. However, Mutomo and Mwingi stations reveal positive trends of up to 7.3 mm pa.

Table 1: Trend analysis summary of rainfall by station of lower Eastern Kenya

District	Season	Slope	a-value	R^2	Sig	Trend
Machakos	MAMJ	-0.070	1143	0.000	0.976	Negative
Machakos	ODNJ	-0.302	1143	0.000	0.943	Negative
Machakos	Annual	-1.4	1218	0.004	0.727	Negative
Makindu	MAMJ	-2.93	6028	0.085	0.11	Negative
Makindu	ONDJ	-1.70	3731	0.004	0.707	Negative
Makindu	Annual	-5.60	11869	0.056	0.198	Negative
Mutomo	MAMJ	2.9	7812	0.033	0.325	Positive
Mutomo	ONDJ	3.16	7990	0.012	0.554	Positive
Mutomo	Annual	7.3	19002	0.04	0.260	Positive
Kibwezi	MAMJ	-1.30	3696	0.012	0.587	Negative
Kibwezi	ONDJ	-2.30	6662	0.014	0.523	Negative
Kibwezi	Annual	-1.70	5201	0.004	0.715	Negative
Mwingi	MAMJ	0.731	-1744	0.005	0.700	Positive
Mwingi	ONDJ	4.10	-10693	0.047	0.24	Positive
Mwingi	Annual	4.67	-8639	0.003	0.672	Positive
Kitui	MAMJ	-5.06	10300	0.078	0.203	Negative
Kitui	ONDJ	-10.5	21335	0.112	0.127	Negative
Kitui	Annual	-14.37	29374	0.152	0.072	Negative

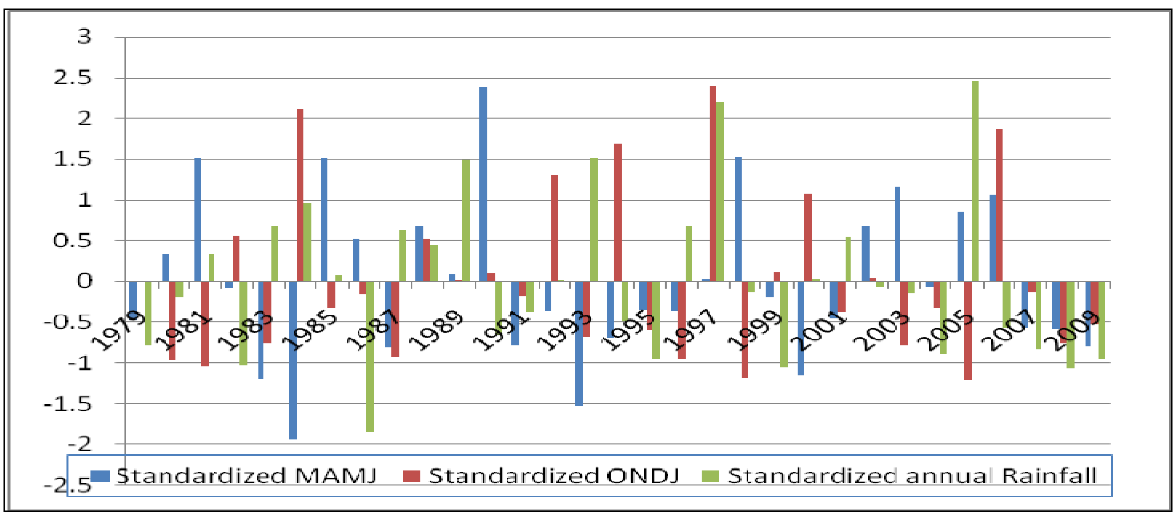

Fig. 1: Machakos station seasonal and annual rainfall anomalies (1979-2009).

Annual and seasonal temperature patterns and trends

Seasonal and annual maximum and minimum temperature revealed wide variability. Analysis of growing seasonal (October-November-December-January) maximum temperature for Makindu and Machakos reveal upward warming at the rate of up to 0.03 ^{0}C pa (Fig 2).

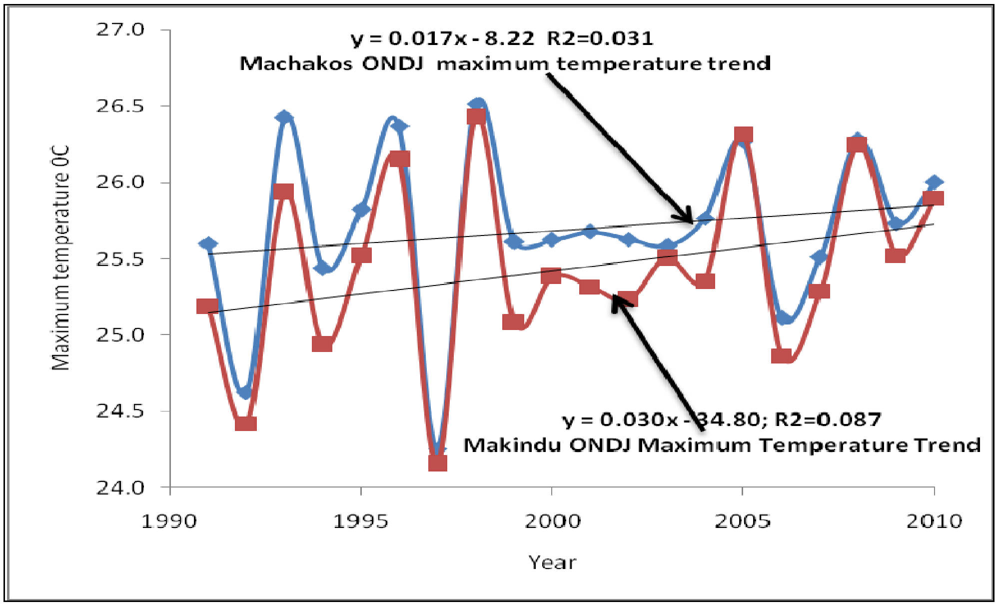

Fig 2: Seasonal maximum temperature and trend line for Lower Eastern Kenya districts

Analysis of potential evaporation trends

Seasonal and annual potential evapotranspiration revealed increasing trend over the period (Fig.3).

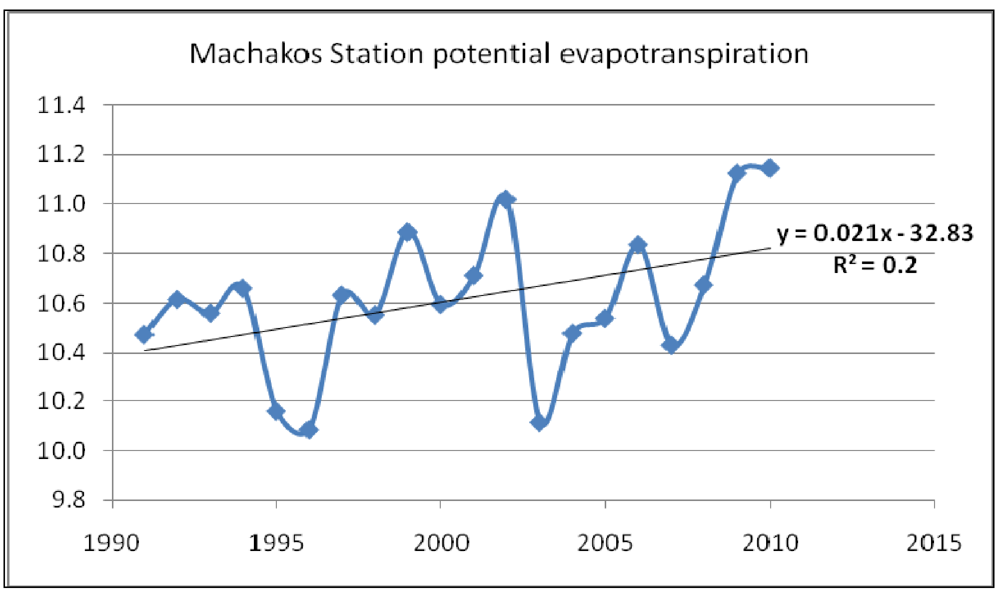

Fig 3: Potential evaporation and trend for Machakos station (1991-2009)

Analysis of maize yield responses to climate

The mean maize yield in Machakos was 688.7 Kg/acre, in Makueni is 264.0Kg/acre, Kitui District has 429.0 Kg/acre while Mwingi is 244.8 Kg/acre giving the overall mean of 296.1 Kg/acre. The highest maize yield obtained was 1932.1Kgs/Acre in Kitui District (1999) while the lowest yield was 17.8 Kg/acre in 1987 observed in Mwingi District (Table 2). The average maize yield for the four ASAL districts over the period was 431.3 Kgs. From the analysis the highest observed maize yields are in Machakos District (Mean =688.7 Kgs) while Mwingi District realized the lowest average maize yield. The findings revealed that there is wide variability in maize yields in the four Districts over the period. Yield variability is strongly influenced by climate and weather variability and change in ASALs particularly of lower eastern Kenya.

Table 2: Maize yield descriptive summary for lower Eastern Kenya

District	Lowest yields	Highest yield	Mean	S.D	CV
Machakos	176.5 (1998)	1862.8 (1988)	688.7	246.5	41.9
Makueni	129.3 (2005)	1100.0 (1993)	508.0	264.0	52.0
Kitui	17.8(1987)	1932.1(1990)	547.8	429.0	78.3
Mwingi	96.3 (2005)	989.9 (1993)	411.8	244.8	59.4
Average	105.0	1471	431.3	296.1	68.6

The trend over the 1979-2009 period showed that maize yields have been declining sharply in all the Districts. The spatial rate of decline of maize yields was 22.5Kg/acre pa in Machakos District, 11.75 Kg/acre pa in Kitui and 8.7 Kgs/acre in Makueni District (Fig 4). Kitui District had the highest variation in maize yields with CV of 78.3 while Mwingi had the lowest variation (CV = 59.4 %) over the period. Makueni District had the lowest CV of 52.0%. Student's one-sample t-test of mean maize yields time series revealed that they were statistically significant at 0.05 per cent level.

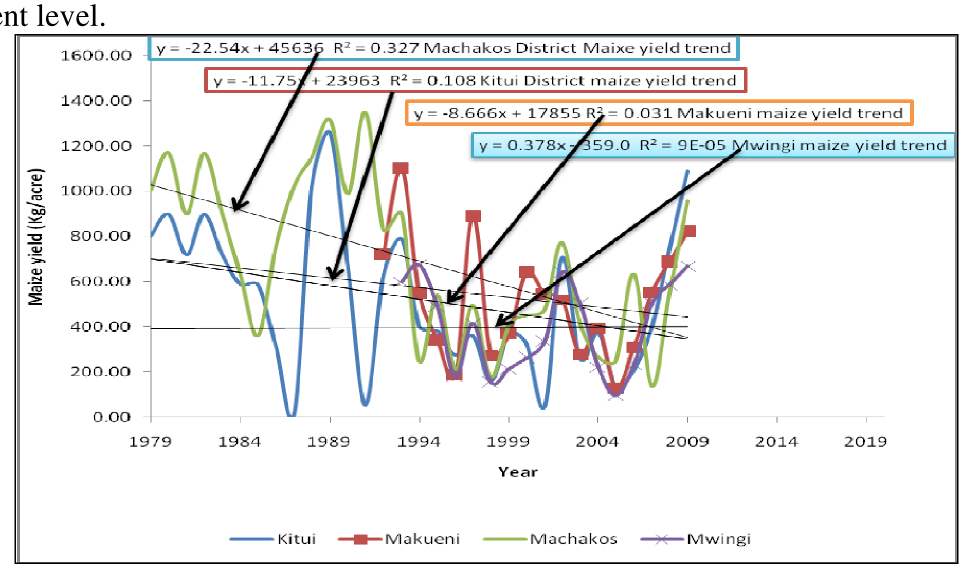

Fig 4: Maize yield and trend line of the lower Eastern Kenya's ASAL districts

Maize yields Z-distribution is varying in magnitude between -3 and + 3 in all the four ASAL districts (Table 3). The observed Machakos District maize yield for 2007 represented the lowest yield anomaly with a low Z- value of -1.5. The observed Mwingi District maize yield in 1993 has the highest anomaly (Z =1.7) (Table 3). Evidently the period 1979-1993 Machakos District has predominately positive Z-values. In the period 1994-2009 the yield anomalies have predominately negative Z-scores. The findings show that the highest positive Z-score of 2.2 for Makueni Districts maize yield was realized in 1993. In 2009 Makueni District had the lowest Z-score of 1.5. Mwingi maize yields Z-scores show positive scores for the period 2000-2004 and then the period 2005-2009 are all Z-values are negative. Positive Z-values imply there has been affirmative impact of climate particularly rainfall on maize yields. On the other hand negative Z-score indicate negative impacts of weather/climate on crop yields. Evidently there are predominately negative Z-score in Machakos District in the period 1994-2008. In the same period Mwingi District indicate negative Z-score except year 2002. Mwingi and Makueni show a mixed pattern of positive and negative Z-values over the period. Another observation we can make from the Z-score distribution is that the highest positive Z-value is observed is 2.2 in Mwingi in 2002. The lowest Z-value from the analysis is 1.5 at Machakos County in 2007. Noticeably all the four ASAL districts have distinctively negative Z-scores in 1996, 1998, 1999, 2004, 2005, 2006 and 2007 (Table 3). The year 2005 has the lowest (negative) Z-values in all the districts implying it is the period the climate had the worst impact on maize yields. This would be due to low and unreliable rainfall experienced in that year (Fig.1). The year 2005 had a huge negative Z-score for the ONDJ (October-November –December-January) seasonal rainfall with Z-values ranging between 0.8-1.5. This is the main crop growing season when most farmers plant their food crops such as maize, beans, sorghum and pigeon peas in lower Eastern (Nyandiko *et al.,* 2012). Wide variability in Z-values reflects enormous impacts of climate on maize and other dominant crops.

Table 3: Maize yield Z-values for the four ASAL districts Lower Eastern Kenya

Year	Machakos	Kitui	Mwingi	Makueni
1979	0.786356	0.575322		
1980	1.235854	0.817523		
1981	0.521948	0.380608		
1982	1.235849	0.817513		
1983	0.521948	0.380608		
1984	-0.18929	0.054856		
1985	-0.90051	0.054856		
1986	0.142575	-0.61594		
1987	0.845923	-1.32809		
1988	1.182972	1.104854		
1989	1.625137	1.694813		
1990	0.756231	0.229131		
1991	1.711783	-1.23646		
1992	0.331038	0.161554		0.77773
1993	0.521946	0.547139	0.419806	2.241552
1994	-1.19673	-0.38961	0.597489	0.122868

1995	-0.42994	-0.4417	0.162405	-0.67619
1996	-1.29864	-0.70081	-0.57526	-1.27456
1997	-0.54823	-0.49542	-0.01675	1.441978
1998	-1.39109	-0.98219	-0.63601	-0.93779
1999	-0.77473	-0.4652	-0.49038	-0.56105
2000	-0.6603	-0.5802	-0.37847	0.472081
2001	-0.5986	-1.25224	-0.20612	0.111183
2002	0.184625	0.345585	0.515331	0.010476
2003	-0.76637	-0.73358	0.190283	-0.92497
2004	-1.16023	-0.4652	-0.47653	-0.47019
2005	-1.19849	-1.04162	-0.77353	-1.4976
2006	-0.17986	-0.86408	-0.44848	-0.79932
2007	-1.49532	-0.39319	0.195344	0.138148
2008	-0.41089	0.441494	0.388534	0.652542
2009	0.67342	1.276293	0.581184	1.166954

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