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Climate Change Variability Analysis in and around Jinka, Southern Ethiopia. With Special Emphasis on Temperature and Rainfall

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ABSTRACT

Purpose: *Climate variability is a serious problem affecting the livelihoods of farmers in developing countries particularly those depend on rain fed agriculture. This study was carried out to investigate the extent of climate variability by using temperature and rainfall as key variables.*

Research Method: *In this study the annual rainfall and temperature data of forty six years (1970- 2015) were analyzed using descriptive statistics such as mean, std. error of mean, variance, range, coefficient of variation, minimum and maximum values.*

Findings: *The result of the study revealed that monthly rainfall variability was high both in dry month (CV=0.48) and peak rain month (CV=0.51). The result showed that from 1970 to 2015 the annual rainfall increased (R2=0.001) whereas the mean annual maximum and minimum temperature increased by 0.3620c and 0.3360c respectively. The linear trend line analysis shows a slightly increasing average annual rainfall, maximum and minimum temperature. The mean annual temperature of the area varies from a mean minimum of 21.20c, to a maximum of 22.80c with average temperature of 21.63 over the last forty six years.*

Research Limitations: *This research is based on temperature and rainfall data of the study area.*

Originality: *This study has shown rainfall and temperature variability over the last forty six years in Jinka station. In order to manage rainfall and temperature variability related risks, all concerned stakeholders should have to take into consideration for climate variability adaptation and mitigation strategies in order to minimize all potential risks and losses in the future.*

Keywords: *climate change, climate variability, Ethiopia, Jinka, linear tendline*

INTRODUCTION

Climate change is one of the current global concerns and is characterized as the most pressing issues in 21st century (Barbi and Ferreira, 2013). Climate change is frequently cited as the main driver of food insecurity because it acts both as an underlying, ongoing issue and as a short-lived shock (Gregory *et al.,* 2005). As reported by Sietz *et al.,* (2012) climate change affects food security through reduced crop yield that directly influence the availability of food. African continent is very vulnerable to climate change and variability as its economies are largely based on weather sensitive agriculture (Hope, 2009). It is crucial to know the fact that both climate variability and climate change can occur together in a particular region.

Climate variability refers to variations in the mean state and other climate statistics like standard deviations and the occurrence of extreme events (Food and Agriculture Organization

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of the United Nations (FAO, 2007). Climate variability causes considerable economic damage of developing countries (Mirza, 2003). Climate change can hold back development of a nation by minimizing crop yield, which leads to food insecurity (Gemeda and Sima, 2015). According to Kumsa and Jones (2010), African farmers are losing about US$ 28 per year due to a 1^0c global temperature increase. Hulm e*et al.,* (2001) predicted that temperature will rise by 2-6^0c over the next 100 years. Another study conducted by James and Washington (2013) found that temperature in all African countries are projected to rise faster than the global average increase during 21st century. Similar to other African countries, temperature variability is also reported for Ethiopia. For instance, previous study conducted by Suryabhagavan (2017) has shown that minimum temperature has shown a steady increase over time and the mean surface temperature spatially exhibited significant increasing trend over Ethiopia.

It is estimated that an increase of 3^0c in temperature may lead to 3% reduction in country Gross Domestic Product (Zhao, 2011). In the tropical and sub-tropical regions, crop yields may decrease by 10 to 20%, by 2050 due to increment of temperature and drought occurrence (Thornton and Cramer, 2012). Gemeda and Sima (2015) conclude that increasing surface temperature and rainfall variability reduce agricultural production that affects the livelihoods of African people. As reported by the Intergovernmental Panel on Climate Change (IPCC, 2014), precipitation amounts are likely to decrease for most parts of sub-Saharan Africa while rainfall variability is expected to increase.

Study conducted by Alemayehu and Bewket (2016) in the central highlands of Ethiopia conclude that climate variability has a significant impact on crop production which has a serious implication on food security. Study conducted by Abebe (2017) on 18 weather stations in Ethiopia indicated that there is a declining level of average annual rainfall and high-inter-annual fluctuations in different agro-ecological zones of the country. Williams and Funk (2011) also found that over the last three decades rainfall has decreased over eastern Africa. Another study conducted by Cheung *et al.,* (2008) confirms that the country has both spatial and temporal rainfall variability. A case study conducted at Batti district in Amhara National Regional State of Ethiopia by Teshager *et al.,* (2014) indicates the mean temperature was increasing by 0.03^0c per year and rainfall showed a declining rate with 2.22 mm per annum. A recent study by Asfaw *et al.,* (2018) in the north central Ethiopia indicates that summer rainfall has decreased with the rate 13.12 mm per decade.

It is believed that climate change and variability is common everywhere. However, the temporal variations of rainfall and temperature in the study area are not investigated. Understanding how rainfall and temperature are changing locally is an important pre-requisite task for planning suitable adaptation measures, as changes in climate elements have major impacts on the community livelihoods and well being of an individual. Therefore, this study will address the existing knowledge gaps on the temporal variations of rainfall and temperature of Jinka, southern Ethiopia. It is known that rainfall and temperature variability is one of the key parameters to evaluate the climate condition of aparticularly area. Therefore, investigating the trends of rainfall and temperature data is important for soil and water conservation planning.

MATERIALS AND METHODS

Location of Study area

This study was conducted in Jinka, Southern Nations, Nationalities, and People's Regional state in the southern Ethiopia (Figure 01). Jinka is situated at 5.760N and 36.550E. Elevation above the sea level is 1373 meters. It is located about 563 kms South-West of capital city, Addis Ababa. According to the 2007 Population and Housing Census of Ethiopia, Jinka has a total population of 20, 267 (10,726 males and 9,541 females) with 5, 188 housing units. Currently, the total of residents was estimated at about 32, 115. Based on the Koppen climate classification Jinka belongs to the tropical wet and dry climate with an extended dry season during winter, and it receives annual precipitation of about 1274 mm. The average annual temperature is 21.1^{0}c and the variation in annual temperature is around 3.5^{0}c.

Data type and Sources

Rainfall and temperature data for 46 years (1970 to 2015) were obtained from Ethiopia National Meteorology Agency (NMA). Supplementary literature review was also obtained through Google based search engine to understand the climate of Jinka and its surrounding including demographic and topographic information of the study area.

Data Analysis Techniques

Rainfall and temperature data were coded, entered, and descriptively analyzed using Microsoft Office Excel sheet and Statistical Package for Social Scientists (SPSS) version 20 and analyzed using tables and graphic trends of analysis. Annual rainfall and average temperature of 46 years were considered in order to demonstrate Jinka mean annual rainfall and their inter-annual fluctuations and average annual temperature for respective years. Before data analysis, missing values were replaced by using SPSS a linear interpolation method. After interpolation of the missing rainfall and temperature data, various statistical analysis was conducted. Descriptive statistics such as mean, std. error of mean, variance, range, coefficient of variation (CV), minimum and maximum values were used for rainfall and temperature variability analysis.

RESULTS AND DISCUSSION

The annual rainfall pattern around Jinka shows a distinct bimodal rainfall distribution namely spring and autumn (Figure 02 and 04). The area also receives a moderate rainfall during summer season (which varies from 93.85 mm to 104.60 mm rainfall). In contrast to majority of south western parts of Ethiopia, Jinka receives small amounts of rainfall during the summer season (June, July and August). The maximum and minimum recorded rainfalls were 1742 mm (in 1989- the wettest year) and 821 mm (in 1985- the driest year) respectively (Figure 02). The findings in Figure 03 indicate that, the annual rainfall patterns from 1970 to 2015 were observed to increase by rate of R2=0.001.

Historical monthly decadal average rainfall shows that overall rainfall decreased in Jinka. The findings are consistent with findings of other studies (Williams and Funk, 2011; IPCC,2014; Abebe, 2017; Asfaw *et al*., 2018) which show that the annual rainfall decreased in most parts of African countries. The monthly decadal average rainfall fluctuated, consisting both declining and increasing trends, but significant increasing trends were recorded in the month of April (middle) of spring season (Figure 04).

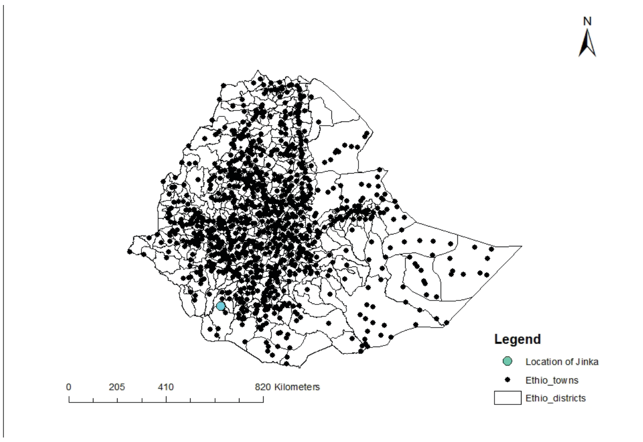

Figure 01: Location of Jinka on Ethiopia Map

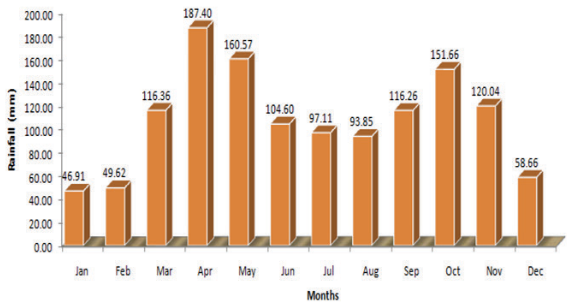

Figure 02: **Historical average monthly rainfall of Jinka (1970-2015)**

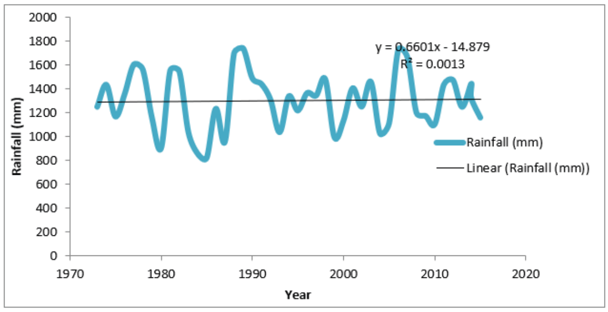

Figure 03: **Total yearly annual rainfall linear trendline of Jinka station**

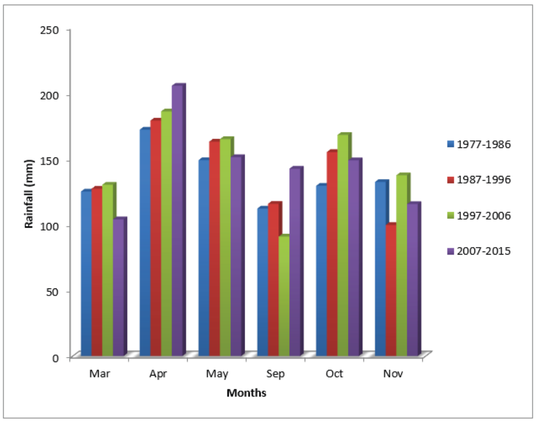

Figure 04: **Historical monthly decadal average rainfall (1977-2015) of Jinka**

On monthly basis, the highest rainfall was recorded in April followed by May and October (the wettest months) and the lowest rainfall was recorded in January, February and December (the driest months). The results of (CV>30) indicates that rainfall in the study area is less reliable. As can be seen from Table 01, annual rainfall coefficient of variation varies from 66.7% to 48% in the month of October and January respectively. These results agree with the findings of Cheung *et al.,* (2008) and Abebe (2017) which show rainfall variability in different agro-ecological zones of Ethiopia. This variability has a negative implication on economic activity of the region which requires special attention from the society.

It has been found that both annual maximum and minimum temperature fluctuations' variation has been observed in this study. This fluctuation in temperature affects not only crop yields but also they have an effect on the daily activities of the community. As can be seen from Figure 05, the annual maximum temperature over the last forty six years in Jinka station showed a steady increase over time. These results are consistent with the findings of Suryabhagavan (2017) which were based on 87 weather stations across Ethiopia over three decades (1983-2012). Both the annual maximum and minimum temperature are increasing over time with great temporarily fluctuations. These findings are in agreement with the findings of other studies (Hulme *et al.,* 2001; James and Washington, 2013; Teshager *et al.,* 2014; Suryabhagavan, 2017) which have shown that the amount of temperature is increasing in various regions because of various anthropogenic and natural causes. The mean annual maximum temperature patterns increased significantly at the rate of R2=0.362 while the mean annual minimum temperature increased significantly at R2=0.336 which indicates an increasing trend. The linear regression model indicates that both annual average maximum and minimum temperature is around its mean. Annual average maximum and minimum temperature variability was illustrated in (Figure 05 and 06).

Table 01: Descriptive statistics for annual monthly rainfall over 46 years at Jinka

Months	N	Range	Minimum	Maximum	Sum	Mean		Std. Dev	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
January	46	201	0	201	2205	46.91	7.017	48.104	2314.036
February	46	238	0	238	2332	49.62	7.046	48.308	2333.676
March	46	245	33	278	5469	116.36	8.797	60.307	3636.975
April	46	237	98	335	8808	187.40	7.526	51.597	2662.290
May	46	232	41	273	7547	160.57	8.503	58.295	3398.337
June	46	356	19	375	4916	104.60	8.764	60.080	3609.637
July	46	367	12	379	4564	97.11	9.724	66.661	4443.706
August	46	274	12	286	4411	93.85	8.524	58.438	3414.999
September	46	255	34	289	5464	116.26	7.352	50.404	2540.542
October	46	326	16	342	7128	151.66	9.732	66.721	4451.751
November	46	263	14	277	5642	120.04	9.377	64.288	4132.911
December	46	229	0	229	2757	58.66	8.550	58.615	3435.751

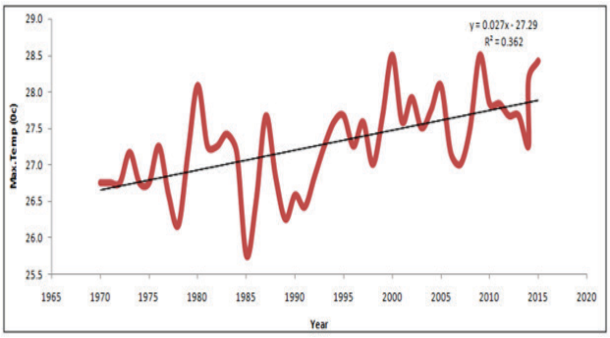

Figure 05: Annual average maximum temperature over 46 years at Jinka

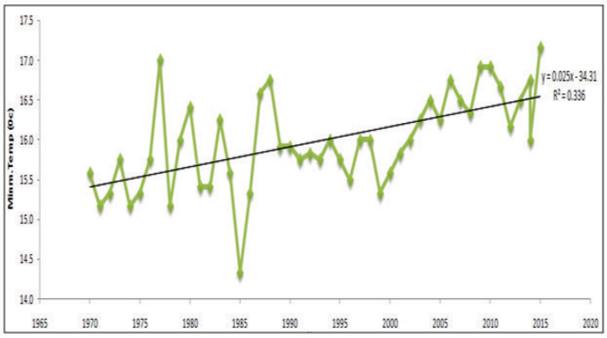

Figure 06: Annual average minimum temperature over 46 years at Jinka

As indicated in Table 02, both rainfall and temperature variability are observed. When we compare the average annual rainfall of 1970's with that of 2010's, there isa reduction by about 130 mm. The mean temperature in the study area ranges from 21.2^{0}c to 22.8^{0}c with average temperature of 21.63^{0}c over the last forty six years. The maximum annual temperatures (28.5^{0}c) were rescored in the year of 2000 and 2009 while the minimum average annual temperature (14.3^{0}c) was recorded in 1985.

The maximum monthly temperatures were recorded in the month of February and March (32^{0}c) while the minimum monthly temperatures were in the month of November and December (12^{0}c). These results indicate that February and March are relatively the hottest months whereas the month of November and December were relatively the coldest months. A variance value for monthly maximum temperature ranges (2.4 to 0.8) indicates that the recorded temperatures are very spread out from the mean, and from each other. The overall descriptive statistics measurement results for both monthly maximum and minimum temperature were summarized (Table 03 and 04).

Table 02: Annual average rainfall and temperature variation in Jinka, Southern Ethiopia (1970-2015)

Country	Station	Year	Average annual rainfall (mm)	Max. Average annual temp. (0c)	Min. Average annual temp (0c)	Mean annual temp. (0c)
Ethiopia	Jinka	1970	1291	26.8	15.6	21.2
Ethiopia	Jinka	1971	1109	26.8	15.2	21.0
Ethiopia	Jinka	1972	1567	26.8	15.3	21.0
Ethiopia	Jinka	1973	1250	27.2	15.8	21.5
Ethiopia	Jinka	1974	1436	26.8	15.2	21.0
Ethiopia	Jinka	1975	1169	26.8	15.3	21.0
Ethiopia	Jinka	1976	1356	27.3	15.8	21.5
Ethiopia	Jinka	1977	1605	26.6	17	21.8
Ethiopia	Jinka	1978	1563	26.2	15.2	20.7
Ethiopia	Jinka	1979	1159	27.2	16	21.6
Ethiopia	Jinka	1980	902	28.1	16.4	22.2
Ethiopia	Jinka	1981	1555	27.3	15.4	21.3
Ethiopia	Jinka	1982	1549	27.3	15.4	21.3
Ethiopia	Jinka	1983	1036	27.4	16.3	21.9
Ethiopia	Jinka	1984	858	27.2	15.6	21.4
Ethiopia	Jinka	1985	821	25.8	14.3	20.0
Ethiopia	Jinka	1986	1235	26.5	15.3	20.9
Ethiopia	Jinka	1987	957	27.7	16.6	22.1
Ethiopia	Jinka	1988	1699	26.8	16.6	21.7
Ethiopia	Jinka	1989	1742	26.3	15.9	21.1
Ethiopia	Jinka	1990	1491	26.6	15.9	21.2
Ethiopia	Jinka	1991	1442	26.4	15.8	21.1
Ethiopia	Jinka	1992	1310	26.8	15.8	21.3
Ethiopia	Jinka	1993	1037	27.3	15.8	21.5
Ethiopia	Jinka	1994	1339	27.6	16	21.8
Ethiopia	Jinka	1995	1219	27.7	15.8	21.7
Ethiopia	Jinka	1996	1366	27.3	15.5	21.4
Ethiopia	Jinka	1997	1345	27.6	16	21.8
Ethiopia	Jinka	1998	1483	27.0	16	21.5
Ethiopia	Jinka	1999	995	27.7	15.3	21.5
Ethiopia	Jinka	2000	1134	28.5	15.6	22.1
Ethiopia	Jinka	2001	1407	27.6	15.8	21.7
Ethiopia	Jinka	2002	1252	27.9	16	22.0
Ethiopia	Jinka	2003	1461	27.5	16.5	22.0
Ethiopia	Jinka	2004	1026	27.8	16.3	22.0
Ethiopia	Jinka	2005	1113	28.1	16.3	22.2
Ethiopia	Jinka	2006	1728	27.2	16.8	22.0
Ethiopia	Jinka	2007	1668	27.0	16.5	21.8
Ethiopia	Jinka	2008	1200	27.5	16.3	21.9
Ethiopia	Jinka	2009	1174	28.5	16.9	22.7
Ethiopia	Jinka	2010	1104	27.8	16.9	22.4
Ethiopia	Jinka	2011	1437	27.8	16.7	22.3
Ethiopia	Jinka	2012	1475	27.7	16.2	21.9
Ethiopia	Jinka	2013	1250	27.7	16.5	22.1
Ethiopia	Jinka	2014	1444	28.2	16.8	22.5
Ethiopia	Jinka	2015	1160	28.4	17.2	22.8

Table 03: Descriptive statistics for monthly maximum temperature (1970-2015)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	29.21	30.00	29.36	27.06	26.23	25.81	25.38	25.74	26.68	26.66	27.04	28.23
Std. Error of Mean	.192	.224	.226	.170	.137	.148	.154	.162	.197	.137	.164	.220
Std. Deviation	1.318	1.532	1.552	1.169	.937	1.014	1.054	1.113	1.353	.939	1.122	1.507
Variance	1.736	2.348	2.410	1.365	.879	1.028	1.111	1.238	1.831	.882	1.259	2.270
Range	5	6	6	6	5	5	4	4	7	4	6	6
Minimum	26	26	26	24	24	23	24	24	23	25	24	25
Maximum	31	32	32	30	29	28	28	28	30	29	30	31

Table 04: Descriptive statistics for monthly minimum temperature (1970-2015)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	14.98	16.02	16.98	17.13	16.91	16.30	15.94	15.96	16.26	16.26	14.89	14.17
Std. Error of Mean	.151	.144	.144	.124	.132	.109	.103	.125	.127	.141	.156	.159
Std. Deviation	1.032	.989	.989	.850	.905	.749	.704	.859	.871	.966	1.068	1.090
Variance	1.065	.978	.978	.722	.819	.562	.496	.737	.759	.933	1.141	1.188
Range	6	5	6	5	5	3	3	4	4	5	5	6
Minimum	13	14	14	15	14	15	15	14	14	13	12	12
Maximum	19	19	20	20	19	18	18	18	18	18	17	18

CONCLUSIONS

This study has shown the existence of rainfall and temperature variability over the last forty six years in Jinka. The present study concluded that rainfall and temperature variability has been occurred in the study area. This climate variability has a negative impact on rain-fed dependent society, providing adequate climatic information in the form of early warning system should be given for public in order to minimize risks and losses associated with climate variability. Clearly, further research on climate variability should be conducted by incorporating other climate variables like relative humidity, evaporation and atmospheric pressures. It is also crucial to investigate the most efficient and effective mechanisms how the community may respond and adapt such climate variability.

Conflicts of Interest and Acknowledgement of Sources of Funding

Competing interests

The authors declare no competing financial interest

Availability of data and material

All data generated or analyzed during this study are included in this published article.

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