

Research Article

Characterization of Local Climate and Its Impact on Faba Bean (*Vicia faba* L.) Yield in Central Ethiopia

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Climate change is a major threat to agricultural production and undermines the efforts to achieve sustainable development goals in poor countries such as Ethiopia that have climate-sensitive economies. The objective of this study was to assess characterization of local climate and its impact on productivity faba bean (*Vicia faba* L.) varieties (Gora and Tumsa) productivity in Welmera watershed area, central Ethiopia. Historical climate (1988–2017) and eight years of crop yield data were obtained from National Meteorological Agency of Ethiopia and Holeta Agricultural Research Center. Trend, variability, correlation, and regression analyses were carried out to characterize the climate of the area and establish association between faba bean productivity and climate change. The area received mean annual rainfall of 970 mm with SD of 145.6 and coefficient of variation (CV %) of 15%. The earliest and latest onset of rainfall were April 1 (92 DOY) and July 5 (187 DOY), whereas, the end date of rainy season was on September 2 (246 DOY) and October 31 (305 DOY), respectively. The average length of the growing period was 119 days, with a CV% of 35.2%. The probability of dry spell less than 7 days was high (>80%) until the last decade of May (151 DOY); however, the probability sharply declined and reached 0% on the first decade of July (192 DOY). Kiremt (long rainy season that occurs from June to September) and belg (short rainy season that falls from February to April/May) rainfall had increasing trends at a rate of 4.7 mm and 2.32 mm/year, respectively. The annual maximum temperature showed increasing trend at a rate of 0.06°C per year and by a factor of 0.34°C, which is not statistically significant. The year 2014 was exceptionally drought year while 1988 was wettest year. Kiremt (JJAS) start of rain and rainy day had strong correlation and negative impact on Gora yield with ($r = -0.407$ and -0.369), respectively. The findings suggests large variation in rainfall and temperature in the study area which constraints faba bean production. Investment on agricultural sector to enhance farmer's adaptation capacity is essential to reduce the adverse impacts of climate change and variability on faba bean yield. More research that combines household panel data with long-term climate data is necessary to better understand climate and its impact on faba bean yield.

1. Introduction

Climate change/variability brought about by human activity and natural processes is expected to have a significant impact on world food supply [1]. Low-income countries in tropical regions with low adaptation capacities are particularly sensitive to the negative effects of climatic variability and change [2]. Due to low-population adaptability capability, developing countries are projected to be particularly sensitive to the negative effects of climatic variability and

change. The Intergovernmental Panel on Climate Change (IPCC) estimates that altering land surface temperature and rainfall variability will reduce agricultural yields by 50% in rainfed systems [3, 4]. Similarly, Africa is rapidly warming, and arid zones are spreading across the continent [5].

Ethiopia is one of the sub-Saharan countries where agriculture is afflicted by recurrent drought, flood, erratic rainfall, and other climate extremes [6]. Historical climate data from 1951 to 2006 revealed that the mean annual minimum and maximum temperatures in Ethiopia have

increased at a rate of 0.13°C per decade and 0.37°C per decade, respectively [7]. Several studies predict that in 2020s and 2050s, temperature will likely rise throughout the year in the country [8–10]. Hadgu et al. [8] showed a significant increase in lowest temperature trends, while [9] saw a general trend of increasing warm and decreasing cold extremes. Rainfall also tends to decrease in both long and short rainy seasons [11]. Although rainfall has a propensity to rise, its trend and pattern have become increasingly unreliable spatially and temporally [8, 10].

Faba bean (*Vicia faba* L.) is a cool season crop that is grown all over the globe for food, feed, and ecosystem services [12]. The crop is used as a source of protein and carbohydrates for both humans and animals [13]. The ideal temperature for faba bean growth and development has been determined to be between 18 and 27°C [14]. After peas, chickpeas, and lentils, faba bean is the fourth most popular food legume in the world [15]. Future global faba bean crop production faces interacting challenges; with an increasing global population, more food is required, but with climate change and associated extreme weather condition is becoming more difficult to produce food [16]. Crop yield is particularly susceptible to adverse weather conditions during floral development and anthesis have a relatively short stage crucial to yield production that is highly susceptible to short periods of high temperature and/or drought [17]. Faba bean is an important highland crop that covers over half millions hectares of the countries' cultivated land. Its production is projected to account for 3.94% of total grain production in Ethiopia and it is the country's economic backbone [18]. In Ethiopia, faba bean productivity remains well below global production level (3.8 t/ha), which has been hampered by a variety of biotic and abiotic factors [18]. In addition to nonclimatic factors, recurrent drought flooding, unreliable rainfall amount, and distribution contribute to low faba bean productivity in the country [19]. Climate also increased, the incidence of many fungal diseases, posing a major threat to faba bean yield [20].

Increased rainfall in some areas led to waterlogging and nutrient leaching, which contributed to low faba bean yield [21]. Previous research in Ethiopia on the impact of climate change/variability on crop productivity has found little to considerable correlations between crop yield and climate [22]. Faba bean is considered to have high adaptation to current climate change, but no studies explored its yield relationship to climate variables at local scale [23]. Welmera district is one of the districts of West Shoa Zone, which has been experiencing high fluctuation of climate variables [24]. Faba bean is quite popular crop in the district with smallholder farmers and produced for various purposes but faces climate variations and has become a challenge of production in recent years. No studies have explored historical climate of the district and its association with faba bean yield. This is vital information to devise appropriate policy formulation and context-specific adaptation practices. Therefore, the objective of this study was to characterize local climate of Welmera district and analyze its influence on faba bean yield.

2. Research Methodology

2.1. Description of the Study Area. Welmera district is one of 18 districts of Oromia Special Zone surrounding Addis Ababa, Ethiopia. It is located along the Ambo road about 30 kilometers from Addis Ababa, at an elevation between 2000 and 3380 meters above sea level [24]. It is bordered by Sululta district in the north, Sebeta Awas district in the south, Burayu City Administration in the west, and Ejere district in the east (Figure 1).

2.1.1. Climate and Topography. The region has a bimodal rainfall pattern, with 70% of the rainfall falling during the main rainy season (kiremt), which lasts from June to September, and 30% falling during the short rainy season (belg), which lasts from February to April [24]. In the study area, the months of July and August receive the highest monthly rainfall, while May and July are the warmest months, respectively. The two agro-ecological zones that comprise the Welmera district are lowland and midland. Most of the area has mild to uneven topography with little elevation variation. With the exception of a few problematic areas and hectares in the southern portion of the district, the district is entirely on plain land; in general, woinedega/temperate [25].

2.1.2. Vegetation and Livelihood. The area's vegetation is made up of grasslands, shrubbery, and forests along the watersheds of the ridges. The majority of the forest is made up of artificially planted eucalyptus and conifers. Majority of smallholder households depend on cereal cultivation and marketing for a living, making it the single largest subsector of the Ethiopian economy. Around 30% of GDP is accounted for by cereal, which accounts for around 60% of rural employment, 80% of all arable land, more than 40% of typical household food expenses, and more than 60% of all caloric intakes [25]. The area is distinguished by mixed crop-livestock agricultural systems, where both crop and livestock production play an important role in the livelihood of the farming community, similar to other central highlands of Ethiopia. The faba bean is the first main staple crop in the area, and it is followed by other crops like barley, *teff*, legumes, and potatoes. In the growing season of 2011–2012, faba beans occupied around 33% of the cropland [26]. Most of the field crops are grown in rainfed settings throughout the main growing season [27].

2.2. Data Collection

2.2.1. Historical Climate Data. In this regard, rainfall (mm) and temperature (°C) data of Welmera district for the period of 1988–2017 were acquired from National Meteorology Agency (NMA) of Ethiopia.

2.2.2. Crop Yield Data. Crop yield data for two improved faba bean varieties (Gora and Tumsa) were gathered from HARC for an eight-year period (Table 1). Additionally, these varieties genotypes of faba bean are commonly employed as

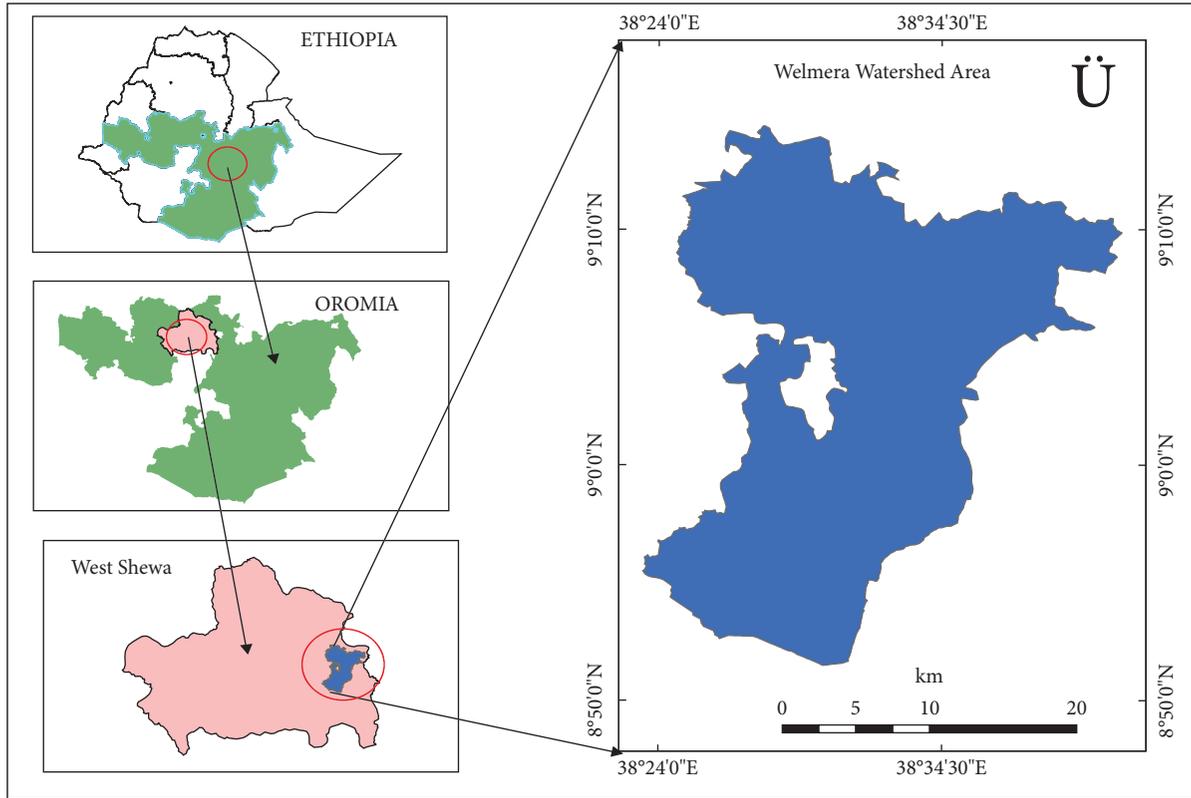


FIGURE 1: Map of the study area.

TABLE 1: Faba bean yield (Gora and Tumsa) varieties production in kg/ha for the study area.

Year	2010	2011	2012	2013	2014	2015	2016	2017	Mean
Gora yield (kg/ha)	3340	2624	1700	2135	2179	2400	1300	3639	2415
Tumsa yields (kg/ha)	3701	3114	1600	2240	2394	2500	1400	3537	2561

local check varieties with other genotypes of faba bean in the national variety trial (evaluating new breeding lines) by local farmers and HARC, and they were selected for their distinct maturation periods and the availability of long-term data [26].

2.3. Data Analysis. Data quality control: Climate data are highly sensitive to erratic values and outliers as these can compromise data quality. Therefore, before analysis of time-series climate data, trimming of outliers in a methodical manner is an essential to reduce the size of the distribution tails and provide reproducible and reliable [28, 29]. In this particular study, the Tukey fence outlined in [30] was used to detect outliers through XLSTAT 2014 software.

2.3.1. Analysis of Rainfall and Temperature Characteristics. Rainfall and temperature data analysis was carried out using techniques that generally fall under variability and trend analyses. Climate variability over the study area during the study period was carried out using coefficient of variation and standardized anomaly. The coefficient of variation is calculated as

$$CV = \left(\frac{\delta}{\mu} \right) 100, \quad (1)$$

where CV is the coefficient of variation, δ is the standard deviation, and μ is the mean for rainfall. According to [31], CV values describe the degree of variability as: less ($CV < 20\%$), moderate ($CV 20$ to 30%), and high ($CV > 30\%$) are considered to be vulnerable to drought.

2.3.2. Mann-Kendall Trend Analysis. The Mann-Kendall (M-K) trend test, which is a nonparametric statistical test, was employed to assess monotonic trends in seasonal and annual rainfall and temperature data and whether the trends are statistically significant or not [32]. The M-K test statistic "S" is calculated using the equation (4):

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n-1} \text{sgn}(x_j - x_i), \quad (2)$$

where S is the M-K test statistic, x_i and x_j are the annual data values in years i and j ($j > i$), and n is the length of the time series. According to this test, a positive S value indicates an

increasing trend and a negative value indicates a decreasing trend in the data. The sign function is given as

$$\text{Sgn}(x_j - x_i) = \begin{cases} +1, & \text{if } (x_j - x_i) > 0, \\ 0, & \text{if } (x_j - x_i) = 0, \\ -1 & \text{if } (x_j - x_i) < 0. \end{cases} \quad (3)$$

For $n \geq 10$, ZMK approximates the standard normal distribution [32, 33] computed as

$$\text{ZMK} = \begin{cases} \frac{s - 1}{\sqrt{s(\text{var})}}, & \text{if } s > 0, \\ 0, & \text{if } s = 0, \\ \frac{s + 1}{\sqrt{s(\text{var})}}, & \text{if } s < 0, \end{cases} \quad (4)$$

where s is the variance and the presence of a statistically significant trend is evaluated using the ZMK value based on the critical value of student t -text of $Z_{\alpha/2}$ ($Z_{0.01} = 2.33$, and $Z_{0.05} = 1.645$).

The magnitude of a time-series trend was evaluated by Sen's slope estimator. This method is found to be a powerful tool to be used with missing data and remain unaffected by outliers [34].

2.3.3. Climate Characterization of the Study Area. In this study, the nature of onset and cessation of rainfall was examined in the study area over the study period. Onset of the rainy season was defined as any day when accumulated rainfall amount for three consecutive days is larger than 20 mm and there is no dry spell greater than 10 days within the following 30 days [8, 35]. On the other hand, the cessation was defined as any day after the first decade of September when soil water balance reaches to zero [35]. Moreover, for shaping cessation, 4 mm/day evapotranspiration for the study area and 100 mm/m of the actual soil moisture holding capacity (at field capacity) were considered using InStat plus (v3.36) and estimated ETo/day was calculated by CROPWAT_v8.0 statistical software, respectively [36]. Length of the growing season (LGS), a key factor in deciding on the maturity of cultivars to be grown in dissimilar rainfall regimes [37], was calculated by subtracting onset date from the beginning of the rainy season from the cessation of rainy season [38].

2.3.4. Number of Rainy Days and Dry Spell Length. According to [39], a day is defined as a rainy day if it accumulates 1 mm or more rainfall. The number of rainy days was counted starting from the first day of June to end of September 30 for *kiremt* season. In the context of Ethiopia, [40] employed three rainfall thresholds to define rainy day (-0.1, 0.5 and 1 mm). In this study, the minimum rainfall threshold definition suggested by [40, 41], which is 1 mm or more per 24 hrs, was adopted. Furthermore, maximum

number of consecutive dry days (a day that accumulate rainfall < 1 mm) was counted to determine dry spell length in *kiremt* season. The probability of dry spells in the study area was calculated following the first-order Markov analysis [36]. The length of dry spell that exceeds 5, 7, 10, and 15 days was analyzed using InStat (+v3.36) software [36].

2.3.5. Rainfall Anomaly. Standardized anomaly of rainfall was calculated as the difference between the annual total of a particular year and the long-term mean rainfall records divided by the standard deviation of the long term data. Standardized rainfall helps to determine dry and wet years; it is also used to assess frequency and severity of droughts. Standardized anomaly is calculated using the equation (5):

$$z = \frac{X - \mu}{\delta}, \quad (5)$$

where Z is the standardized rainfall anomaly, X is the annual rainfall total of a particular year, μ is the mean annual rainfall over a period of observation, and δ is the standard deviation of annual rainfall over the period of observation. Based on Z values, drought severity classes are given as extreme drought ($Z < -1.65$), severe drought ($-1.28 > Z > -1.65$), moderate drought ($-0.84 > Z > -1.28$), and no drought ($Z > -0.84$), [42]. The same method was used by [8, 43] to identify dry and wet years in their study.

2.4. Regression and Correlation Analyses. Multiple regression analysis was employed to quantify the relationship between faba bean yield and rainfall and temperature features such as onset, cessation, *kiremt* rainfall total, *kiremt* rainy days, and *kiremt* average temperature. The regression equation for the study is in the following form:

$$Y = a + b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + \dots + b_n \cdot x_n + e, \quad (6)$$

where Y is the value of the dependent variable (faba bean yield in kg/ha), a is Y intercept and $b_1, b_2, b_3, b_4, \dots, b_n$ regression coefficients, $x_1, x_2, x_3, x_4, \dots, x_n$ are the independent variables (rainfall characteristics such as onset, cessation, LGS, *kiremt* rainfall total, *kiremt* rainy days, and average of *kiremt* temperature), and e is the error of estimate or residuals of the regression.

Coefficient of determinations (R^2) was used to determine percentage of faba bean yield variation explained jointly by climatic features. Pearson correlation coefficient (r) was used to analyze the correlation between crop yield of faba bean (Gora and Tumsa) yields expressed in kg/ha with rainfall characteristics. Correlation coefficient ranges between -1 and +1; r values close to +1 indicate a positive correlation while close to -1 indicate a strong negative correlation; r value of 0 indicates no linear correlation. Similarly, student t -test and beta coefficients were used to determine the significance and magnitude of each prediction for each independent variable [44, 45] values were calculated using SPSS software. Variation inflation factor was employed to assess the multicollinearity problem in the data.

3. Result and Discussion

3.1. Characterization of Climate in Welmera District.

Table 2 shows a summary of rainfall characteristics for the research area. *Kiremt* rainy season in the study area began on average on May 20 (141 DOY), with a coefficient of variation of 21.2% and an SD of 30 days, indicating moderate fluctuation in the study area. During the last three decades, the major rainy season in the research region ended on average on September 16 (260 DOY) with a CV of 7.6%, which is less variable than the start of the rainy season. The rainy season began on April 1 (92 DOY) and ended on July 5 (187 DOY), respectively (Table 2). The results were in line with [46], which revealed that late start is the least desirable method since it shortens the crop growth period and reduces the ability to meet crop water requirements. The moderate fluctuation of onset and end date observed in this study is consistent with the results reported by [40], in Ethiopia. Irregularities and unpredictability in start and end dates influence agricultural production, with the former having a greater impact than the latter on farmers' cropping calendar [47].

During the study period, the average LGP in the study area was 119 days (Table 2). It had a high degree of variability, with a CV of 35.2% and an SD of 42 days. The significant unpredictability of LGP is attributable to the high variability of the *kiremt* rainy season's onset date. This finding was in line with a result reported by a research conducted in Ethiopia's Central Rift Valley, particularly at Ademi Tulu (Ziway), where the LGP ranged from 76 to 239 days [48]. Despite the large variability in start date, there was a 75% chance of attaining a 152-day LGP, indicating that the location is suitable for rainfed agriculture but if the fluctuation continues, the condition may likely be marginal very slow.

Mann-Kendall trend analysis revealed that annual and *kiremt* numbers of rainy days were falling by a factor of 0.595 and 0.39 days, respectively (Table 2). The findings were consistent with those of [48], at Jijiga station, shows a decline of 4 days per decade and weak declines in the annual number of rainy days at Negele and Gore are also found, these being 2.3 days/decade and 1.7 days/decade, respectively, and again also in eastern of Ethiopia parts, the annual number of rainy days decreased from a mean of 63 rainy days to 43 rainy days (decrease by 31%). The decline in the annual number of rainy days in central and western Ethiopia is less pronounced and is about 12%.

The probability of dry spell lasting less than 7 days was high (>80%) until the last decade of May (151 DOY) (Figure 2). However, the likelihood of a dry spell lasting less than 7 days decreased dramatically, reaching 0% in the first decade of July (192 DOY). With a similar pattern, the number of dry spells lasting more than 7 days climbed dramatically after the second decade of October (284 DOY) and reached 100% by the end of the month. The current results were consistent with that of [49] who discovered low probabilities of dry spell from June to September in eastern Ethiopia.

A dry spell of any length can occur at any stage of crop development, although it can be particularly detrimental

during blooming and grain filling [50]. Evidence on the likelihood of a wide variety of dry spell lengths could be beneficial to both risk takers (resource affluent farmers) and risk averse farmers (resource poor farmer) [50].

Drought sensitivity is high in most legume crops, especially during the flowering and maturation stages. Estimating the likelihood of dry spells over the growing season can aid in altering planting time so that the crop's sensitive period coincides with water availability [51].

3.2. Trends and Variability of Annual and Seasonal Rainfall.

Table 3 shows the annual and seasonal rainfall totals over the research area, as well as their trends and variability. The study area received mean annual rainfall total of 970 mm during the study period. The *kiremt* season contributed 73.8% of the annual rainfall total, whereas the area received 21.1% of the yearly rainfall during the *belg* season, and only 5.1 percent during the remaining *bega* season. In terms of trend, *kiremt* and *belg* rainfall at Holeta station had decreased at a rate of 4.7 and 2.32 mm/year, respectively. In line with this, [43] found that annual and seasonal *kiremt* and *belg* rainfall at Kombolcha and Srinka stations decreased from 1979 to 2008. Similarly, studies in different locations of Ethiopia, [51–53] revealed statistically nonsignificant increasing trends in annual and seasonal rainfall totals.

The mean rainfall for *kiremt* season was 715 mm, with a CV of 15.1%, which is lower than the variation of *belg* season (32.7%) and the dry period (*bega* season) (75.3%). This suggests that the *kiremt* rainfall season was less unpredictable than *belg* and *bega* seasons. *Belg* rainfall was more erratic than *kiremt* season rainfall [54]. This does not necessarily imply that *kiremt* rainfall was stable; in fact, the peak quantity of rain during the *kiremt* season was 923.4 mm, while the lowest amount of rain received in the study area was 498.4. The results were comparable to those of [55] who found a statistically insignificant result. Although the mean rainfall total of *kiremt* is projected to increase, the projected decline in August may have adverse impact on faba bean production as it may coincide with critical growth/developmental stages [56].

3.2.1. Annual and Seasonal Rainfall Anomaly Index.

During the period 1988–2017, the study area had 13 years (43.67%) had rainfall below normal and 17 years (56.67%) had rainfall above normal (Figure 3). The years 2009, 2014, and 2015 were classified as severe to extreme drought years. Similarly, [52] discovered that 2009 was the second driest year on record, trailing only the historic year 1984. According to the study, rainfed agricultural production dropped during the driest years in the study area.

Kiremt rainfall anomaly revealed that half of the observation years had rainfall amounts that were lower or greater than the long-term average (Figure 4). The years 2013, 2014, and 2015 were severe to exceptional drought years according to the index categorization used in [8, 55]. According to similar investigations, the years 2002 and 2009 were shown to be severe to extreme *kiremt* drought years in

TABLE 2: Rainfall characteristics for Welmera district in the period of 1988–2017 years.

Rainfall charact.	Min	Quartile1 25%	Median 50%	Quartile3 75%	Max	Mean	SD (\pm)	CV (%)	ZMK	Slope
SOS	92	110	142	170	187	141	30	21.2	0.083 ^{ns}	0.44
EOS	246	246	247	271	305	260	20	7.6	-0.044 ^{ns}	0
LGP	59	80	115	152	196	119	42	35.2	-0.092 ^{ns}	-0.6
ANRD	91	117	139	157	171	137	24	17.5	-0.595 ^{ns}	-2.11
KNRD	63	75	86	92	98	84	10	11.5	-0.39 ^{ns}	-0.54

SOS; start of rainy season, EOS; end of rainy season, LGP; length of growing period, ANRD; annual number of rainy day, KNRD; *kiremt* number of rainy day, ZMK; Mann-Kendall trend test, slope (Sen's slope) is change/yr, and ns; nonsignificant at 0.01 and 0.05 significance level.

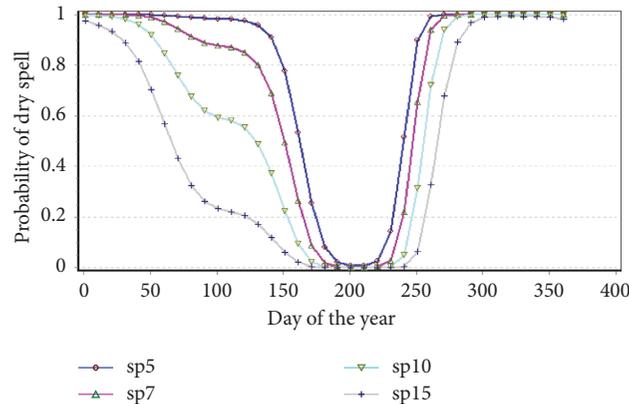


FIGURE 2: Dry spell lengths of 5, 7, 10, and 15 days at Welmera district (1988–2017).

TABLE 3: Trends and descriptive statistics of annual and seasonal rainfall totals of Welmera district in the period of 1988–2017.

RF (mm)	Mean	Min	Max	SD	CV (%)	ZMK	Slope
<i>Kiremt</i> rainfall	715	498.4	923.4	107.9	15.1	-0.25 ^{ns}	-4.70
<i>Belg</i> rainfall	205	49.2	348.7	67.0	32.7	-0.25 ^{ns}	-2.32
<i>Bega</i> rainfall	50	9.5	142.7	37.3	75.3	-0.18 ^{ns}	-0.80
Annual rainfall	970	714.5	1247.2	145.6	15.0	-0.33 ^{ns}	-8.53

ZMK, Mann-Kendall trend test and slope, Sen's slope and it is the change (mm/year), ns; non-significant at 0.01 and 0.05 significance level.

Ethiopia [52]. The year with the most favorable rainfall anomalies was 1988 (Figure 5).

Figure 5 shows the *belg* seasonal (FMAM) rainfall anomaly in the study area. Data analysis revealed that, 50% of the years in the studied period (1988–2017) had rainfall below the long-term average. The year of 2009 was classed as a severe to extreme drought year in the research area. The current findings are similar to those of [52], who observed severe to exceptional drought years in north-eastern Ethiopia from 1972 to 2011.

Furthermore, the current analysis revealed that the years 1997, 1999, and 2012 were classified as moderate-to-severe drought years, with seasonal rainfall amounting below the study period's long-term mean. The years 1990, 1995, and 2001, on the other hand, had highlighted by high rainfall levels above the long-term mean in the study area, making them the wettest years during the study period (Figure 5).

3.3. Trend Analysis of Temperature in the Study Area. Over the study area, the annual mean, CV, and SD of maximum temperature were 22.8°C, 4.1 percent, and 0.94°C, respectively

(Table 4). Annual maximum temperature increased by a factor of 0.34°C, which is nonsignificant and 0.06°C change each year (Table 4). The current finding is congruent with [39], who found a 0.37°C increase in annual mean maximum temperature over Ethiopian highlands each decade.

The maximum temperature in *belg* season increased by 0.046°C per year, however the trend was statistically insignificant at the *P*-values 0.01 and 0.05 significance levels. Droughts are likely to be exacerbated by this warming, which may result in reduced crop production [57].

Annual minimum temperatures grew by a factor of 0.005°C each year and 0.05°C per decade, according to the Mann-Kendall trend test (Table 5). Similarly, [39] found a 0.1°C increase in the average annual lowest temperature across the country every decade. In comparison to the *belg* season, the average, CV, and SD of *kiremt* minimum temperature showed less variability (Table 5). Furthermore, the *kiremt* lowest temperature grew by 0.007°C every year, whereas the *belg* season decreased by 0.062°C per year. The findings were consistent with those of [57, 58] who claimed that Ethiopia's temperature had risen in recent decades.

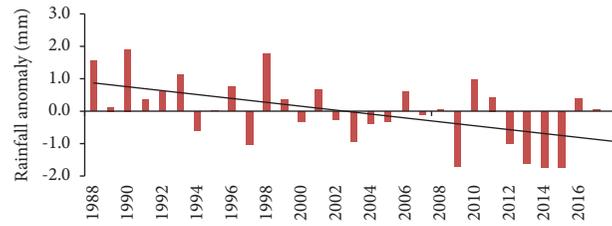


FIGURE 3: Annual rainfall anomaly at Welmera district in the period of 1988–2017.

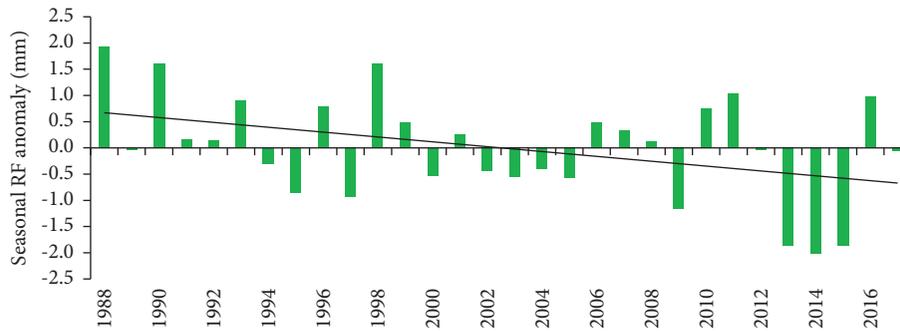


FIGURE 4: Kiremt rainfall anomaly (JJAS) at Welmera district in the period of 1988–2017.

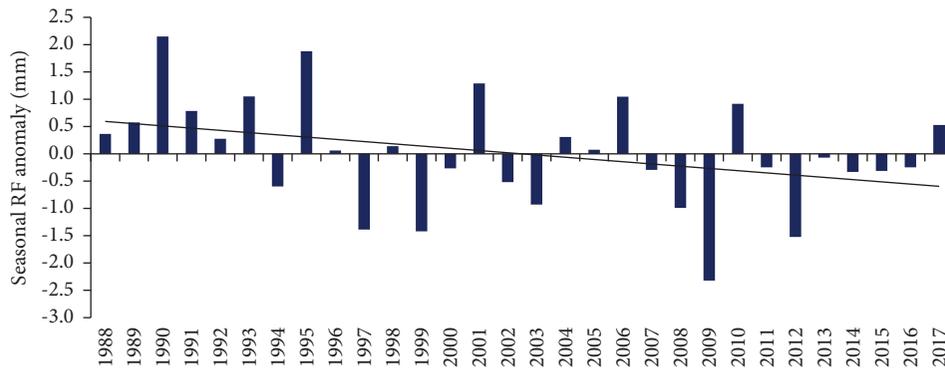


FIGURE 5: Belg rainfall anomaly (FMAM) at study area in the period of 1988–2017.

TABLE 4: Annual and seasonal maximum temperature trends at Welmera district (1988–2017).

Period	Mean	SD	CV (%)	ZMK (ns)	Sen's slope
Belg	24.49	1.06	4.3	0.26	0.046
Kiremt	21.04	1.22	5.8	0.34	0.074
Annual	22.83	0.94	4.1	0.34	0.060

SD; standard deviation, CV (%); coefficient of variation, ZMK; Mann–Kendall trend test, slope (Sen's slope) is the change °C/year and ns; –statistically nonsignificant at 0.01 and 0.05.

3.4. Correlation and Regression Analysis of Faba Bean Yield and Climate Variables. Demonstrates the relationship between the yield of one variety (Gora variety) temperature and rainfall parameters (SOS, EOS, LGP, *kiremt* rainfall totals, and *kiremt* rainy days) were observed at Holeta station (Table 6). The correlation analysis revealed a positive but nonsignificant relationship between *kiremt* total rainfall and *kiremt* mean temperature and Gora variety. Furthermore, the yield of the Gora variety exhibited a nonsignificant negative association with the onset of the rainy season ($r = -0.407$) and the *kiremt* number of rainy days ($r = -0.369$). End of rainy season ($r = 0.665$) and LGP

($r = 0.588$) were, on the other hand, positively and significantly associated with Gora output, implying that end of rainy season and LGP are strongly influence faba bean production in the research area.

Table 7 shows the relationship between Tumsa variety and rainfall features (SOS, EOS, LGP, *kiremt* rainfall totals, and *kiremt* rainy days) as well as *kiremt* mean temperature at Holeta station. The start of rainy season ($r = 0.482$) and *kiremt* rainy days ($r = 0.605$) had a moderate and substantial relationship with Tumsa yield, respectively. Yield of Tumsa variety was substantially correlated with the end of the rainy season ($r = 0.755$) and LGP ($r = 0.692$). The total amount of

TABLE 5: Annual and seasonal minimum temperature trends in the study area (1988–2017).

Period	Mean	SD	CV (%)	ZMK	Sen's slope
<i>Belg</i>	6.64	1.30	19.6	−0.29 ^{ns}	−0.062
<i>Kiremt</i>	8.33	1.17	14.0	0.05 ^{ns}	0.007
Annual	6.2	0.83	13.5	0.05 ^{ns}	0.005

ZMK; Mann–Kendall trend test, Slope (Sen's slope) is the change °C/year, ns; statistically nonsignificant at 0.01 and 0.05 significance level.

TABLE 6: Pearson's upper triangular correlation matrix of Gora yields with seasonal rainfall and kiremt average of temperature characteristics at Welmera area.

	Gora	SOS	EOS	LGP	JJAS	<i>Kirt</i> rainy day	<i>Kirt.</i> temp. aver
Gora	1	−0.407	0.665**	0.588**	0.044	−0.369	0.026
SOS		1	−0.444	−0.912**	0.437	0.548*	0.280
EOS			1	0.773**	−0.251	−0.455*	0.356
LGP				1	−0.433	−0.596**	−0.028
JJAS.RFT					1	−0.298	0.050
<i>Kiremt</i> rainy day						1	−0.335
<i>Kirt.</i> temp. aver.							1

JJAS; June, July, August, September (*kiremt*) rainfall total, KR; *kiremt* rainy day. **Correlation significant at the 0.05 level (2-tailed). *Correlation significant at the 0.01 level (2-tailed).

TABLE 7: Pearson's upper triangular correlation matrix of Tumsa yield with seasonal rainfall and kiremt average of temperature characteristics at Welmera area.

	Tumsa	SOS	EOS	LGP	JJAS	<i>Kirt.</i> rainy day	<i>Kirt.</i> temp. ave
Tumsa	1	−0.482*	0.755**	0.692*	0.115	−0.605**	0.15
SOS		1	−0.434	−0.907**	0.447*	0.545*	0.26
EOS			1	0.773**	−0.251	−0.455*	0.36
LGP				1	−0.433	−0.596**	−0.03
JJAS-RFT					1	−0.298	0.05
<i>Kiremt</i> rainy day						1	−0.34
<i>Kirt.</i> temp. aver							1

JJAS-RFT; *kiremt* rainfall total, *Kirt*; *kiremt* rainy day and average of temperature. **Correlation is significant at the 0.05 level (2-tailed). *Correlation is significant at the 0.01 level (2-tailed).

rain in kiremt ($r=0.115$) and the mean temperature of *kiremt* (0.150) had positive but nonsignificant relationship with Tumsa yield. The aggregate findings indicate that SOS and kiremt rainy days reduced faba bean yield due to increased waterlogging and flooding and temperature stress [56]. This positive correlation between climate variables (rainfall and temperature) shows that the variation in these variables can partially explain the low and variability of agricultural production in Ethiopia [59].

Regressing the yield of the Gora variety against chosen climate variables yielded the regression or forecast result (Table 8). The results showed that the end date and kiremt rainfall total had a positive but statistically nonsignificant effect on Gora yield. The findings were consistent with those of [60], who found that temperature had an influence on plant disease resistance due to interactions between temperature and some corresponding gene pairs.

The climate variables in the model explain 56% of the variation in Gora yield ($R^2 = 0.56$) (Table 9). The values of the variance inflation factor suggested that there was a multicollinearity problem between start date and duration of length of growing period. As a result, both variables were not considered as predictor in the regression model analysis. According to [60], *kiremt* rainfall total and kiremt rainy days account for 51.2% of the variability in barley yield per

hectare over the previous 19 years in Sinana district, which is more than half of the total variance in crop output.

The yield of Tumsa varieties was regressed against end date, kiremt rainfall total, kiremt number of rainy days, and average temperature variables provided in Table 10. The results showed that end date and kiremt rainfall total were the most important variables in the regression model, with nonsignificant but favorable impacts on Tumsa yields in the research region. Higher average annual temperatures and rainfall variability are endangering food security in low-income and agriculture-based countries, according to [61], who documented decreasing crop production with increased average annual temperatures and rainfall variability.

The estimated coefficient of determinations (R^2) was 0.744 (74.4%), showing that kiremt (average of temperature, total rainfall, and rainy day) and the end of the kiremt rainy season could explain the Tumsa yield variation (Table 11). The findings are similar to those of [59], who found that rainfall has an impact on yield variability in Ethiopian agriculture. The coefficient determination (R^2) results and the variance inflation factors both revealed reasonable values, indicating that the commencement date and the length of the growing period had a multicollinearity problem. As a result of the multicollinearity issues, both variables were already excluded from the predictor regression model.

TABLE 8: Coefficient of regression analysis for rainfall and temperature at Welmera area.

Model	Unstandardized coefficient		Standardized coefficient	<i>t</i>	Sign
	B	Std. error	Beta		
Gora	-42.135	176.539		-0.239	0.8271
EOS	0.327	0.196	0.830	0.665	0.194
JJAS-RFT	0.054	0.091	0.265	0.586	0.599
<i>Kiremt</i> rainy day	-0.016	0.972	-0.008	-0.016	0.988
<i>Kiremt</i> temp. aver	-3.689	5.429	-0.285	-0.680	0.545

^aDependent variable: Gora yield of variety.

TABLE 9: Regression values for predictor.

Model	<i>R</i>	<i>R</i> -square	Adjusted <i>R</i> -square	Std. error of the estimate
1	0.748 ^a	0.560	-0.028	9.051

^aPredictors (constant): *kiremt* (average of temp., rainfall total and rainy day) and EOS. ^bDependent variable: Gora yield of variety.

TABLE 10: Coefficient of regression analysis for rainfall and temperature in the study area.

Model	Unstandardized coefficient		Standardized coefficient	<i>t</i>	Sign
	B	Std. error	Beta		
Tumsa	-3.517	126.917		-0.028	0.098
End date	0.293	0.141	0.789	2.078	0.129
JJAS.RFT	0.048	0.066	0.251	0.728	0.519
<i>Kiremt</i> rainy day	-0.466	0.698-	-0.252	0.667	0.553
<i>Kirt.</i> temp. aver	-2.947	0.903	-0.242	-0.755	0.505

^aDependent variable: Tumsa yield variety.

TABLE 11: Regression values for predictor.

Model	<i>R</i>	<i>R</i> -square	Adjusted <i>R</i> -square	Std. error of the estimate
1	0.863 ^a	0.744	0.403	6.51

^aPredictors (constant): *kiremt* (average of temperature, total rainfall and rainy day), EOS. ^bDependent variable: Tumsa yield variety.

4. Conclusion

In the study area, both edaphic and climatic factors constrain faba bean yield. In order to study the relationship between climate variables and faba bean yield, secondary data of long-term rainfall and temperature and crop yield were collected from the NMA of Ethiopia and district offices, respectively. The results revealed an increase in onset end date, LGP and the number of *kiremt* rainy days declined in the study area during the study period, which are important climatic factors that could adversely affect faba bean yield. The CV values of belg (32.7%) and bega (75.3%) seasons showed substantial variation while the main growing season showed mild variation (15.1%). During the study period, there were negative and positive rainfall anomalies, with some of them coinciding ENSO phenomenon and adversely agricultural production in the study area. The study also revealed that the length of the growing season had a positive and strong relationship with Gora and Tumsa yields, as determined by multiple correlation coefficients between faba bean varieties (Gora and Tumsa). This relationship was statistically significant at the $P = 0.01$ and 0.05 . Onset of *kiremt* season and the number of *kiremt* rainy days, on the other hand, exhibited a negative relationship with Gora and Tumsa yields. Tumsa yield had a coefficient of determination (R^2) of 0.74, which was significantly higher than Gora yield (R^2) values of 0.56. This implies that yield of Tumsa

variety is more likely to be affected by rainfall and temperature features in the study area than Gora variety.

Since multiple features of rainfall and temperature had influence faba bean yield in addition to soil fertility and acidity problems, the farmers should get climate information services and use this knowledge to make farm-level decisions. Long-term integrated research that includes farmer's perception and meteorological analysis will shed more light on the impacts of climate variables on faba bean yield in the area.

Data Availability

Data will be made available on the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest concerning the publication of this article.

Authors' Contributions

Girma Asefa, Mengistu Mengesha (PhD), and Gebre Hadgu (PhD) were responsible for protocol design of the research. Girma Asefa was responsible for the collection of historical climate and downscaling of future climate data from

National Meteorological Agency of Ethiopia and Markism weather daily generator tool, respectively. Gebre Hadgu assisted the analysis and interpretation of the results. Girma Asefa wrote the draft manuscript, while both Mengistu Mengesha and Gebre Hadgu contributed to manuscript revision. All authors read and approved the final manuscript.

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