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Agro Climatic Characterization of the Western Zone of Tigray Region, Humera

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Abstract
Climate characterization is very use full for understanding the current occurrence of the climate in the area for agricultural planning; therefore climate characterization of the western Tigray, Humera is very useful The main objectives of this work is to statistically investigate the climate characterization of the western part of the Tigray region. Climate of the study area was analyzed using Instat and Mann-Kendall software's. Using the observed climate data (1980 to 2009), the annual rainfall in the study area revealed a decreasing trend with an inter-annual variability of 16.7%. Of all the historical climate data (30 years), 70% of the onset date was on first week of June, while the cessation date was on September 15. The Markov chain first order model indicates that the probability of 7 and 12 days dry spell on May (80%) and September (90%) were very high. The mean minimum temperature ranges between 17.5^{0}C and 22.2^{0}C, while, the mean maximum temperature varies between 33^{0}C and 41.7^{0}C.
Keywords: Characterization, Mann-Kendall, Markov chain

1. Introduction

Changes in rainfall and temperature patterns are observed in many semi-arid parts of the developing world that are likely to become even hotter and dryer with time (Collier et al., 2008). Recent observational and modeling studies showed that the warmest temperature extremes, particularly those derived from minimum temperature, have significantly increased over the 20th century and will continue to increase throughout the 21st century.
Each year there are climatic events that represents risk to people and organization, these rise from normal day to day seasonal ,and year to year variability in climate as well as regional climate differences. Most organization has practice and strategies in place to deal with this routine climate variability. For these organizations, climate variability will continue to raise challenges and risk that have to be managed. However, when managing climate variability in the future, organization cannot simply rely on the assumption that the prevailing climate will be more or less the same as it was over the past fifty or hundred years (Ramakrishna et al., 2002).Therefore, characterizing the climate of the area is very important for agricultural planning

MATERIALS AND METHODS

THE STUDY AREA

Kafta Humera is located in the north-western Ethiopia and in the western part of Tigray Regional State (Figure 1) and 585km away from Mekelle and is located at 14^{o}15' latitude and 36^{o}37' longitude. Kafta Humera is bordered with "*Tsegede*" on the south and with Sudan in the west. In the north, the Tekeze River separates the district from Eritrea, in the east "Tahtay-Adiyabo" bordered with the district and in the southeast with "*Wolqayt*". The district covers an area of 632,877.75 ha which is about 23.6 percent of the western zone of Tigray.

Method of data analysis

Instat software was used to characterize the climate of the study area. Historical observations of temperature and rainfall data were mainly used to characterize the climate of the study area. The Data were generated following the first order Markov chain model using INSTAT plus (v3. 6) Software (Stern et al., 2006). Then, the generated data were checked for their physical representative of the respective site. INSTAT plus was also used to summarize the daily data into annual, monthly and seasonal totals and to analyze the onset and cessation of the rainy season and length of growing period (LGP). In this particular study, Mann-Kendall's test was employed. Mann-Kendall's test is a non-parametric method, which is less sensitive to outliers and test for a trend in a time series without specifying whether the trend is linear or nonlinear (Partal and Kahya, 2006).

Knowing Length of growing period is crucial for growing of different crops based on their maturity. According to Madeoye (1986) and Zargina (1987) the duration of the growing season can be determined by subtracting, the date at which the rain started from the date at which rainfall stopped for each year, The soil is assumed to be at field capacity of 100 mm on the last day of rain that is greater than 0.5 PET provided that the date is not proceeded by a dry spell (less than 1mm average daily rainfall) or more than five days (Benoit 1977; Stern et al., 1982). It is also assumed that the depletion of available soil moisture below 40% of its field capacity will cause rapid reduction in water availability to crops. Potential evapotranspiration is the amount of water that would evaporate from the soil surface and from plants when the soil is at field capacity while field capacity is the amount of water the soil holds after it has been saturated and then drained, until drainage virtually ceases. Actual evapotranspiration also becomes less than potential evapotranspiration when plant canopies do not totally cover the soil. Potential evapotranspiration is greatest in dry months with low humidity and predominantly clear skies and least in wet years with high humidity and cloudier-than-normal

To analysis the Number of rainy days and dry spell length from the definition of National Meteorological Service Agency of Ethiopia, we considered that a day as a rainy day if it accumulates 1 mm or more rainfall (NMSA, 2001).The number of rainy days was, therefore, counted starting from June 15 to September 15 (*Kiremt* season) in each year. Therefore, below this value was considered as dry spell. The probability of dry spell lengths of 7, 12, and 15 days during the growing season were determined using the Markov chain model to get an overview of dry spell risks during the crop growing period. Crop water requirement was determined from the interrelationships of the ET, soil type, bulk density of the soil, field capacity and permanent wilting point of the soil and the effective root zone. The crop ET (ETC) was estimated by FAO Penman-Monteith equation (FAO, 1992)

Etc = K C x ETO ____eq. 1

The crop water requirement of sesame crop was determined by using 30-year climatic data in CROPWAT 8. The Reference crop evapotranspiration (ETo) was determined using the FAO Penman Monteith method. For this crop we were considered that four season stages like initial stage, development stage, mid-season and late season.

RESULT AND DISCUSSION

Rainfall

The study area receives an average rainfall ranging from 400 to 650mm. Long term average rainfall (31 years) result indicates that the rainfall reaches its peak on July and August (figure 3).

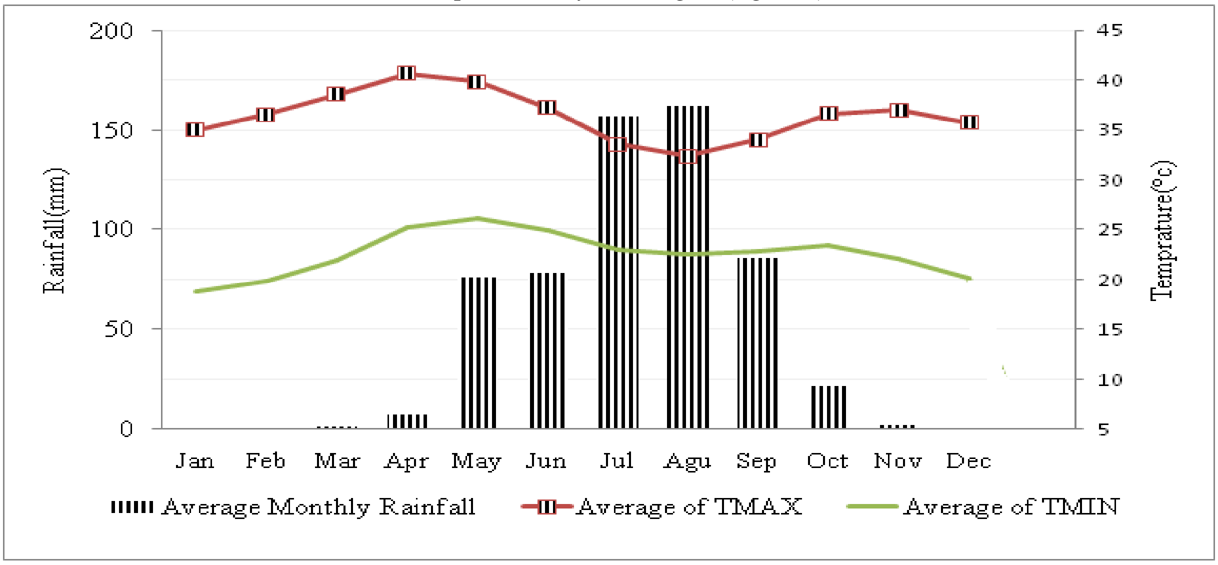

Figure 1: The long term average rainfall and temperature (31 years) for Humera site

Rainfall in the study area is generally characterized by low inter annual and seasonal variability. In the study areas mean of rainfall is 540.6 and varies from 357.8mm and 650mm minimum and maximum respectively. The median rainfall of the study area is 549.5mm annually and the coefficient of variation (CV) of the annual rainfall was low (16.7 %) implying the less variability of rainfall. On average the main rainy season (85%) contributes largely to the annual rainfall totals. The Mann–Kendall trend test had indicated an increasing trend of both the annual and seasonal rainfall (ZMK=0.65ns with a slop of 1.508).This result agrees with the findings of Hadgu et al. (2013) at Adigrat station.

Temperature Pattern

Thirty years (1980-2009) historical data were used to characterize the temperature of the study area. The minimum annual temperature varies from a maximum 22.2 ^{O}C to a minimum of 17.5 ^{O}C with a mean of 22.6 ^{O}C. The maximum annual temperature also varies from a maximum of 41.7^{O}C to a minimum of 33^{O}C with a mean of 36.52 ^{O}C. The coefficient of variations for the maximum and minimum temperatures was 1.8% and 2.3%, respectively which implies that the maximum temperature is less variable than the minimum temperature. Temperatures rise to an average 42 degrees Celsius between April and June and fall to between 25 and 35 degrees Celsius during the moderate months between June and February. The standard deviation of the maximum and minimum temprature is 0.66 and 0.52, respectivley. This indicates that there is less variablity between the months.The average yearly maximum temperature of the study area over the past 30 years has increased by about 0.035 ^{0}c annually, while the minimum temperature has increased by about 0.034 ^{0}c. The trend shows that, the maximum temperature as well as the minimum temprature of the study area revealed an increasing trend.

Evapotranspiration and effective rainfall

According to Michael (1999), water is important for plant growth and food production and there is competition between municipal, industry users and agriculture for the finite amount of available water, estimating irrigation water requirements accurately is important for water project planning and management. When precipitation is insufficient, irrigation is needed to apply water to meet the crop evapotranspiration. The available water is crucial for the economy, health and welfare of a very large part of the developing world. Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime,

Water requirements of crops depend mainly on environmental conditions. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Different crops have different water requirements, under the same weather conditions (Broner and Schneekloth 2003).

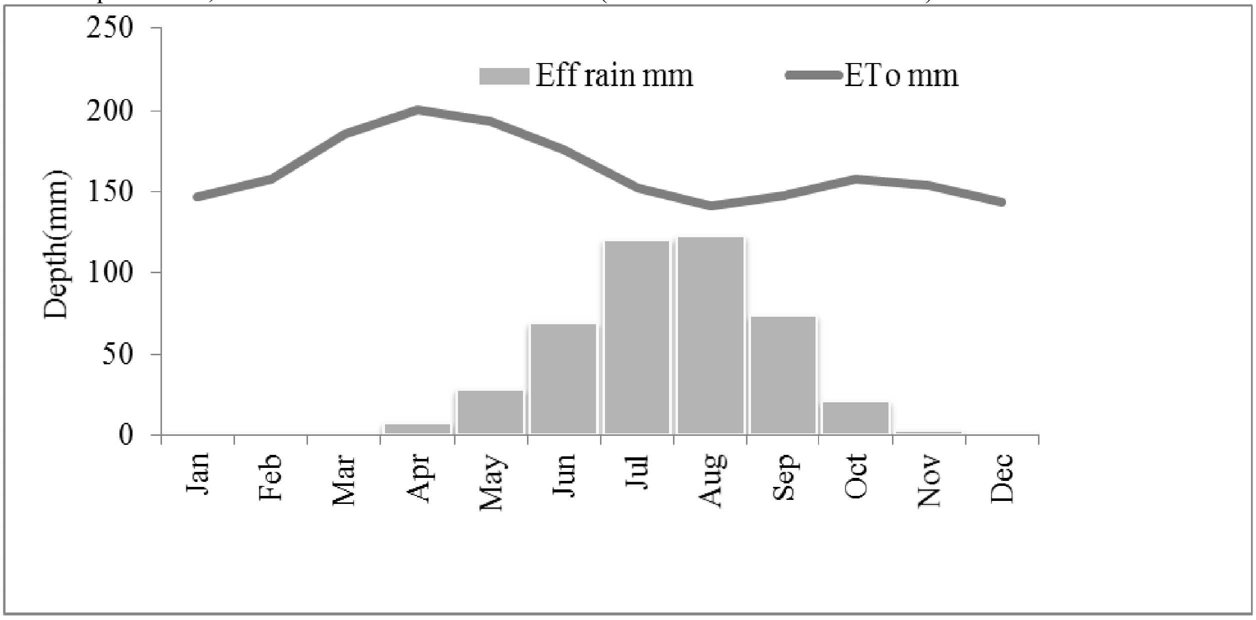

Figure 2: Monthly rainfall, evapotranspiration and Effective rainfall of the study area

Mean monthly evapotranspiration rate of the study area ranged between 141.6 and 200.7 mm/month, April (200.7 mm) and December (144 mm) being the highest and lowest, respectively (Figure 5). During this time, the annual mean monthly rainfall varies between 78.8 mm to 167.7 mm. The total mean seasonal rainfall for the growing season (JJAS) was 558.6 mm whereas the total seasonal evapotranspiration for the main growing season was 617.71mm.The monthly evapotranspiration of September, October and January was similar. In the study area, we observe that, the monthly evapotranspiration is higher in the dry months, indicating that there is high temperature in these months whereas the evapotranspiration during the rainy months was relatively low due to the effect of cloud.

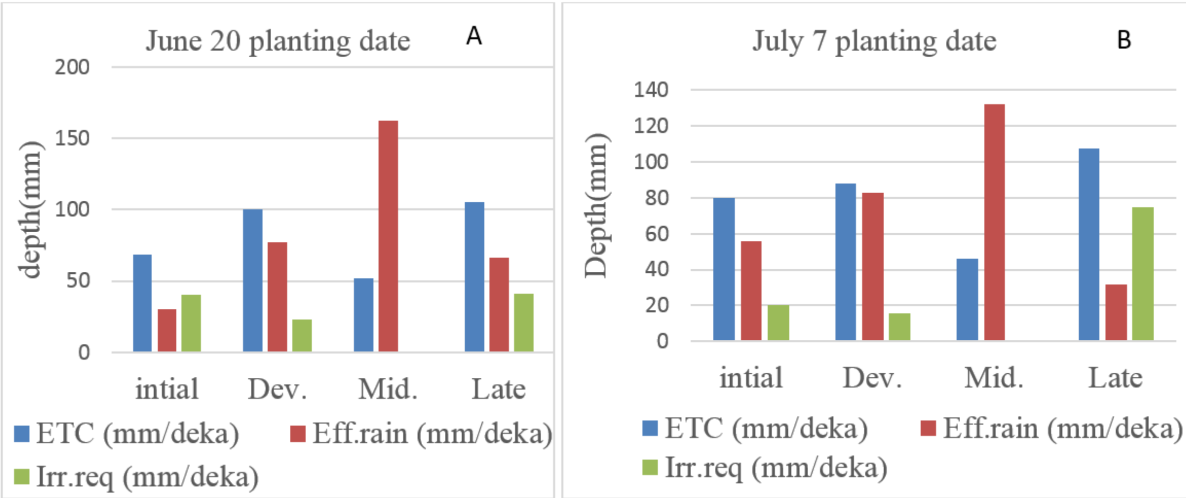

Figure 3: Crop water requirement, effective rainfall and irrigation requirement of each sesame growth stages
Where: (A) Early planting and (B) Normal planting

The sesame water requirement is the highest in the same sub periods at development/flotation phase on which major irrigation volumes required. The highest crop evapo transpiration (ETc) values during the development phases can be explained by the fact that the maximum water absorption occurs at flowering. ETc decreases at the end of the cycle., this is because due to leaves senescence, reducing the leaf area and, thus the exposed area to transpiration (Lima et al., 2006)

The most determinant influencing factor for yield of sesame was effective rainfall, although in the analysis we observed that the effective rainfall was very less variable across the different planting dates. The irrigation requirement across the different planting dates for early, normal and late planting dates were 66.2, 35.8 and 80.5 mm, respectively. This pointed out that normal planting seems advantageous in terms of less irrigation demand compared to the other planting dates. The water requirement of crops varies along their growth stages. Hence, what matters for yield may not be the total amount of rainfall in the growing period, but it is the distribution of the rainfall throughout the critical growth stages of the crop (sesame).The most critical growth stages of most crops are mid and development growth stages. Therefore, if the crop water requirement is not fulfilled in the mid growth stage, there will be more likely to decrease the yield.

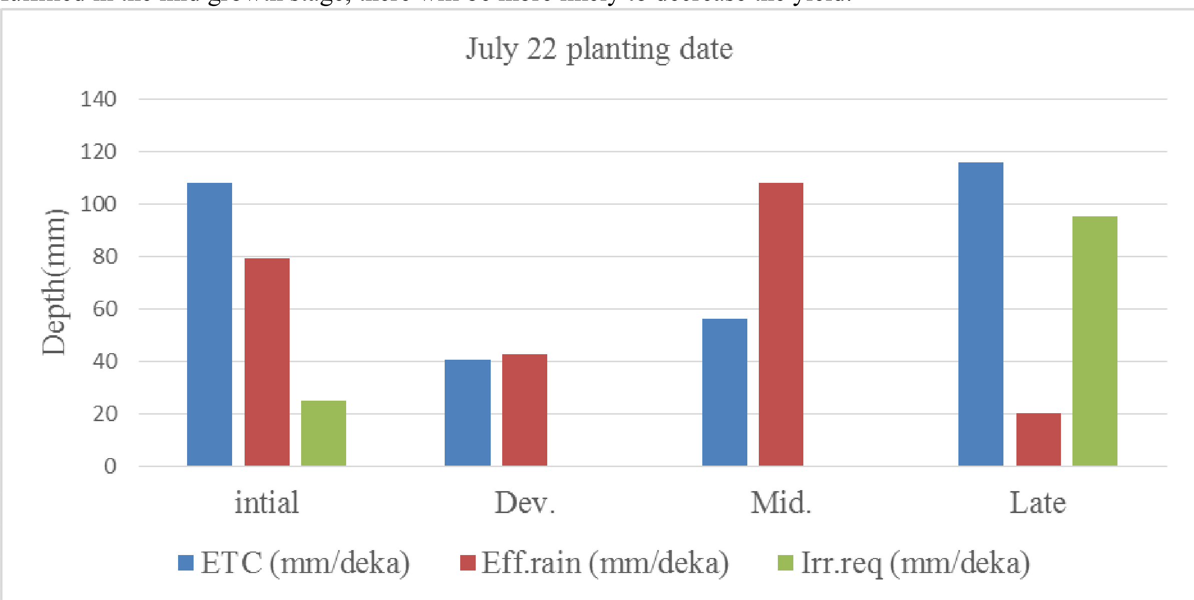

Figure 4: Crop water requirement, effective rainfall and irrigation requirement of each sesame growth stages

Onset and cessation

The onset date of the study area over the last 30 years indicated that the median onset of *Kiremt* rainfall was on the first week of June (Table 1). It was also characterized with a large standard deviation (SD=13 days). This implies that patterns couldn't be easily be understood and consequently decisions pertaining to crop planting and related activities should be taken with great care. Furthermore, the result also indicated that the onset date in the last 31 years was not significantly changed. Inline to this Hadgu et al. (2013) also stated that the trend was not significantly altered particularly at Alamata and Edagahamus.

The cessation of Kiremt rainfall starting from the second week of September as indicated in (Table 1) (Araya and Stroosnijder 2011) have also reported similar findings in northern Ethiopia. The median date of the cessation of the Kiremt season was characterized by low standard deviation (<5 days). Hadgu et al, (2013) also discussed similar result for Adigudom, Mekelle and Adigrat. In the study area sesame is grown under rainfed condition. Length of growing period (LGP) of the area varies from 52 days (minimum) to 120 days (maximum) with a median of 88 days. The coefficient of variation (18.2%) which is less interannual variability in the length of growing period and help to plan the type of crops grown based on their maturity period. Besides, the LGP of the study area has shown significantly (p=0.05) decreasing trend in the thirty years (Table 1).

Table 1: Statistical characteristics and trends of onset, cessation and LGP over the period 1980-2009 in Western Tigray

Rainfall characteristics	Statistics					
	Mean	SD	Median	CV	Slope	ZMK
Onset date (DOY)	162.35	13.21	177	7.4	0.091	1.5
Cessation date (DOY)	257.74	5.1352	264	1.9	0.039	0.88
LGP (days)	95.387	15.818	88	18.2	-0.045	-0.39
Annual Rainfall (mm)	540.6	90.509	549.5	16.7	0.0	1.14

ZMK is Mann–Kendall trend test, Slope (Sen's slope) is the change (days)/annual; **,* is statistically significant at 0.05 and 0.1 probability level; ns is non-significant trend at 0.1; SD is standard deviation; CV is coefficient of variation.

Length of growing period (LGP)

As the pattern of rainfall in the study area is uni-modal, the length of growing period is from 1st June to mid of September (figure 9). According to the definition of LGP from the rainfall and potential evapotranspiration relationship point of view, mid June, July, August and the first decade of September were the months that the rainfall exceeds half of the evapotranspiration and hence, considered as the growing months (Figure 9). In the remaining months, particularly April and May the evapotranspiration exceeds rainfall.

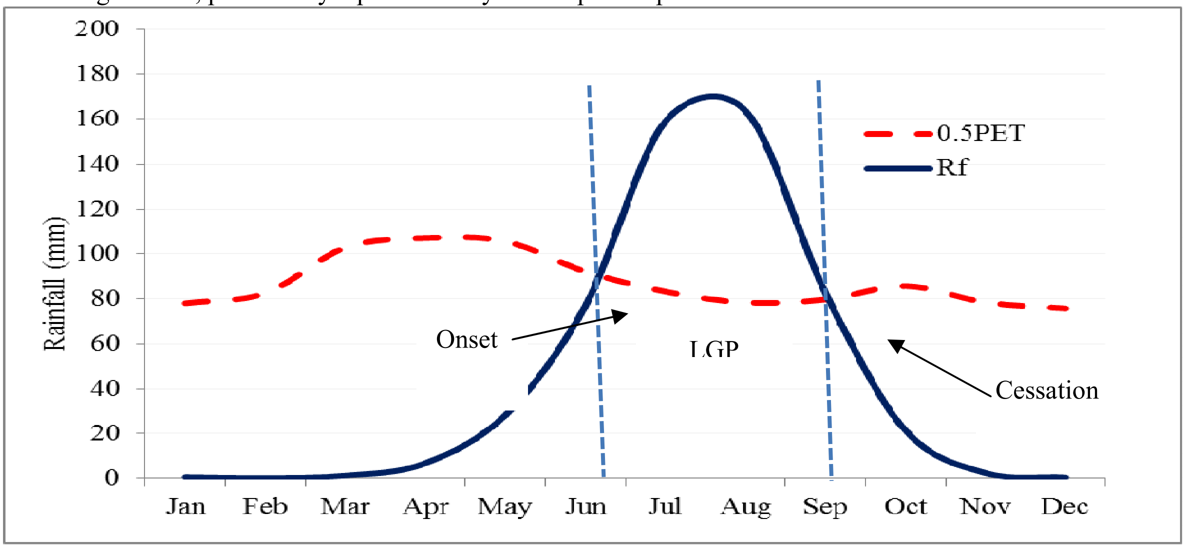

Figure 5: Length of growing period determined from rainfall –potential evapotranspiration of the study area

Number of rainy days and dry spell length

Accordingly, maximum number of rainy days and dry spell length was observed in *Kiremt* season from the period of 1980-2009. The number of rainy days observed in the given duration varied from 34 to 80 with the mean average of 55.774 .The inter annual variability of number of rainy days have shown moderate variability (CV=23.2%).

Sesame production is particularly related to the Kiremt rainfall as this crop is highly sensitive to water stress. For this reason, the crop needs a great attention in selecting the appropriate sowing date in order to avoid the long dry spells during the flowering stage and reduce the possible negative impacts. The average length of dry spell during the *kiremt* season over the study area was too short (Figure 10). We considered that a threshold value of greater or equal to 0.85 mm was as a rainy day and all below this value was as dry spell. The probability of dry spell lengths of 7, 12, and 17 days during the growing season were determined using the Markov chain model to get an overview of dry spell risks during the crop growing period. The probability of being 7 days dry spell is about 80% in May and around 90% in September. The probability of occurrence of 12 days dry spell is

30% in mid may, while its 50% in November. The probability of 17 days dry spell occurrence is very small, it is about 10% in first may and accompanied by 20% in the end of October (Figure 10).

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