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# Influence of rainfall features on barley yield in Sinana district of Ethiopia

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## ABSTRACT

Rainfall data and barley production of Sinana district, South East Ethiopia for the period 1995-2016 were used to analyze influence of rainfall features on barley yield using correlation and regression techniques. Downscaled output of CSIRO-Mk3.6.0 GCM model for RCP 8.5 emission scenario for the period 2020-2049 were used to determine future rainfall and to ascertain its impact on barley yield. Six rainfall characteristics viz. onset date, end date, length of growing season, seasonal (June-September, *kiremt*) rainfall, and total annual rainfall were analysed. *Kiremt* (JJAS) contributes 37 per cent of annual rainfall and varied between 271.4 mm and 854.0 mm during the study period with coefficient of variation (CV) of 43 per cent. The barley yield was found to vary between 14.79qha$^{-1}$and 35.84qha$^{-1}$ with CV of 27.9 per cent during the same period. The results indicated that among all the rainfall features studied, the *kiremt* rainfall had strong positive relationship (r = 0.668**) with barley yield and explained nearly 45 per cent of total variance in the yield. Under future climatic scenario during 2020-2049 period, the projected rainfall is going to be less than the mean rainfall that may cause reduction in barley yield by 1.8 to 4.4 per cent in Sinana district.

***Key words :*** Ethiopia, barely yield, kiremt (JJAS) rainfall, onset date,correlation coefficients

Climate variability has always been identified as a challenge for African farmers. Studies in Ethiopia have shown that rainfall variability, unreliable occurrences in sufficient amount and delay in onset dates contribute to decline in crop yields with reasonable amount in almost all parts of the country (Godswill *et al*., 2007). Rainfall variability has historically been found as a major cause of food insecurity and famine in the country (Beweket, 2009). The trends in the contribution of agriculture to the country's total GDP clearly explains the presence of strong relationship between the performance of agriculture and climatic conditions. Most of the study revealed that agricultural sectors of the country have been highly affected by climate related hazards (NMA, 2001; Deressa, 2007). The crop yield variations in Ethiopia can be mainly attributed to rainfall patterns.

Sinana district is a small portions of Southern highlands of Bale zone in Ethiopia located at $6^0 50'$ N-$7^0 17'$ N and $40^0 06'$ E-$40^0 24'$ E. It extends from 1700 to 3100 mean above sea level (m.a.s.l). This district is under Indian Ocean influences as southerly fluxes generating rainfall when strong southerly moisture flow and easterly perturbation engulf. Rainfall patterns of the area also follow a bimodal distribution (NMSA, 1996). Agriculture is the main economic practices in the district, from which the majority of dwellers earn their livelihood income mainly from crop cultivation. Major crops grown in the district include wheat, barley, oat, maize, bean and peas (Bogale *et al.*, *2009).* Barley is practiced during *Kiremt,* the main rainy season (June to September), generally planted between mid-June and early July and harvested after mid-October. So far hardly any attempts have been made to investigate whether there exist any quantifiable relationship between barley yield and rainfall in Sinana district. The objectives of this study are, therefore, to identify the rainfall features and investigate its relationship with the yield of barley and to predict the future rainfall and analyze its impact on barley yields.

## MATERIAL AND METHODS

Barley production data for the period1995-2016 were obtained from Sinana District Agricultural Offices (SDAO) for the *Kiremt* season (JJAS). Rainfall data for Sinana meteorological stations for the same period were obtained from National Meteorological Agency of Ethiopia. Future rainfall data (2020-2049) for Sinana meteorological sites were downscaled from CSIRO-Mk 3.6.0 Atmosphere-Ocean GCM for RCP 8.5 emission scenarios of IPCC-AR5 using a web based software tool (http/

**Table 1:** Descriptive statistics of rainfall features and barley yield for Sinana

| Variables | Minimum | Maximum | Mean | SD | CV (%) |
|---|---|---|---|---|---|
| Onset date | June 3 | Sept. 14 | July 3 | 25 | 14.1 |
| End date | Oct. 25 | Dec. 11 | Nov. 19 | 15 | 4.7 |
| Length of growing period (Days) | 86 | 187 | 139 | 33.9 | 24.3 |
| *Kiremt* rainfall total (mm) | 217.4 | 854.0 | 440.9 | 189.0 | 42.9 |
| *Kiremt* rainy day | 18 | 94 | 60 | 18.9 | 31.6 |
| Total annual rainfall (mm) | 648.9 | 1073.8 | 838.7 | 110 | 13.2 |
| Barley yield ($qha^{-1}$) | 14.79 | 35.84 | 22.7 | 6.3 | 27.9 |

:WWW.MarksimGCMWeatherGenerator.Com). Marksim is a spatially explicit daily weather generator that uses a third order Markov chain process to generate daily rainfall.It requires geographical location to downscale and generate daily future data for a given site (Jones and Thornton, 2000).

### *Determination of rainfall features*

The onset date was determined when 20 mm of total rainfall is received over three consecutive days and not followed by dry spell of greater than 10 days after planting (Raman, 1974). On the other hand, the end of the rainy season was defined as any day after the first of September, when the soil water balance reaches zero (Stern and Coe,1982). In determining the end date, 3.4 mmday$^{-1}$ evapotranspiration of the study site and 100 mmm$^{-1}$ of the plant available soil water were considered. CROPWAT 8.0 software was used to calculate evapotranspiration. The duration of the rainy season was determined by counting the number of rainy days between the onset and the end date of the rainy season in a given time for the study area. The seasonal total rainfall from June to September (*kiremt*) was calculated. The number of rainy days was determined by counting the days having at least 0.3 mm of rainfall in 24 hours period.

### *Correlation and regression analysis*

The data of rainfall features and barley yields were subjected to statistical analysis. Standard deviation, mean and coefficient of variation were employed in investigating the variation. Correlation and multiple linear regression methods were used to establish the relationshipbetween rainfall features andbarley yields. Coefficients of multiple determinations ($R^2$) were used to select the best model. The selected model was used to ascertain the impact of future rainfall variability on barley yields, using projected rainfall for 2020-2049 period.

## RESULTS AND DISCUSSION

### *Variation in rainfall features and barley yield*

The descriptive statistics computed for rainfall characteristics and barley yield are shown in Table 1**.** The mean onset date for Sinana meteorological stations is July 3 with coefficient of variation (CV) of 14.1 per cent which agree with Segele and Lamb (2005) who had reported the mean date for the onset of the main rainy season (*kiremt*) for Robe and the surrounding including Sinanaas 1$^{st}$July. The mean end date was November 19 with CV of 4.7 per cent only which does not agree with the finding of Segele and Lamb (2005) who had reported the mean date of end of the main rainy season as October 28. This is due to the fact that after the end of the rainy season the soil is assumed to be a field capacity of 100 mm so for this study in determining the end date 3.4 mm evapotranspiration per day of the study area and 100 mm of the plant available soil water were considered which is used to state the end of the growing season (Sternand Coe,1982).The length of growing period which varied between 86 to 187 days during the study period, had CV of 24.3 per cent. The seasonal rainfall (*kiremt*) varied between 217.4 mm and 854.0 mm with mean total rainfall of 440.9 mm and CV of 42.9 per cent. The highest barley yield of 35.84 qha$^{-1}$ and the lowest of 14.79 qha$^{-1}$ with the mean yield of 22.7 qha$^{-1}$were reported during the study period **(**Table 1**)**.

### *Correlation and regression*

The correlation coefficients computed between barley yield and rainfall features for Sinana meteorological station showed that only *kiremt* rainfall (r=0.668**) had highly significant positive correlation with barley yield. The length of growing period (r= 0.324) and end date of the rainy season (r=0.241) had positive but non-significant correlations while *kiremt* rainy day (r=-0.095), onset date (r=-0.339) and annual rainfall (r=-0.060) had non-significant

**Table 2**: Correlations between rainfall features and barley yield in Sinana district

| S. No. | Rainfall features | Correlation coefficient (r) |
|---|---|---|
| 1 | Onset date | -0.339 |
| 2 | End date | 0.241 |
| 3 | Length of growing period | 0.324 |
| 4 | Seasonal (*kiremt*) rainfall | 0.668** |
| 5 | Rainy days | -0.095 |
| 6 | Annual rainfall | -0.060 |

**significant at the 0.01 level; *significant at the 0.01 level

**Table3:** Projected rainfall and per cent change in barley yield in Sinana district

| Years | Projected rainfall (mm) | Projected yield ($qha^{-1}$) | Percent change (%) |
|---|---|---|---|
| 2020 | 431.0 | 22.3 | -1.8 |
| 2030 | 402.9 | 21.7 | -4.4 |
| 2049 | 402.9 | 21.7 | -4.4 |

negative correlations with the barley yield (Table 2).In order to quantify physical relationship between rainfall features and barley yield the step wise regression analysis were carried out. Among all the equations developed, the only one with seasonal rainfall was found the best one having highest coefficient of determination, as given below;

$$Y = 12.811 + 0.022 {*}X \quad R^2 = 0.446^{**}$$
$$(2.66) \quad (0.006)$$

Where, Y is barley yield ($qha^{-1}$) and X is seasonal total rainfall (mm)

The above simple linear regression model represents that given a unit change in the *kiremt* rainfall ($X_1$), the yield of barley will change at the rate of 0.022$qha^{-1}$.These results show that among all the rainfall characteristics studied, the *kiremt* rainfall is the only one important variable that has significant impact on barley yield.The $R^2 = 0.446^{**}$ signifies that 44.6 per cent of the variation in the barley yields for the past 22 years in Sinana district is explained by *kiremt* rainfall. The remaining 55.4 per cent of the variation, however, could be explained by other climatic and non-climatic factors.

To study the impact of future rainfall on barley yield, the above regression model was used. Since the projected rainfall for years 2020, 2030 and 2049 were 431, 402.9 and 402.9 mm respectively, which were less than the present mean seasonal rainfall of 440.9 mm, the predicted barley yield were also less than the current mean yield of 22.7 $qha^{-1}$. The reduction in barley yield during 2020-2049 period would be between 1.8 to 4.4 per cent (Table 3). It is seen that in year 2030 and 2049, the projected rainfall and yield were same with highest reduction in yield of 4.4 per cent. Similar results in yield reduction were reported in Oromia Regional State and national level (Zerihun, 2012).

## CONCLUSION

The result showed that the seasonal (June to September) rainfall was highly variable and causes significant variation in barley yields. The *kiremt* rainfall alone explained 44.6 per cent variation in the yield in Sinana district. The projected rainfall for 2020-2049 showed decrease in rainfall in years 2020, 2030 and 2049, which is likely to reduce the barley yield by 1.8 to 4.4 per cent in Sinana district of Ethiopia.

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