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Original Research

Ecological Relationships between Faba Bean (*Vicia faba* L.) Yield and Climate Variability in Horro District, Horro Guduru Wollega Zone, Ethiopia

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Abstract

This study aimed to analyze the effects of climate variability on production of faba bean in Horro district. A cross-sectional study design was used. Thirty years of climate data were obtained from the Ethiopian Meteorological Institute, and 10 years faba bean yield data were obtained from Horro district. Climate variability was characterized and trend analyzed using R-instant 0.76 version software and the Mann Kendell test, respectively. The relationship between faba bean productivity and climate conditions was examined using correlation and regression. The area had an annual rainfall of 1879.1 mm. The standard deviation for rainfall was 469.6, and CV was 24.9%. Rainfall showed an increase over the years, but not in a statistically significant. The increase was 6.6 mm per year during Kiremt, 3 mm per year during Belg, and 2.4 mm per year during Bega. The annual maximum temperature went up by 0.02 °C each year, while the minimum temperature increased by 0.006 °C per year; both trends were not statistically significant. Kiremt total rainfall had a negative relationship, while mean maximum temperature had a positive relation on faba bean yield with (r=-0.63 and r=0.29), respectively. Together, Kiremt total rainfall, mean maximum temperature, and the end of the season explain 73.3% of the variation in faba bean yield in the study area. This suggests that these factors play a role in determining yield of faba beans. As a result, family heads in the research area should seek climate information services and other adaptation techniques before making farm-level choices.

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INTRODUCTION

The risks of climate variability in East Africa, particularly Ethiopia, will be increased by anticipated increases in mean temperature and precipitation (Gebrechorkos *et al.,* 2023; Choi *et al.,* 2023). The agricultural output of small farmers, who primarily rely on subsistence rain-fed agriculture, is threatened by warming and more frequent drought conditions, which are a significant contributor to food insecurity in the nation (Tesfaye *et al*., 2017). The scientific community is also increasingly in agreement that rising temperatures and shifting precipitation patterns will lower food yields in developing nations (Alemu and Mengistu, 2019).

Agriculture is extremely vulnerable to climate variability and change, especially in underdeveloped nations where smallholder farmers have limited ability to adjust to rising temperatures and increasingly unpredictable weather patterns. Sub-Saharan Africa (SSA) is especially vulnerable to climate change due to its heavy reliance on rain-fed agriculture, widespread food insecurity, and weak adaptive capacity (Connolly-Boutin and Smith, 2016). Ethiopia is one of the most susceptible countries in SSA because of its heavy reliance on agriculture (Gemeda and Sima, 2015). Agriculture continues to provide a key source of income for more than 80% of Ethiopia's population, leaving a considerable proportion of the population vulnerable to climatic variability and its effects on agricultural productivity and food security (Gezie, 2019). In addition, variations in farm sizes, swift population growth, reliance on subsistence farming, along with insufficient agricultural technologies and extension services, all led to decreased land productivity and crop yields (Paul and Gĩthĩnji, 2018).

Key legumes that can provide protein and carbohydrates, such as broad bean (*Vicia faba* L.) is cultivated worldwide for consumption by both humans and animals. It also serves as a great addition to crop rotation for fixing atmospheric nitrogen and functions as a cover crop (Dhull *et al*., 2022). Faba bean production has varied more than the area harvested, and over the last 50 years, global land dedicated to beans has diminished (Terefe *et al*., 2016). It is estimated that 3.94% of Ethiopia's overall grain output is derived from broad bean cultivation (Bekele, 2020; CSA, 2014).

Previous research carried out in various regions of Ethiopia on the effects of climate variability, particularly concerning seasonal and annual fluctuations on crop yield decline, has important consequences for multiple facets of crop management and planning. These studies offer crucial insights and data for farmers when deciding on crop selection, appropriateness of crop varieties, management practices, protective measures for plants, and farming activities (Abera *et al*., 2018). An earlier investigation carried out in Ethiopia analyzed the effects of climate change on agricultural productivity, particularly faba bean, revealing different levels of relationship between crop yield and climatic factors (Abera *et al*., 2018; Bogale *et al*., 2022).

Faba bean is a well-known crop among smallholder farmers in the Horro district, cultivated for multiple uses, but it struggles with climate change, posing a challenge for its production. Nevertheless, the study area's population's ignorance or unawareness regarding climate change and crop management techniques suited to the Horro district's specific climate conditions could not be established. Thus, the objective of the study was to investigate the impact of climate variability on faba bean production and the adaptation strategies adopted by farmers in the Horro district of the Horro Guduru Wollega zone in Ethiopia.

MATERIALS AND METHODS

This research was carried out in the Horro district of the Horro Guduru Wollega Zone, Ethiopia. Horro district (Figure 1) is situated 320 km west of Addis Ababa, with coordinates of 09°18'00"N - 09°50'00"N and 37°00'00"E - 37°20'00"E; elevation ranges from 1540 to 2844 m asl. The primary types of soil present in the research region are clay, loam, and sand. The makeup of these soil types is as such: Clay: 73%, Loam: 25%, and Sand: 2% (Olika *et al*., 2023). The district's agroecology consisted of highland (43%), midland (55%), and lowland (2%), with an annual rainfall average of 1566 mm.

The landscape of the region primarily consists of rolling terrain, cliffs, and mountains, with parts of the area featuring flat land at the bottom (Olika *et al*., 2023). The district's monthly average temperature ranges between 10 and 25°C (Degefa *et al*., 2022). Land closures, homesteads, irrigated areas, and forested land constitute most of the land uses and coverage in the research region. Grazing land comprises approximately 14% of the total land area within the study region. The area of cultivated land reached around 64250 hectares. Primarily, the region is characterized by agro-forestry, incorporating annual crops like teff, barley, wheat, and corn (Olika *et al*., 2023).

Two kinds of seasons were observed in the study area. Seasons that last three months known as Winter (December–February), spring (March–May), summer (June–August) and autumn (September–November); and seasons that last four months known as Kiremt (rainy season) from June to September, Belg (short rainy season) from February to May and Bega (dry season) from October to January (Feke *et al*., 2021).

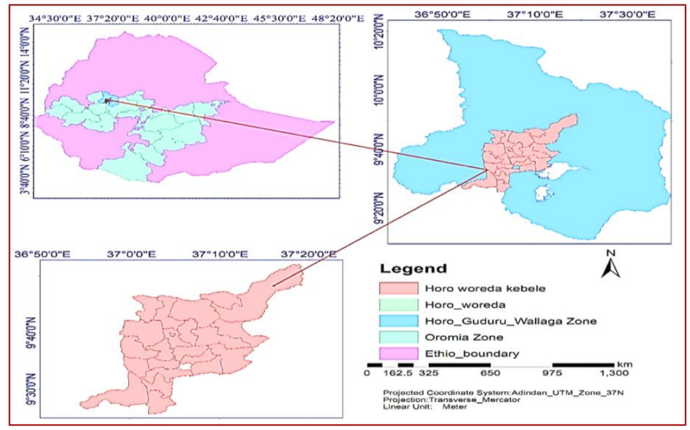


Figure 1. Map of Horro District.

Type and Source of Data

Information for this study was composed of secondary and primary sources. The primary data were collected from selected household heads through a questionnaire survey. Secondary data, such as bean yield figures and climate data, were collected from the Horro district and from EMI, respectively. Gathered yearly faba bean yield data (in quintals) were gathered from the Agriculture Office of Horro district. Data concerning the assessed climate factors, directly linked to the faba bean growth and yield, were obtained from EMI.

Methods of Data Collection

The minimum and maximum temperatures, along with daily rainfall gridded climate data for the Horro district covering the years 1992 to 2021, were sourced from the EMI. Yield data for beans from the past ten years were sourced from the agriculture office in Horro district. This research utilized a decade's worth of data solely due to the presence of recorded faba bean information from the district's agricultural office for only that ten-year period.

Research Design

A cross-sectional study design was used because of long-term trends in the data. The reasoning for selecting this design is that it serves to outline the features of an event and particular forecasts while narrating facts and characteristics regarding a circumstance; in this instance, the research examined climate variability and its influence on bean production. Additionally, this study primarily utilized a quantitative research method to examine climate variability and its effects on faba bean production, while also incorporating a qualitative method to assess farmers' adaptation strategies related to the impacts of climate variability on faba bean production in the area using instruments such as a semi-structured questionnaire.

Sampling Design and Sample Size for Household Heads

Multi-stage sampling techniques were employed to select samples. Purposively selected bean-producing kebeles (Table 1) and from those selected kebeles faba bean-producing household heads were identified. From those household heads, simple random sampling methods were used to choose representative samples. The lists of households that produce beans in each sampled kebele were utilized as sampling frames. The sample size was determined as per Kothari (2004) at 95%. Accordingly, 135 HH were selected for the questionnaire survey by using simple random techniques.

Table 1. Number of household heads selected from each kebele.

Name of Kebele	Total HH in each kebele	Total highly bean-producing HH in kebele	Total sample taken from each kebele
Kombolcha Chancho	278	69	46
Laku Igu	262	62	42
Gitlo Dale	290	72	47
Total	**830**	**205**	**135**

Statistical Data Analysis

The information gathered via questionnaires was examined through qualitative and quantitative data analysis. Prior to data analysis, the raw data underwent processing to produce pertinent information. Data were examined through statistics such as frequency distribution, mean, and ratio utilizing SPSS version 20. Linear and multiple linear regression models were employed to reveal the association between independent variables (climate factors) and dependent variables (faba bean). The analysis of rainfall and temperature was carried out using procedures that are commonly used in variability and trend analysis. Climate variability during the study period was determined by computing the CV and the standardized anomaly index. The Mann-Kendall test was used for a non-parametric statistical test to determine if monotonic trends in seasonal and annual rainfall and temperature data are statistically significant or not (Mann, 1945; Kendall, 1975).

The standard rainfall anomaly is determined as the difference between a given year's annual total and the long-term mean rainfall records divided by the long-term data standard deviation. Standardized data is used to determine dry and wet years, as well as to estimate the frequency and severity of drought. The Pearson correlation coefficient (r) analysis was applied to examine the relationship between faba bean yields (qt ha^{-1}) and rainfall characteristics along with temperature components. Multiple regression analysis was applied to measure the impacts of climate variables on the yield of faba beans.

RESULTS AND DISCUSSION

Features of Rainfall Patterns

The yearly precipitation in Horro district varies from 925.89 to 2644.33 mm, averaging 1879 over the past 30 years. The graph below illustrates yearly rainfall patterns at the station. This signifies the occurrence of variations in rainfall over the past 30 years (1992-2021). Interannual trends in rainfall distribution showed that yearly totals fell short of the long-term average during 1999-2006 and 2018 (Figure 2). The yearly precipitation exhibited a variable pattern, indicating that in certain years it surpasses the long-term average while in others it falls short; these changes impact agricultural output and productivity in various ways (Teshome, 2017). Thus, the yearly variation in rainfall trend in Horro district is 6.4248*1=6.43, and the ten-year variation in rainfall trend in Horro district is 6.4248*10=64.3.

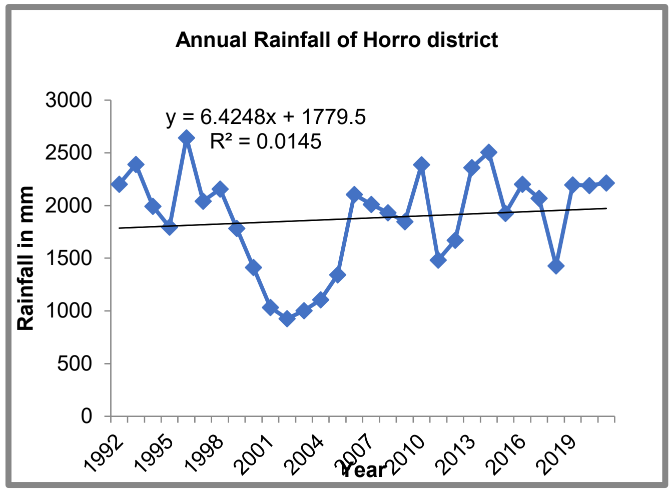


Figure 2. Rainfall distribution pattern of Horro district from the year 1992-2021

The analysis from EMI reveals that Kiremt rainy days typically commence around May 02 in the years 1992, 1995, and 2005 (122 DOY), exhibiting a coefficient of variation of 8% and a standard deviation of 10 days, reflecting moderate variability. Over the past three decades, the main rainy season concluded on average on October 1 (304 DOY) with a coefficient of variation of 8.3%, showing greater variability than the onset of the rainy season. This outcome aligns with the results of Abdullahi (2021), who indicated that the mean, median, minimum, and maximum end date of the rainy season (EOS) was 269 (September 25), 265 (September 21), 245 (September 1), and 320 (November 15) DOY, respectively, in the Kurfa Chele District of East Hararge Zone. The results indicate that the average duration of the growing season in the Horro district is 171 days (Table 2) during the study period. It exhibited a minimal level of variability with a CV of 17% and a standard deviation of 29 days. Throughout the study duration, the shortest and longest growing period measures 111 and 232 days, respectively. It displayed a moderate level of variability, with a coefficient of variation of 17% and a standard deviation of 28.9 days.

Table 2. Rainfall Characteristics of Horro District.

Rainfall Characteristics	Min	Max	Mean	SD(±)	CV (100%)	ZMK	Slope	*P-value*
S Rain	92	154	117	17	14	-0.095	0.333	0.464
SOS	122	159	133	10	8	-0.122	-0.125	0.352
EOS	266	361	304	25	8.3	0.288	1.267	0.026
LGP	144	202	171	28.9	17	0.295	1.25	0.022
ANRD	186	250	218	18.1	8.3	-0.025	-0.13	0.844
KNRD	110	122	119.5	3	2.6	0.023	0.001	0.869

RF: Rainfall; Min, minimum; Max, Maximum; SD, standard deviation; CV, Coefficient of Variation; ZMK: trend test; S Rain, start of rain; SOS, Start of season; EOS, End of season; LGP, Length of growing period; ANRD, Annual number of rainy days; KNRD, Kiremt number of rainy days

Trend analysis showed that the annual and beginning of the rainy season had reduced by a factor of 0.025 and 0.095, with CVs of 8.3% and 14%, respectively (Table 1). The results aligned with those of Bogale *et al*. (2023) at Holota station, indicating a decrease in annual rainfall and the onset of the rainy season by factors of 0.595 and 0.083, respectively. The reduction in the yearly count of rainy days in central and western Ethiopia is more subtle and is approximately 12%. The yearly highest and lowest counts of rainy days are 250 and 186, respectively, averaging 218. The pattern of yearly rainy days indicates a decline that is not considerable, with a CV of 8.3 days. The trend test for this shows that the yearly count of rainy days is reduced by a factor of 0.025. These results are in line with those of Kassie *et al*., (2014), who note a reduction of 4 days per decade and slight decreases in the yearly count of rainy days at Negele and Gore, which are 2.3 days/decade and 1.7 days/decade, respectively. Similarly, in parts of eastern Ethiopia, the yearly number of rainy days has fallen from an average of 63 to 43 (a decrease of 31%). The reduction in the yearly count of rainy days in central and western Ethiopia is more subtle and approximately 12%. The total count of rainy days during Kiremt was 122, which is the highest, and the average is 119.5.

The study area's precipitation has exhibited fluctuations between years and inconsistent rainfall patterns in the last 30 years. The year with the least rainfall was 2002, recording a minimum of 925.89mm, while the year with the most rainfall was 1996, with a maximum of 2644.33mm. As shown in (Figure 3), from 1992 to 2021, the study region experienced 18 years (60%) of rainfall that was above normal and 12 years (40%) of below-normal rainfall. The years 2001, 2002, 2003, and 2004 were regarded as the years with the least amount of rainfall. The present study showed that the years 1993, 1996, and 2014 were marked by elevated rainfall levels exceeding the long-term average in the study area, identifying them as the wettest years throughout the study period. The years 2001, 2002, and 2003 are deemed extreme drought years due to their z values (z=-1.7, -1.9, -1.7, respectively), while 2004 is considered a severe drought year (Z=-1.5). The years 2000 and 2005 are identified as moderate drought years (Z=-0.9 and -1.1, respectively), while all other years are categorized as non-drought years based on the classification by Hadgu *et al*. (2013)

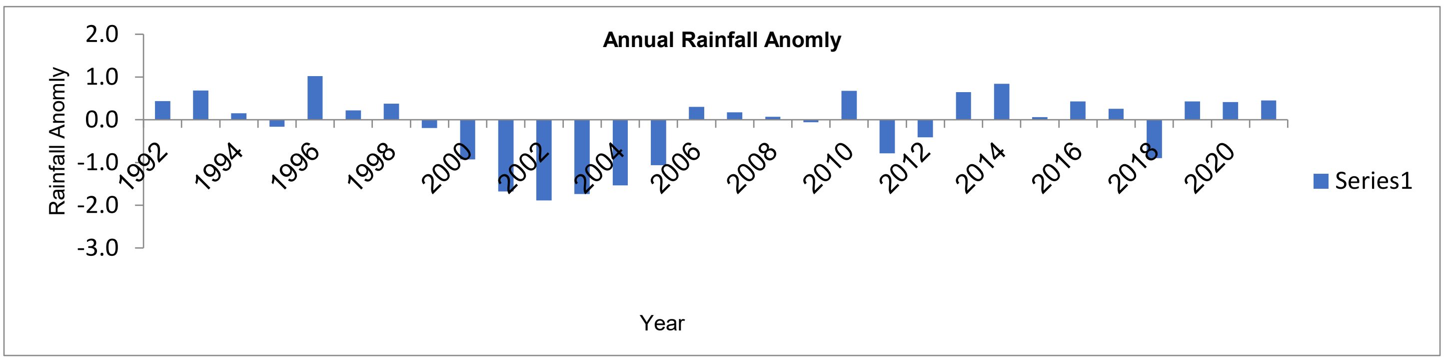


Figure 3. Annual Rainfall anomaly of Horro district from 1992-2021

Figure 4 describes Bega rainfall anomaly, which indicates that 11 years of observation (36.66%) had rainfall above normal and 18 years (60%) had rainfall below normal. Accordingly, the year 1994 is regarded as a severe drought with the value of *Z*=-1.5. The year 2004 and 2012 are regarded as moderate drought years (*Z*=-1.1 and -0.9 respectively), and the remaining years are considered to be no drought years according to the classification used by Hadgu *et al.* (2013).

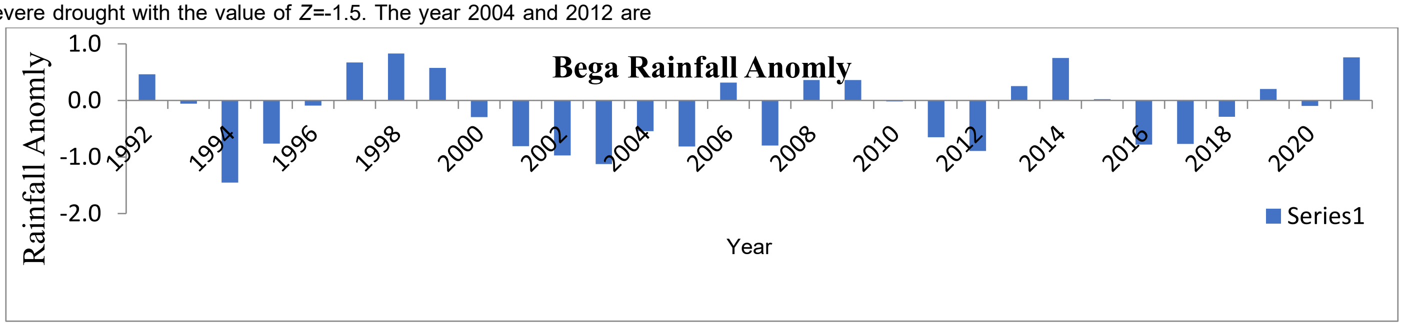


Figure 4. Bega Rainfall anomaly of Horro district from 1992-2021

Figure 5 explains the Kiremt rainfall anomaly, which describe that 19 years of the observation (63.33%) had rainfall above normal and 11 years (36.67%) had rainfall below normal. Even though the year 2000-2004 received the rainfall below the long-term average, according to the classification given by the Z value, those year are considered to be no drought years.

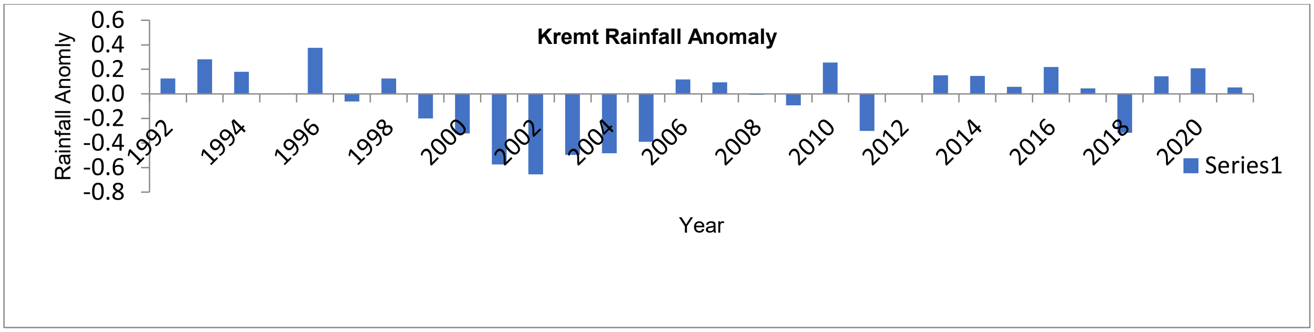


Figure 5. Kiremt rainfall anomaly of Horro district from 1992-2021

Figure 6 depicts the Belg season rainfall anomaly in the study area. Data analysis found that rainfall fell below the long-term average for 18 years (60%) of the study period (1992-2021). The year 2004-2006 indicated that those years got rainfall below the long-term average but, according to the anomaly classification value (Z=value), those years are considered to be no drought years because their Z=value is between -0.8 and -0.5.

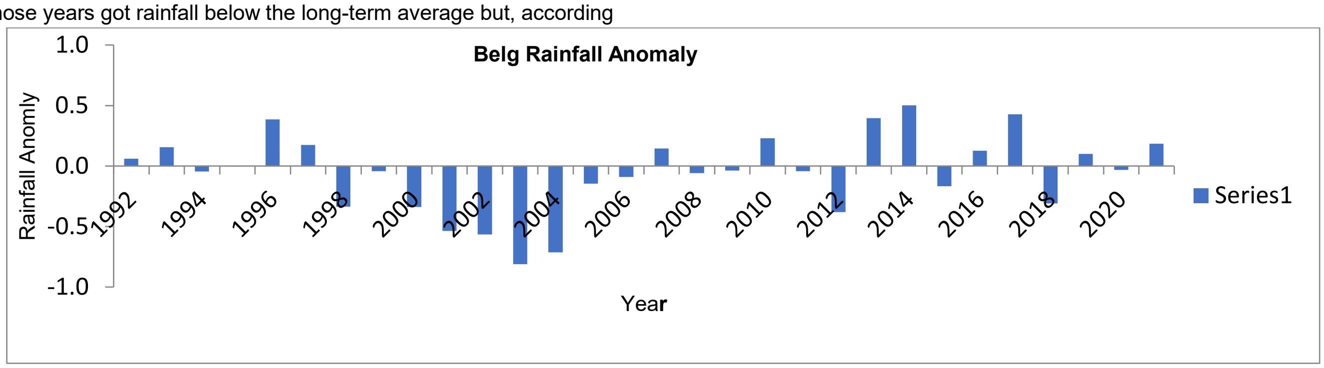


Figure 6. Belg rainfall anomaly of Horro district from 1992-2021

Table 4 demonstrates the annual and seasonal precipitation totals for the study area, as well as their trends and variability. The area received an average annual rainfall of 1879.1 mm throughout the study period. The seasonal rainfall's annual contribution in the region is 69.7%, 20.6%, and 9.7% for Kiremt (JJAS), Belg (FMAM), and Bega (ONDA), respectively. This result is associated with the conclusions of Bedane *et al*., 2022, who indicate that the long rainy season, referred to locally as Kiremt (July to September), contributes about 699.9 mm (64%) of the yearly rainfall, whereas the short rainy season (February to May), called Belg, represents around 28% of the total annual rainfall. The dry season, referred to locally as Bega (October to January), brings 90.8 mm of rainfall, accounting for 8% of the yearly total. The current finding is in line with Alemayehu *et al.* (2020), who indicate that Kiremt rainfall accounts for the majority of the yearly rainfall (55%), followed by Belg (26%) and Bega (19%), respectively. The results of Feke *et al*. (2021) align with the current findings, indicating that the summer season accounts for the greatest proportion, constituting over 50% of the total rainfall recorded during the period from 1987 to 2016 in northwestern Ethiopia. Concerning the trends, the precipitation in Horro districts showed a slight rise at rates of 6.6, 3, 2.4, and 0.6yearly, for Kiremt, Bega, and Belg, respectively (Table 3).

The average rainfall for the Kiremt season was 1310 mm, with a CV% of 25.5%, which was lower than the variance witnessed in the Belg season (31%), and the Bega season (51.4%). This demonstrates that the Kiremt rainfall was more consistent than the Belgian and Bega seasons. Belg rainfall was less probable than the Kiremt season rainfall. This doesn't imply that Kiremt rainfall was consistent; however, it is clear that the maximum rainfall recorded in the Kiremt season was 1902.7 mm, while the minimum amount of rain in the study area was 627.1 mm. Regarding the trend, the Kiremt and Bega rainfall at Horro station showed a slight increase annually by 3 and 2.4 mm/year, respectively. These results align with those of Viste *et al*. (2013), who showed a negligible upward trend in annual and seasonal rainfall across various regions of Ethiopia.

Table 3. Statistics of annual and seasonal rainfall totals of Horro district from 1992-2021

RF mm	Mean	Min	Max	SD	CV (%)	ZMK	Slope
Kiremt RF	1310	627.1	1902.7	333.7	25.5	0.0571^{ns}	3
Bega RE	186.1	30.5	364.9	95.7	51.4	0.122^{ns}	2.4
Belg RF	383	145.110	619.720	118.5	31	0.057^{ns}	0.58
Annual RF	1879.1	925.9	2644.3	469.6	24.9	0.085^{ns}	6.6

The year 1996 saw the highest Kiremt (JJAS) total rainfall at 1902.66 mm, while the lowest Kiremt (JJAS) total rainfall of 627.14mm was noted in 2002 (Figure 7). Thus, the years 1996 and 2002 were the most precipitation-filled and the most arid year in the research region, respectively. The year 2014 saw the highest total rainfall for Belg (FMAM) at 619.72 mm, while 2003 marked the lowest total rainfall for Belg at 65.46 mm. In the Bega (ONDJ) season, noted for its minimal rainfall, the year 1998 saw the highest total rainfall for Bega at 364.88mm, while 1994 recorded the lowest total rainfall at 30.54mm.

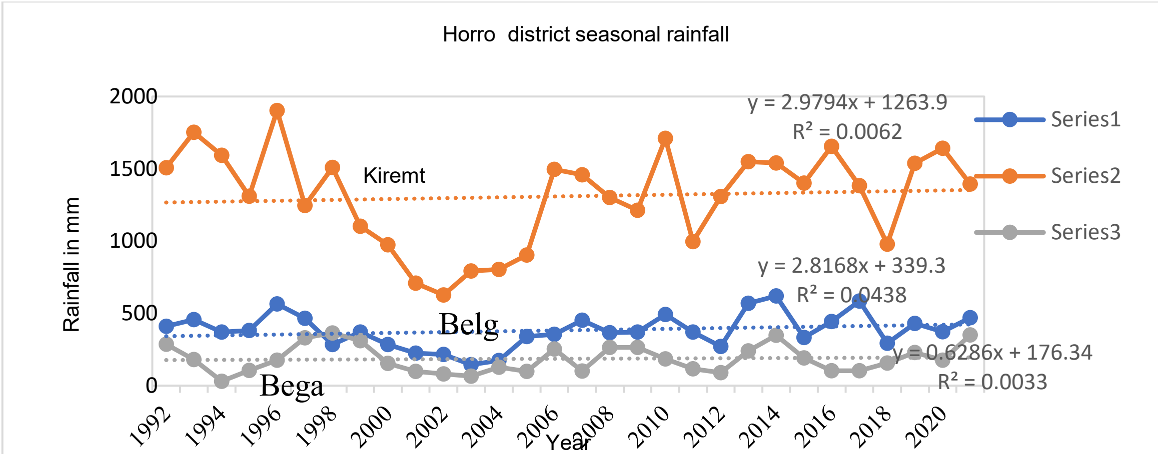


Figure 7. Horro district seasonal rainfall

In the Horro district, the annual maximum temperature had a maximum of 27.5℃, a minimum of 24.3℃, a mean of 25.5℃, a standard deviation of 0.77, and a coefficient of variation of 3% (Table 3). The maximum temperature recorded annually rose by 0.172℃, a change deemed non-significant, translating to an annual increase of 0.02℃. The current result aligns with (Daba, 2018) that in western Oromia, specifically Chelia, Sibu-sire, Jima Arjo, Gida Kiremu, and Diga, the average minimum and maximum temperatures displayed a rising trend that was not statistically significant.

The average and lowest maximum temperature during the Belg season in the study region are 22.1 and 21.3, respectively, which increase significantly by 0.255℃ and 0.029℃ each year. The peak temperature during the Belg season rose by 0.255℃, which is not significant, and shows an annual change of 0.029℃. This rise in temperature is expected to exacerbate droughts, potentially resulting in reduced agricultural yields (Funk, 2012). The mean maximum, average of maximum, and mean minimum of maximum temperature in the Bega season is 28, 25.2, and 24, respectively, which are increased by factor of 0.099 and 0.017 each year (Table 4).

Table 4. Annual and Seasonal trends of maximum temperatures at Horro districts

Period	Mean	Min	Max	SD	CV (%)	ZMK	Slope
Belg	22.1	21.3	23.4	0.53	2.4	0.255 ^{sig}	0.029
Kiremt	22.1	21.3	23.4	0.53	2.4	0.255^{sig}	0.029
Bega	25.2	24	28	1	3.84	0.099 ^{ns}	0.017
Annual	25.5	24.3	27.5	0.77	3	0.172^{ns}	0.02

The yearly average minimum, average, and maximum temperatures in the study area are 13.2, 13.9, and 14.4, respectively, showing an increase of 0.09, which is not significant, and a change of 0.006 each year (Table 5). In the same way, (Bogale *et al*., 2022) discovered that yearly minimum temperatures increased by 0.005°C annually and 0.05°C per decade at Holota station. The mean minimum temperatures for Kiremt in the study area are 14, 14.5, and 15, representing the minimum, average, and maximum. The mean minimum temperature trend rises notably by 0.347 ℃ and experiences a change of 0.013 annually.

Table 5. Annual and Seasonal trends of minimum temperatures at Horro districts

Period	Mean	Min	Max	SD	CV (%)	ZMK	Slope
Belg	15.4	14.3	16.6	0.58	2.4	0.044^{sig}	0.006
Kiremt	14.5	14	15	0.22	1.5	0.347 ^{sig}	0.013
Annual	13.9	13.2	14.7	0.37	2.7	0.090^{ns}	0.006

The average, minimum, and maximum Belg season mean minimum temperature in Horro district is 14.5, 14.3, and 16.6, respectively, and it shows an increasing trend by a factor of 0.060 each year. The present findings were consistent with the findings by Taye *et al*. (2013) which stated that a recent increase in Ethiopia's temperature was true. The current result aligns with Tofu and Mengistu's (2023) findings that mean seasonal and yearly minimum temperatures in West Shewa show statistically significant trends (P<0.01). In terms of seasonal variability, the mean lowest temperature was low throughout the year.

Correlation and Regression Analysis of Yield of Faba Bean and Climate Variables

The *faba bean* yield of ten years (2012-2021) was obtained from the district Agriculture Office. This is because there is a new district that departed from the Horro district, and the only clear recorded data is only for 10 years. Thus, the analysis of ten-year climate variables is compared with the present faba bean yield data. The statistical analysis result showed that 23,959 and 36,720 quintals of *faba bean* yield were the minimum and maximum yield harvested over the production period extending from the year 2012 to 2021, respectively, as represented in the table below. The production of faba bean shows an increasing trend;

this might be due to the increasing size of *faba bean* production land (in hectares) over this period, found to range from 1843 to 2251 hectares (Table 6 and Figure 8).

Table 6. Bean yield data of Horro district

Years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
L/ h	2027	1897	2025	2132	2503	2251	2160	1843	1903	2228
Y/h	12	13.5	14.2	14.5	12.5	15	17	13	14	16
Total Yield	24324	25609	28755	28755	31287	33765	36720	23959	26642	35648

Accordingly, the correlation and regression of only ten years of climate data were analyzed with respect to bean yield of the same years.

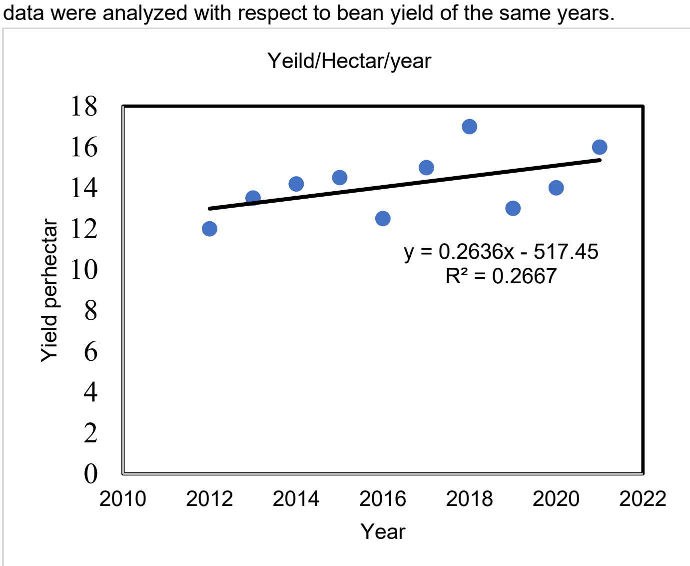


Figure 8. The trend of faba bean yield

The correlation analysis for faba bean yield and climate variables found a negative and weak relationship between the start of season (r=-0.17) and Kiremt mean minimum temperature (r=-0.04) (Table 7). Additionally, bean yield has a nearly strong negative relationship with Kiremt total rainfall (r=-0.63).

Table 7. Pearson's correlation of Bean yield and climate variables of Horro district

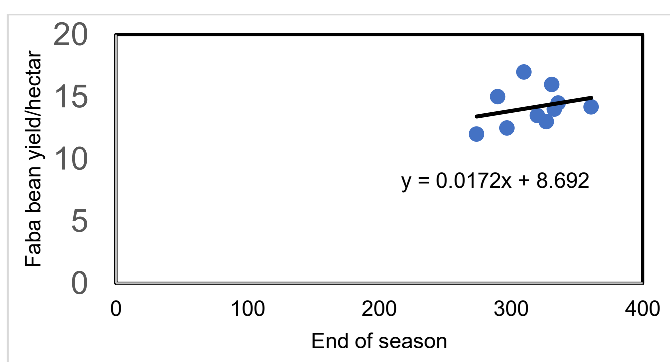
	SOS	EOS	K mean min T	K mean max T	K Rainfall Total	Bean Yield
SOS	1					
EOS	-0.62	1				
K mean min T	-0.30	0.31	1			
K mean max T	0.02	-0.10	0.66	1		
K Rainfall Total	-0.39	0.30	0.28	-0.26	1	
Bean Yield	-0.17	0.28	-0.04	0.29	-0.63	1

SOS, start of rainy season; EOS, end of rainy season; K mean min T, Kiremt mean minimum temperature; K mean max T, Kiremt mean maximum temperature; K Rainfall Total

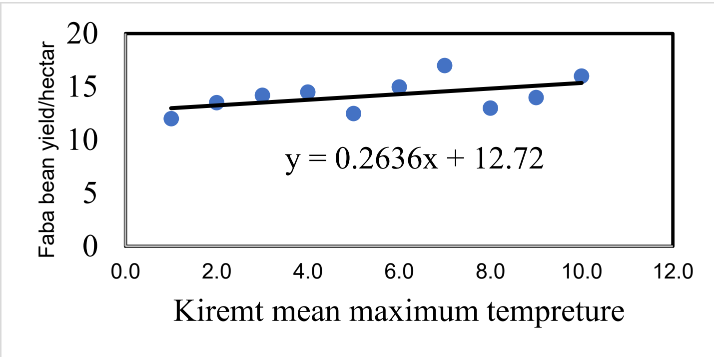
This indicates that the Kiremt total rainfall negatively influences the yield of faba bean. This may be due to flooding, waterlogging, nutrient leaching, etc. The Kiremt mean maximum temperature and end of the rainy season had a positive relationship with the yield of faba bean in the study area, with r=0.28 and 0.29, respectively. This result is consistent with the finding that the optimal temperature for faba bean growth and development is between 18 and 27°C (Abdalla *et al*., 2015).

A) Positively correlated to harvested faba bean yield over 2012 to 2021

i) End of rainy season (r=0.28)

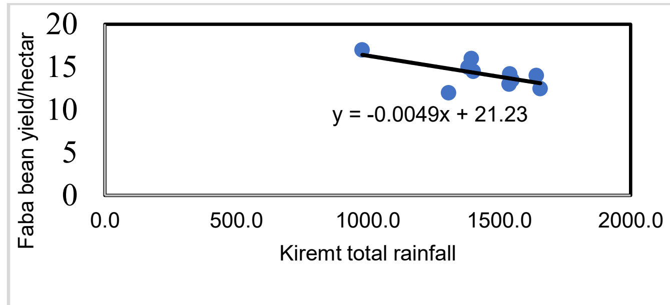


ii) Kiremt mean maximum temperature (r=0.288)

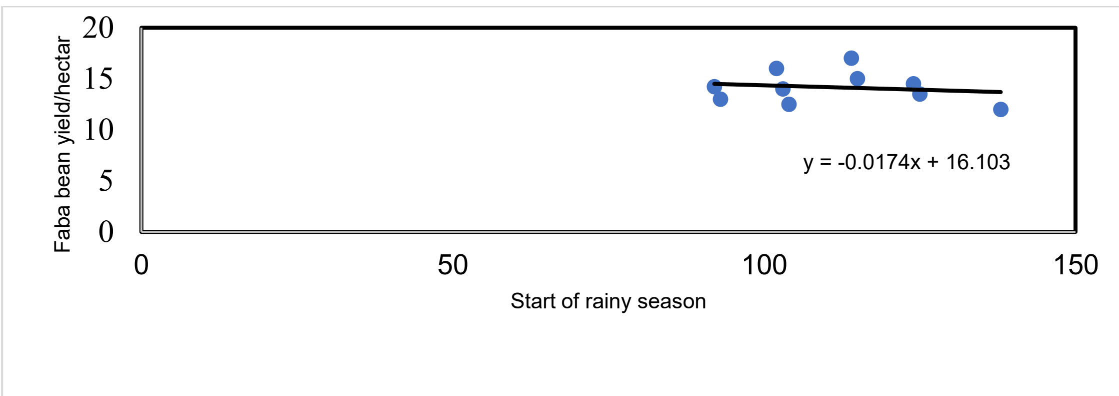


B. Negatively correlated to harvested faba bean yield over 2012 to 2021

i) Kiremt total rainfall (r=-0.6302)



ii) Start of rainy season (r= -0.168)



iii) Kiremt mean minimum temperature (r=-0.04342)

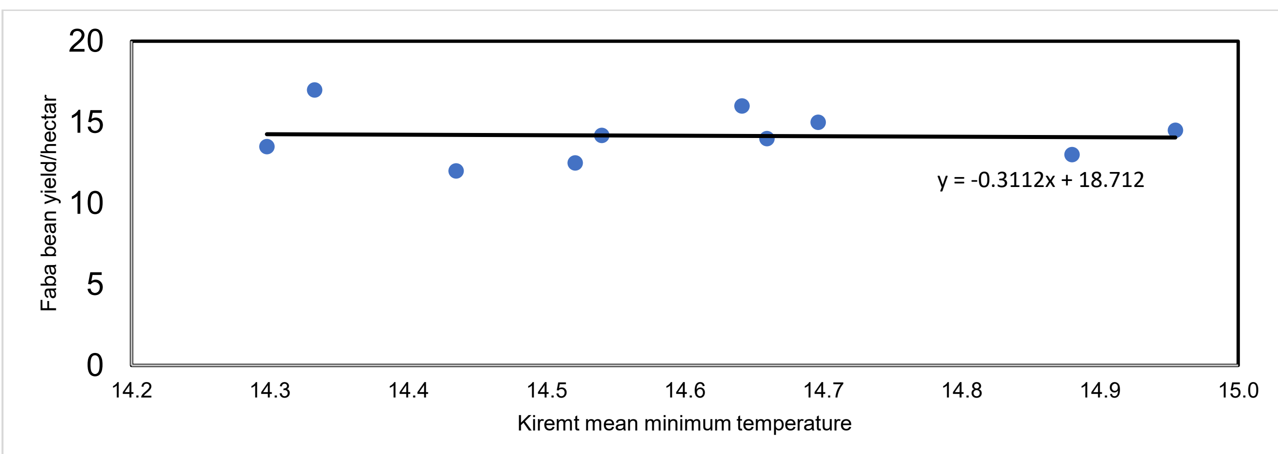


Table 8 below explains one day lag of the start rain season resulted in a reduction of 0.025 quintals of faba bean per year per hectare and also an increment of 1 ^{0}C kiremt mean minimum temperature, resulting in a reduction of faba bean yield by 2.413 quintals per hectare per year. If the Kiremt mean maximum temperature increased by 1^{0}C, faba bean yield increased by 1.559 quintals per year per hectare in the study area according to the regression table. But a 1 mm increment of the Kiremt rainfall total resulted in a 0.005 reduction of faba bean yield in the study area.

Table 8. Coefficient of regression for rainfall and temperature

Model	Coefficients	SD Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	15.831	30.177	0.525	0.628	-67.953	99.616
SOS	-0.025	0.036	-0.701	0.522	-0.125	0.075
EOS	0.029	0.022	1.336	0.253	-0.031	0.090
K. m. min T	-2.413	3.483	-0.693	0.527	-12.082	7.257
K. m. mx T	1.559	1.872	0.833	0.452	-3.639	6.756
K. rfall total	-0.005	0.003	-1.922	0.127	-0.013	0.002

The estimated coefficient of determination R^2 was 0.733 (73.3%), showing that bean yield variation in the study area was determined by climate variables (start of the season, end of the season, Kiremt mean maximum and minimum temperature, and Kiremt total rainfall) (Table 9). The present findings are consistent with those of Bogale *et al*. (2022), who reported that the estimated coefficient of determination (R2) was 0.744 (74.4%), which indicates that Kiremt (average of temperature, total rainfall, and rainy day) and the end of the Kiremt rainy season could describe the faba bean (Tumsa variety) yield in Walmara district.

Table 9. Regression value of the predictor

Model	R	R Square	Adjusted R Square	Standard Error
	0.856	0.733	0.399	1.198

Association between Faba bean Yield and Independent Variables

Table 10 below describes a simple linear regression analysis of the change in harvested faba bean yield was not significant since there are no highly correlated climate variables, both negatively and positively. But at the end of the season and kiremt mean maximum temperature are insignificantly contribute for the yield increment of faba bean. But those other factors are reducing the yield.

Table 10. Regression analysis results and equations for the ecological association between annual harvested faba bean yield (dependent) and other independent variables, including year change from 2012 to 2021.

	Correlation Value (r)	Faba bean yield function when only the factor included	Significance	R-squared
SOS	-0.17	Y=-0.014x+15.6	0.73	0.016
EOS	0.28	Y=0.016x+8.956	0.47	0.067
K. m. min T	-0.04	Y =-0.963x+28.145	0.692	0.021
K. m. mx T	0.29	Y =0.663+1.523	0.704	0.019
K. rfall total	-0.63	Y =-0.005x+21.383	0.051	0.397

The RPCA is used in this research to determine which independent factors have a greater impact on the dependent variable. As presented in Table 11 below, Rotated Principal Component Analysis (RPCA) was conducted and from those five independent variables, three variables (Kiremt total rainfall, Kiremt mean maximum temperature, and End of season) are the main factors that determined the maximum variability of faba bean yield with Eigenvalues of 2.142, 1.670, and 1.485, respectively. As presented below in Table 11; these are the three principal components with Eigen value greater than 1 which can well determine the variability in annual harvested faba bean yield over the past study period from the year 2012 to 2021. With these three principal factors only, harvested annual faba bean yield can be mathematically estimated using the multiple linear regression function of:

Y=-0.005x1+1.559x2-0.029x3, where x1-x3 represent Kiremt total rainfall, Kiremt mean maximum temperature, and End-of-season, respectively. The coefficient of determination (R^2) for this model with these three factors considered statistically estimated to be 88%. The present finding agrees with the findings of Feke *et al*, (2021), who found that the climate variables is determine of the 80% variability in the yield of coffee in western Ethiopia.

Table 11. Rotated principal component analysis results and Eigen values for the 5 independent faba bean yield determinant factors

Independent Components	Eigen Value	% of variance explained
K. r. fall total	2.142	35.707
K. m. mx T	1.670	27.83
EOS	1.485	24.479
SOS	0.396	6.601
K. m. min T	0.717	2.853

CONCLUSION

The Horro district is part of the Faba bean-producing zone of Horro Guduru Wollega. This research focused on examining the influence of climate factors on faba bean yield in the Horro district. For this research, long-term climate data and faba bean yield were acquired from the EMI and Horro district agricultural offices, respectively. The findings reveal that both the yearly rainfall and the beginning of the rainy season have diminished. Precipitation demonstrates a minimally rising trend. Annual maximum and minimum temperatures, along with Kiremt temperatures, show a notable upward trend. The correlation analysis revealed a negative and weak association between the beginning of the season, the conclusion of the season, and Kiremt's average minimum temperature in relation to faba bean yield. Furthermore, bean yield exhibits a nearly strong inverse correlation with total rainfall during Kiremt. The mean maximum temperature during Kiremt has a positive correlation with the yield of faba beans in the region. The yield of faba bean was analyzed in relation to the chosen climate variables, revealing that 73.3 % of the variation in bean yield within the study area was influenced by these climate factors.

Availability of data

The corresponding author can provide data upon reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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