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RESEARCH ARTICLE

MODELING FACTORS INFLUENCING BARLEY YIELD IN ETHIOPIA: AUGMENTED COBB-DOUGLAS PRODUCTION APPROACH

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ABSTRACT

The purpose of this study was to examine the climate and non-climatic inputs influencing barley yield in Ethiopia. The study employed an augmented Cobb-Douglas production functional approach to model factors influencing barley yield. The results revealed that short-season rainfall and temperature variables showed a positive relationship with barley yield, having minimal impact on barley yield. Conversely, long-season rainfall showed negative impact on barley yield, mainly due to extreme rain events such as high rainfall above optimum requirement of the crop as well as scarcity of rainfall in some pocket areas. The result infers that cultivation of barley moderately depends on rainfall. Subsequently, irrigated land, fertilizer and barley seed quantities used exhibited positive impact on barley yield. Fertilizer and barley seed inputs demonstrated positively significant influence on barley yield, implying that barley yield is highly responsive to application of fertilizer and barley seed inputs and moderately responsive to irrigation input.

KEYWORDS

Determinant Parameters, Cereal Crops, Econometric Method

1. INTRODUCTION

Barley (Hordeum vulgare L.) is one of the most important food crops in the world in general and in Ethiopia in particular for a long period of time. While the crop is the fourth important cereal crop in the world production wise, following wheat, rice and maize, it accounts for both 9% in terms total area under cereal crops (0.95 million hectares) and total cereal production in Ethiopia (Yawson, et al., 2020; CSA, 2020; Tuttolomondo, et al., 2009). According to CSA, barley is considered as one of the staple cereal crops after teff, maize, wheat and sorghum (CSA, 2018). In terms of utilization, barley is largely consumed as staple food and used for preparing the popular traditional drink called Tella (Araya et al., 2021).

Historically, Ethiopia is considered as the center of origin and barley diversity in the world having high level of morphological variations between landraces that has developed over time, through adaptation to varied climatic and soil conditions (Lakew et al., 1997). This diversity may have been likely contributed through long- term geographic isolation since barley is considered as a founder crop of Old-World agriculture and may have been cultivated in Ethiopia for the last 5,000 years (Mekonnon, et al., 2014; Bekele, et al., 2005). Currently, producers cultivate the crop from altitudes ranging from 1,400 to over 4,000 meters above sea level (m.a.s.l) under highly variable climatic and edaphic conditions (Asfaw, 2000). Evidences indicate that the crop is grown in all regions of the country (Wosen et al., 2015). The major barley growing regions of the country include former Shewa, Arsi, Bale, Gojam, Gonder, Wollo, and Tigray. Additionally, short season/Belg season barley primarily grown from February to May is mainly produced in Wollo, Shewa and Bale areas. It was estimated that about 1.08 and 2.38 million tons of barley were produced between the period 1981 and 2020 respectively, showing an increase of about 220% over the years.

However, the production of barley crop in the country has been hampered by several factors which include climatic factors (rainfall, temperature, and carbon dioxide); erratic drought strain; potentially low yield of available cultivars; and invasion of crop diseases and insect pests and weeds (Wosene, et al., 2015). Among these factors, change in climate significantly affects crop yields and production. The Intergovernmental Panel on Climate Change (IPCC) confirmed that anthropogenic activities are the main factors changing the climate system globally and will continue to do the same (IPCC, 2014). In the previous last century, the effects of changes in surface temperatures and precipitation on physical and biological systems are progressively being observed.

Many of the countries located in the African continent, including Ethiopia are reported to be highly vulnerable to the elaborated effects of changes in climate factors as these have poor access to mitigation and adaptive resources. Some researchers have measured the impacts these factors impose on barley yield over different regions and locations and reported that climatic parameters have adverse impact on barley yield. A group of researchers in their modeling of climate change and its impact on food barley explored an overall increasing trend in temperature and significant variation of seasonal rainfall from the historical period which adversely affected barley yield (Bekele et al., 2019). A group of researchers modeled crop management and sensitivity of food barley to effects exerted by changes in climate parameters in northern parts of the country and reported a rise in temperature alone by 2, 4, 6 and 8^{0}C from the baseline which considerably and significantly reduced barley yield (Araya, et al., 2021).

Ginbo in his heterogeneous impacts of climate change on crop yields across altitudes in Ethiopia discovered that climate change reduces barley, maize, and wheat yield by 22.7%, 48%, and 10%, respectively, at high altitudes (Ginbo, 2022). Equally, simulated the effect of climate change in barley yield in Italy and reported that yield variability increases slightly with a rise in variability of both temperature and rainfall levels

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(Tuttolomondo et al., 2008). These findings inform us that changes in climatic parameters, such as sea level rise, rising atmospheric temperatures and altering rainfall patterns will pose crop yield reduction including barley. In view of the sensitiveness of barley crop changes in climate factors, the attempts made to quantify the possible effects exerted by climatic variables on barley yield as well as production are limited. Few studies have examined the impact of changes in climate variables on yield of barley (Bekele et al., 2019; Araya et al., 2021; Ginbo, 2022).

However, these studies covered limited and few pocket areas and locations and did not cover the main barley growing belts of the country. It was agreed that there is scarcity of such empirical studies having national scope and focus on the impact imposed by climate change on barley production in the country. Furthermore, unless researches focus on aggregated national level impact analysis of climatic parameters and incorporate mitigation and adaption strategies, future sensitivity of barley yield to climate change will be more damaging. Hence, it would be realistic and meaningful to study the impacts posed by changes in climate factors on the yield of barley aggregately at national level covering the main barley growing belts. The main objective of this study was to examine the influence of climate change and related inputs on barley yield and provide information that could help to design strategies that may guide future mitigation and adaptation responses.

2. MATERIAL AND METHODS

2.1 Description of the Study Area

Evidences show that Ethiopia is located in the Horn of Africa, with latitudinal and longitudinal locations lying between 3° to 15° N and 33° to 48°E, respectively (Ethiopia, 2014). The country borders with Sudan in the west, Eritrea in the north, Djibouti in the east, Somalia in the Southeast, Kenya in the south, and South Sudan in the southwest (World Bank, 2021). Administratively, the country is divided into four levels: regions or city administrations, zones, woredas, and the kebeles; kebele being the lowest grassroots administrative unit. According to the UN Population Funds population projection (2021), the population of Ethiopian has reached 117.90 million with an annual growth rate of 2.6 percent. Evidences show that barley is among the most important food crops grown in the country. According to CSA, the major barley growing belts in the country are located in Oromia, Amhara, Tigray, and Southern Nation Nationality and Regional State, supplying about 99.9% of the total national barley production (CSA, 2018). Zone-wise, barley is mainly grown in the zones of Arssi, Bale, former Shewas, Wollo, Gojam, and Gonder; see Figure 1 for the map (Gashaw and Tura, 2015).

Further evidence show that barley grows best at higher altitudes with an optimum range of 2000-3500 meters above sea levels. Barley is mainly grown as a 'meher' (main season) crop at higher elevation of Dega regions and also widely cultivated as a 'belg' crop in many areas. It is grown mainly in Arssi, Bale, Shoa, Welo, Gojam and Gonder as a belg/short-season crop (Assamere et al., 2021). In general, barley crops are grown during two consecutive seasons: the short/belg-season and long/ meher-season at the higher elevations of Dega agroecologies (Muluken and Jemal, 2011). It has been reported that barley crops are considerably cultivated and supplied by the smallholder subsistence farmers, who mostly use local seed varieties with either little or no application of fertilizers, pesticides, and herbicides.

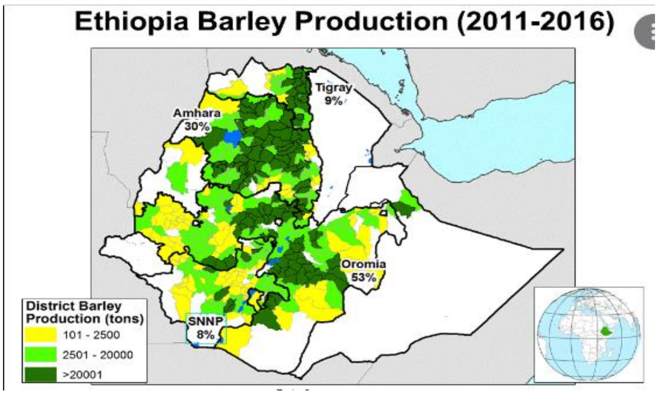

Figure 1: Major Barley Growing Belts of Ethiopia

The amount of crop growing period rainfall required by barley crop ranges between 180 to 400mm depending on altitude and geographic locations (Cammarano et al., 2019). Although the crop mainly grows in the highlands as specified above, it can also moderately be grown in a subtropical climate characterized by hot, humid main-seasons and cool to mild bega seasons (October – December). It has been reported that barley best suits a temperature of 12-15 ⁰C over crop growing period and about 30⁰C temperature at maturity time. According to one study barley has no tolerance capacity to frost at all stages of plant growth, particularly at the flowering stage (Cammarano, et al., 2019). It has been reported that frost highly affects the yield of barley crops during crop flowering stage since this stage represents crop shift from vegetative to reproductive growth (Wiegmann, et al., 2019).

Although suitable agro-ecologies are available for barley crop production, available evidence show that the yield of barley was fluctuating over time. Data compiled from CSA show that the yield of barley declined from 130 kilogram/ hectare in 1981 to 93.4 kilograms/hectare in 2000 and increased by 108.1 kilogram/hectare from 2001 to 198.2 kilograms/hectare in 2017; and then again started declining from 2018 onwards. The trend of barley yield gives clues for the effect posed by climate change and related factors. See Figure 2 for details.

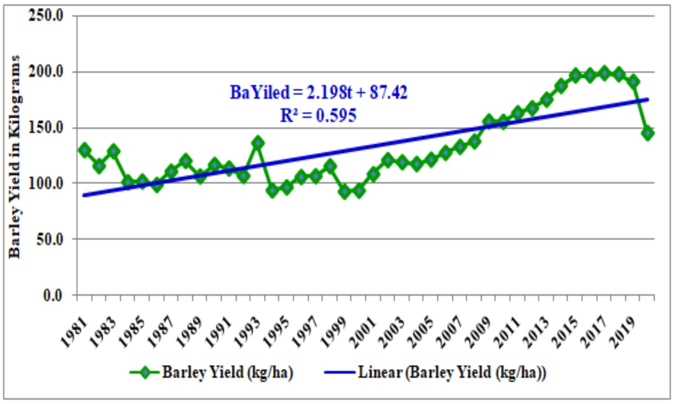

Figure 2: Trend of barley yield over the period 1981 – 2020 (Source: Computed using raw data compiled from CSA)

2.2 Data Type and Source

This study used time series secondary data for the selected explanatory and dependent variables covering the period from 1981 to 2020. The study used one independent variable (yield of barley expressed in kgs/hectare); and explanatory variables (crop growing period seasonal rainfalls expressed in millimeters (mm), crop growing period temperatures expressed in (ºC), barley cultivated area expressed in million hectares, fertilizer and barley seed quantities applied on barley crop cultivation). Data on production and yield of barley crop as well as sorghum cultivated area were compiled from Agricultural Sample Survey Reports of Ethiopian Central Statistical Agency (CSA) covering the period from 1981 to 2020. Data on weather variables, i.e., short-season/belg and long-season/meher rainfalls were purchased from the Ethiopian National Meteorological Agency (NMA) for 12 representative weather stations falling within the major barley growing belts of the country. The purchased weather was then nationally aggregated (pooled) for crop growing period by taking average of weather stations selected for the study over the period 1981 to 2020.

2.3 Empirical Model Specification

Researchers have employed Cobb-Douglas Production model to examine the impacts exerted by climatic factors on cereal crops productivity and production (Gupta, et al., 2012; Shumatie, et al., 2017). This study has employed an augmented Cobb-Douglas Production model to examine climatic and non-climatic factors influencing the yield of barley. The model assumes that agricultural production is a function of many input variables such as cultivated area, fertilizers, seeds, oxen power, labors, working capital, rainfall and temperature. In production theory, the relationship between explanatory variables (climate and related inputs) and crop yield normally takes non-linear form (Chen, et al., 2004; Just and Pope, 1979). In this context, the Cobb-Douglas Production model, in its stochastic form, can be expressed as (Gujarati, 2004):

$$Y_t = AX_1^{\beta 1}X_2^{\beta 2}\ldots X_n^{\beta n\ e\varepsilon} \qquad (1)$$

Where, Y_t represents yield of barley, $X_{s'}$ represent a set of explanatory variables, and $\beta_{s'}$ represent parameters to be estimated. A represents constant term, e is the base of natural logarithm, and ε is the disturbance term with zero mean and constant variance. This non-linear form of Cobb Douglas Production model can be estimated through ordinary least squares (OLS) by adding natural log on both sides of equation (1), which becomes log-linear form. Estimates of this form of production function give direct elasticity coefficients for the variables. The log-linear form of Cobb Douglas Production model in this regard can be expressed as:

$$\ln Y_t = \beta + \beta i \sum_{i=1}^{n} \ln X_i + \varepsilon i \qquad (2)$$

Where $\ln Y_t$ shows barley yield at time t, $\ln X_i$ represents various farm inputs such as cropped land area, fertilizer and barley seed applied, and irrigated land area. Although farm inputs like farm machinery, oxen power, and labors are required to be included in the model, they were not included due to unavailability of time series data. In its functional form, the augmented Cobb-Douglas Production model specified under equation (2) can be specified as:

$$\ln Y_t = \alpha_0 + \beta_1 \ln BLa_t + \beta_2 \ln Fert_t + \beta_3 \ln BS_t + \beta_4 \ln IrrgAr_{it} + \varepsilon_t \qquad (3)$$

where, $\ln Y_t$ represent the natural log of barley yield, $\ln BLa_t$ represent the natural log of cropped land area, $\ln Fert_t$ shows natural log of fertilizer input used on barley crop production, $\ln BS_t$ is natural log of barley seed consumed, and $\ln IrrgAr_t$ is natural log of irrigated area under barley crop production at time t. ε is the disturbance term independently and identically distributed.

The Cobb-Douglas Production model further assumes climatic factors as the main influential input factors for the yield of crops. Climatic variables considered in this study as explained above were incorporated in the crop yield model. After incorporating climatic variables into the model, equation (3) in its log-linear form has been specified as follows:

$$\ln Y_t = \alpha_0 + \beta_1 \ln BLa_t + \beta_2 \ln Fert_t + \beta_3 \ln BS_t + \beta_4 \ln IrrgAr_t + \beta_5 \ln SSR_t + \beta_6 \ln LSR_t + \beta_7 \ln MinTemp_t + \beta_8 \ln MaxTemp_t + \varepsilon_t \qquad (4)$$

Where: $\ln SSR_t$ is natural log of short/Belg-season rainfall, $\ln LSR_t$ is natural log of long/Meher-season rainfall, $\ln MinTemp_t$ is natural log of crop growing period (CGP) average minimum temperature, $\ln MaxTemp_t$ is natural log of CGP average maximum temperature, and the other variables take earlier definitions. Furthermore, t = time period from 1981 – 2018, α_0, β_1, β_2, β_3, β_4, β_5, β_6, β_7, and β_8 are unknown parameters to be estimated, and ε_t is the disturbance. To estimate the Cobb-Douglas Production model specified by equation 4, MedCal- Version 19.1 software and SPSS 24 Statistical packages were used.

2.4 Method of Estimation

The barley yield models have been estimated using Ordinary Least Squares (OLS). Prior to estimation of the model, the data series must be subjected to various tests to confirm that the various properties of OLS approach and the various time series properties confirmed to give results that are efficient and consistent. Since this study uses time series data, it was necessary test the data series for stationarity/ unit root and diagnostic test for checking presence of serial autocorrelation using appropriate methods and tools. In this study, two widely used methods, i.e. Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test were conducted to check the presence of unit roots in the data series (Dickey and Fuller, 1979; Phillips and Perron, 1988). The ADF test for stationarity in a series y can be estimated using the equation:

$$\Delta y_t = \mu + \beta_t + \gamma y_{t-i} + \sum_{i=1}^{p} \emptyset_i \Delta y_{t-i} + \varepsilon_t \qquad (5)$$

Where μ is the constant term, t is the time trend, i is equal the lag length in Δy_{t-i}, p is the maximum lag determined using Akaike Information Criterion (AIC) and Schwartz Criterion (SC) and ε_t is the disturbance term.

Time series were also subjected to a Phillips –Perron (PP) test which has a higher power. The PP test took the form:

$$\Delta Y_t = \theta_0 + \sum_{i=1}^{m} \delta_i \Delta Y_{t-i} + \varepsilon t \qquad (6)$$

Where ΔY_t was the first difference of the dependent variable; i is the number of truncation lags, where i=1, 2,…, m; θ and δ are coefficients and ε_t is the error term. The null hypothesis of, H_0: $\delta_i = 0$ (unit root) was tested against the alternative, H_A: $\delta_i < 0$ (no unit root). If the computed test statistic was found greater than the critical value at 5% level of significance, then the null hypothesis could not be rejected. If H_0 could not be rejected, then the time series variable contained a unit root and hence nonstationary, otherwise it was stationary.

In addition to the unit root and diagnostic tests, the experimental design and scheme to be followed needs to be explained clearly to lead the process of carrying out research as per defined objective of the study and reach results intended. Any experiment design process should start by defining the objective and variables to be included in the experiment. The planning and designing of the study will be explained. Next, the hypothesis of the investigation should be defined which may state 'climate change has no impact on yields of barley'' against the alternative hypothesis of ''climatic and non-climatic factors have impacts on barley yield''. Data collection and modeling of the study will be conducted. The collected data will be analyzed, and results interpreted with focus on whether the hypothesis confirmed the expected results or not. Finally, conclusions will be presented explaining the main results of the study and proposed future research direction. Figure 3 presents an experimental flowchart to plan, conduct and complete the investigation under consideration.

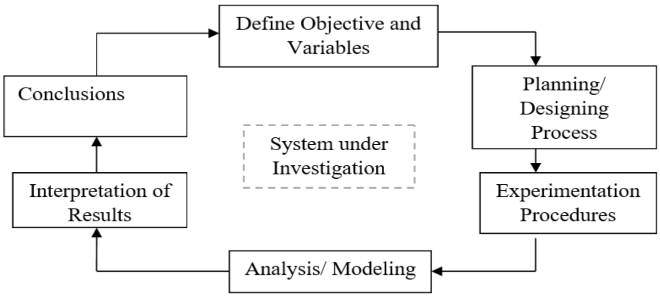

Figure 1: Experimental Flowchart to plan, conduct and complete the investigation under consideration

3. RESULTS AND DISCUSSION

3.1 Results of Unit Root Tests

The unit root test results are presented in Table 1 below. According to the test results, the following variables are stationary at level or order I(0): lnBaY, lnBaAr, lnBaIrrgAr, LnFert, LnBSeed, and LnMaxTemp. Conversely, the following variables were found to be integrated of order I (1): LnSSR, LnLSR and LnMinTemp. The unit root result exhibited a mixture of I(0) and I (1). Whenever, the unit root test demonstrated a mixture of I (0) and I (1) among the data series, most researchers and econometricians recommend use of Cobb-Douglas Production or ARDL modeling as the best approach (Sharma and Singh, 2019; Dushko, et al., 2011).

Table 1: Results of the Unit Root Tests

Variable Table 1:	**ADF**				**PP**				**Result**
	Level		**First Difference**		**Level**		**First Difference**		
	Computed t-Statistic	**Critical Value**	**Computed t-Statistic**	**Critical Value**	**Computed t-Statistic**	**Critical Value**	**Computed t-Statistic**	**Critical Value**	
LnBaY	-0.2272***	-4.25288	-6.19942	-4.2436	-2.1793***	-4.2119	-25.041	-4.21913	I(0)
lnBaAr	-3.6455***	-4.21187	-8.5007	-4.21913	-3.6395***	-4.21187	-19.2650	-3.19831	I(0)
LnBaIrrgAr	-3.6975***	-4.21187	-6.9341	-3.20032	-3.7260***	-4.21187	-11.7046	-3.19831	I(0)
LnFert	-2.9416***	-4.21187	-7.2393	-4.21913	-2.9228***	-4.21187	-13.18991	-3.19831	I(0)
LnBSeed	-1.9332***	-4.21187	-4.9361	-4.23497	-1.7293***	-4.21187	-7.30698	-4.21913	I(0)
LnSSR	-6.41428	-4.21914	3.8001***	-3.2003	-8.47373	-4.21188	-23.27511	-4.21913	I(1)
LnLSR	-4.91008	-3.52976	4.0254***	-4.24364	-4.88583	-3.19641	-20.97917	-4.21913	I(1)
LnMinTemp	-6.35686	-3.19641	-2.50206*	-2.89000	-6.12426	-3.19641	-13.78382	-3.19831	I(1)
LnMaxTemp	-0.97548*	-3.77000	-6.82005	-3.20245	-31.0864	-3.19641	-122.4843	-3.19831	I(0)

*, ** and *** indicates significance level at 10%, 5% and 1%, respectively

3.2 Diagnostic Tests

Next to unit root test, diagnostic tests were conducted to detect the presence of serial correlation and multicollinearity in the data series. The tests demonstrated presence of no serial correlation in the regression models as observed residuals are significant at 5% level and the Durbin Watson statistic is almost close to 2 in most cases. The test also indicates that there is no effect of multicollinearity as the p-values associated with the test statistic is greater than 0.05 for the barley crop yield model. See Table 2 for details.

Table 2: Diagnostic Test Results for Barley Yield Equation

Type of test	Test statistic	Test statistic value	Probability
Normality test	D'Agostino-Pearson test	4.1545	0.4995
Serial Correlation LM Test	Obs*R-squared	0.7480	0.1060
Heteroskedasticity Test: ARCH	Obs*R-squared	0.7220	0.0760

3.3 Modeling Effects Exerted by Climate and Related Inputs on Barley Yield

The Cobb-Douglas Production model was estimated using MedCal-Version 19.1 software and SPSS 24 Statistical Packages. The model was estimated using OLS technique. The elasticity coefficients estimated for the Cobb-Douglas Production model was found significant since the F-value (11.4996) indicates an overall regression model was fitted good following normal distribution for the present data. The D'Agostino-Pearson test conducted to check distribution properties of the model proposed to accept normality at (P=0.4995). Furthermore, the adjusted R^2 was found to be 0.683 implying that 68.3% of the variations in the model have been explained by the input variables included in the analysis, implying good fitness of the estimated model to the data series.

The explanatory variables considered in the model were transformed into their logarithmic form so as to provide convenient interpretations of the elasticity coefficients and to reduce heterogeneity of the variance. The climatic parameters considered in the estimation of Cobb-Douglas Production model included: short-season rainfall, long-season rainfall, CGP average minimum and maximum temperatures (Feb-Sept). Furthermore, land area cultivated under barley crop, barley crop irrigated area, quantity of fertilizer and barley seed applied on barley production were selected and incorporated in the barley yield model.

The elasticity coefficients estimated for the variables included in the barley yield model analysis are presented in Table 3. The elasticity coefficients estimated demonstrated that the climatic factors included in the model, except long-season rainfall, had positive relationship with the yield of barley, although statistically insignificant. The result implies that short-season rainfall, nationally known as belg season and CGP average minimum and maximum temperatures have minimal positive impact on yield of barley. The positive elasticity of short-season rainfall is justified by the fact that short duration barley crops are mainly grown in the mid-highlands of Bale, North Central Shewa, and North and South Wollo zones from February to May season. According MoA report, short/belg-season contributes less than 10% of the total grain production in the country; it is also crucially important for seed-bed preparation for both the short and long-cycle meher crops, and for planting long-cycle cereal crops such as maize, sorghum, and millet MoA (2001).

Conversely, the long-season rainfall demonstrated negative impact on yield of barley, although statistically insignificant. The negative impact registered on yield of barley during main season can be due to extreme rain events such as high rainfall above optimum requirements of the crop and scarcity of rainfall in some pocket areas. High rainfall above optimum requirement can cause flooding, logging of crops and landslides which also affects yield of barley. Scarcity of rainfall during critical crop growth periods can lead to wilting of the stalk of the crop; inhibit proper vegetative growth of the crop; and shrink grain filling. This infers that cultivation of barley in Ethiopia moderately depends on rainfall. The finding of this study is analogous to that of (Kim and Pang, 2009). They conducted a study on the impacts exerted by climatic factors on rice yield in Korea and reported that precipitation has negative impact on the average yield of rice.

According to them, the elasticity coefficients estimated for precipitation were in the range of -0.14 ~ -0.05, which are relatively small. The study results of Singh and Sharma also support the current study (Singh and Sharma, 2018). Singh and Sharma in their study of measuring the productivity of food-grain crops in different climate change scenarios in India found that actual rainfall in Rabi season has negatively associated with barley yield while average minimum and maximum temperatures had positive impact on barley yield, which implies that average minimum and maximum temperatures are beneficial for yield of barley during Rabi season (Singh and Sharma, 2018). Conversely, they reported that yield of barley is negatively and adversely affected due to increased actual rainfall during crop growth period.

Conversely, both CGP average maximum and minimum temperatures have exhibited a positive relationship with the yield of barley over the observation period, which negates the theory and expected results. The results indicate that a 1% increase in temperature parameters will increase yield of barley by 0.81% and 0.035% respectively. Some studies indicate that the effect of increased temperature will depend on the crop's optimum temperature requirement for growth and production for a particular crop like barley (USGCRP, 2014). In this context, warming may benefit the types of crops that are typically planted in some areas or allow farmers to shift to crops that are currently grown in warmer areas within crop's optimum temperature requirement. However, if the higher temperature exceeds a crop's optimum temperature, yields will decline.

According to Jacobs, barley requires a mild climate and grows better in dry, cool climates than in hot, moist areas (Jacobs, 2016). It is well adapted to high altitudes with cold, short season areas. The species possesses moderate resistance to cold, but winter barleys are less winter hardy than winter wheat, triticale or cereal ryes. In Ethiopia, barley well grows in mid-highland and highland climates where temperature is cool. Some cultivars of barley also adapt to dryland areas where temperature is cold dry condition. The finding of this study is analogous to that of (Kim and Pang, 2009). In their study on the impact of climate change on rice yield in Korea, they reported that temperature is positively related to average rice yield. The elasticity for temperature is calculated as 0.82-0.89; thus a 1% rise in temperature increases the average rice yield by 0.8 – 0.9%.

Similarly, elasticity coefficients for non-climatic inputs such as irrigated barley area, fertilizer and barley seed quantity consumed over the observation period showed positive impact on barley yield while land area allocated for barley crop cultivation had negative impact on barley yield, although statistically not significant. Fertilizer and barley seed inputs had positive and significant (at 1% and 5% level) impact on barley yield. The result indicated that a 1% increase in use of fertilizer and barley seed per unit area will increase barley yield by 0.41% and 0.06% respectively. The result implies that barley yield is highly responsive to use of fertilizer and improved seed inputs. Estimates of this study are similar to those of (Kumar and Sharma, 2013; Singh and Sharma, 2018).

Kumar and Sharma conducted a study examine the impacts exerted by climatic factors on agricultural productivity in India and reported that irrigated area and total fertilizer consumption positively affected barley yield, fertilizer consumed being significant at 1% level (Kumar and Sharma, 2013). The result indicates that a 1% increase in fertilizer use led to an increase of barley yield by 0.12%. Equally, Singh and Sharma in their study on productivity of food grain in India during Rabi season found that cropped area and irrigated area under barley crop had positive impact on barley yield, the elasticity coefficients being 0.7356 and 0.0569 (Singh and Sharma, 2018). These coefficients, however, are statistically insignificant.

Table 3: Estimates of Cobb-Douglas Production Function from Barley Yield Model

Independent variables	Coefficient	Std. Error	t-stat	P-value	VIF
(Constant)	2.6724				
lnBaArea	-0.01023	0.2162	-0.0473	0.9626	1.549
lnBaIrrigarea	0.008872	0.05726	0.155	0.8779	1.282
lnFertQ	0.4076***	0.06314	6.455	<0.0001	1.526
lnBSeed	0.0757**	0.02818	2.687	0.0115	1.646
lnSSR	0.08750	0.1579	0.554	0.5835	1.399
lnLSR	-0.06383	0.2709	-0.236	0.8153	1.533
lnMinTemp	0.8118	0.6591	1.232	0.2273	2.056
lnMaxTemp	0.03473	0.3529	0.0984	0.9222	1.890
Sample size		40			
Coefficient of determination R^2		0.7480			
R^2-adjusted		0.6829			
Multiple correlation coefficient		0.8648			
Residual standard deviation		0.1526			
F-Statistic		11.4996			
D'Agostino-Pearson test for Normal distribution		accept Normality (P=0.4995)			

** & *** indicate significance level at 5% and 1% respectively

4. CONCLUSION

Among the climate factors analyzed in this study, short/belg-season rainfall and temperature variables revealed a positive relationship with the barley yield, although statistically insignificant. The result implies that short/belg-season rainfall and average minimum and maximum temperatures have minimal positive impact on the yield of barley. The positive elasticity coefficient of short-season/belg rainfall is justified by the fact that short duration barley crops are grown in the mid-highlands of Bale, North Central Shewa, and North and South Wollo zones from February to May season. The short/belg-season which contribute less than 10% of the total grain production in the country, is crucially important for seed-bed preparation for both short and long-cycle meher crops as well as planting long-cycle cereal crops such as maize, sorghum, and millet. Conversely, long/meher-season rainfall demonstrated negative impact on the yield of barley, although statistically insignificant. The negative impact registered on yield of barley during main/meher-season can be due to extreme rain events such as high rainfall above optimum requirement of the crop and scarcity of rainfall in some pocket areas. High rainfall above optimum requirement can cause flooding, logging of crops and landslides which also affects barley yield. Scarcity of rainfall during critical crop growth periods can lead to wilting of the stalk of the crop; inhibit proper vegetative growth; and shrinks grain filling. This infers that cultivation of barley in Ethiopia moderately depends on rainfall.

Subsequently, the elasticity coefficients of irrigated barley area, fertilizer and barley seed quantities applied on barley production over the observation period demonstrated positive impact on barley yield performance. Fertilizer and barley seed inputs had positive and significant (at 1% and 5% level) impact on barley yield during the observation period. The result implies that barley yield is highly responsive to use of fertilizer and barley seed inputs and moderately responsive to irrigation input. Conversely, barley land area had negative impact on barley yield, although statistically insignificant. In view of the findings of this study and its limitation on impacts imposed by climate factors, the direction of future research should focus on impact analysis as well as mitigation and adaptation strategies to reduce the impacts exerted on barley crop by climatic and related factors. The current study focused on impacts of climatic factors imposed on barley yield and neglected inclusion of mitigation and adaptation strategies that reduce the impacts exerted by climate and related factors on yield of barley.

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DATA AVAILABILITY

The data used for this study can be made available upon request provided there is going to be compliance with the owners' policy concerning sharing.

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AUTHOR'S CONTRIBUTIONS

The author has contributed to the study of conception and design. The author (Abera Gayesa Tirfi) has also performed all the material preparation, data collection and analysis, and writing up of the manuscript.

DECLARATION OF COMPETING INTEREST

The author declares that there have been no competing interests.

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