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Variability of Rainfall Features and it's Implication on Long Season Growing Crops at Alamata Wereda, Northern Ethiopia

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ABSTRACT

Assessment of climate variability at local level, where the driver of the economy is agriculture, has enormous advantage in Ethiopia, . This study was then initiated to analyze the variability of rainfall features and their likely implications on long season growing crop; sorghum in *Alamata Wereda*. Daily climate data was obtained from the National Meteorological Agency of Ethiopia (NMA) and the historical temporal variability of the rainfall features was assessed using Instat and Mann-Kendall statistical softwares. Apart from the interannual variability (26.2%), the annual rainfall has also revealed a decreasing trend. Similarly, the *Belg (FMAM)* rainfall demonstrated a significant decreasing trend with a very high seasonal variability (53.1%). The Markov chain first order model indicates that the probability of 15 and 20 days consecutive dry spell occurrence on May (90%) and June (75%) were very high signaling that sowing on these months could possibly lead to complete or partial failure of seedling establishments. Even though the correlations between yield and monthly rainfalls was positive, only April (r=0.48) and September (r=0.55) rainfall was statistically significant. This indicates that for sorghum production, rainfall during April (for seedling establishment) and September (grain filling) appears to be particularly important (sensitive). Hence, as there is early cessation and high rainfall variability during the *Belg* season (part of sowing period for sorghum), different adaptation strategies such as soil moisture conservation and early maturing cultivars should be practiced to minimize the impact of rainfall variability on sorghum production.

Introduction

There is a growing consensus in the scientific literature that over the coming decades, higher temperature and changing precipitation levels caused by climate change will depress crop yields in many countries (Orindi et al., 2006). This is particularly crucial in low-income countries, where adaptive capacity is perceived to be low (IPCC, 2007). The sensitivity, adaptive capacity and degree of exposure make it agricultural production vulnerable to climate impacts (IPCC, 2001). Besides, 89% of cereals in sub-Saharan Africa are rainfed (Cooper, 2004) that makes climate a key driver of food security (Verdin et al., 2005) in the region. Many African countries, which have economies largely based on weather-sensitive agricultural production, are particularly vulnerable to climate change (IPCC, 2007). For many poor countries that are highly vulnerable to the effects of climate change, understanding farmers' responses to climatic variation is crucial in designing appropriate coping strategies to climate change (Ringler, 2011).

Agriculture is the source of livelihood to majority of the Ethiopian population and is the basis of the national economy, where small-scale subsistence farming is predominant. This sector employs more than 80% of the labor force and accounts for 45% of the GDP and 85% of the export revenue (MoFED, 2006). Ethiopian agriculture is heavily dependent on rainfall, with irrigation agriculture accounting for less than 1% of the country's total cultivated land. The amount and temporal distribution of rainfall and other climatic factors during the growing season are critical to crop yields and can induce food shortages and famine. Ethiopia has suffered from periodical extreme climate events, manifested in the form of frequent drought in 1965, 1974, 1983, 1984, 1987, 1990, 1991, 1999, 2000, 2002, and 2011 years (Salvatore et al., 2011).

Owing to various biotic and abiotic production constraints, the productivity of sorghum in Ethiopia is low (1.5 t/ha). Drought, low soil fertility (nutrient deficiency), stem borers, shoot fly, birds, *Striga*, and other weeds are recognized as major production constraints in Eastern Africa (Wortmann et al., 2006). In Ethiopia, drought and *Striga* were found to be very important in north and north eastern parts of the country (Wortmann et al., 2006). Research has also shown that moisture deficit during grain filling is most important for Ethiopia. In Ethiopia, where more than 50% of the total area is semi-arid, insufficient, unevenly distributed and unpredictable rainfall is usually experienced in drier parts of the country (Gamachu, 1977). Hence, this study was designed to evaluate the implications of rainfall features variability on production of sorghum bicolor L. Moench in *Alamata* wereda.

Materials and Methods

Area Description

Alamata wereda is located at 12°15'N and 39°35'E which is about 600 km north of *Addis Abeba* and180 km south of the *Tigray* Regional capital city, *Mekelle*. According to office of land use and administration of the *Wereda*, the total area of the *Wereda* is about 75,618.7 hectare and of this, 49% is

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cultivable, 34.4% forest area and 6.3% are miscellaneous land. *Gratkahsu*, "the state forest" is found in this *Wereda* with 2600 hectare of estimated area. Majority of *Alamata* land mass is situated in the lowlands (Fig.2) where flood water deposits a huge amount of silt from the surrounding mountains. As a result, fertile soils in the bottom lands of *Alamata* are being silted, affecting productivity of many farmlands.

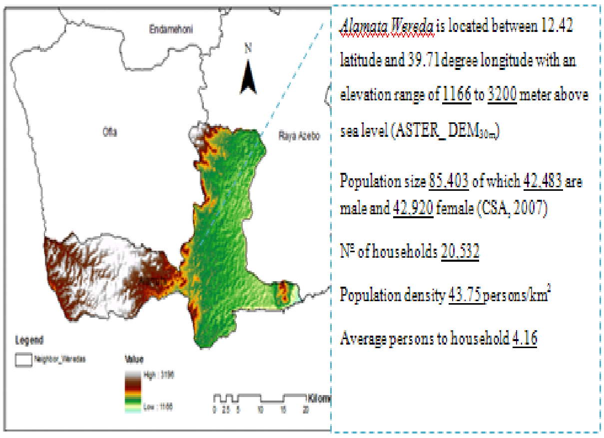

Figure 1. Map of the study area, *Alamata* Wereda (Masked from ASTER_DEM30m)

Although use of flood water as a source of spate irrigation is common, when the intensity of the floods increase a significant amount of farmlands becomes out of production. Even with these and other challenges, *Alamata* is one of the most agriculturally potential areas in the Region. Farmers in the *Wereda* extensively cultivate cereals, vegetables and rear mainly sheep and cattle in the valley. The surrounding mountains in the *wereda* are potential source of runoff to the *Alamata* valley substantially important for crop growth using irrigation. The major crops grown are sorghum and maize in the lowland areas and wheat, barley and pulses in the highland part of the *wereda*. Shortage of rainfall (moisture stress) is a major constraint of agricultural production in the *Wereda*.

According to the IPMS (2008) reports, Eutric Vertisols, Lithic Leptosols (Cambic) and Lithic Leptosols (Orthic) are the soil types covering nearly100% of the land in the wereda. The soil for majority of the valley bottom is Vertisols. Traditionally, fertility of the soils on the plains is believed to be fertile because of the silt coming from the adjacent mountains. However, previous studies by the Raya Valley Project indicate that soil fertility is low. The mountains in the western and northern parts of the valley are believed to be the major sources of alluvial soil because of relatively higher rainfall in these areas. In the study area, altitude and rainfall increase from south to north and east to west. Soil pH for profiles tested by Relief Society of Tigray from the valley bottoms indicate that it ranges from 7.4 to 8.5 and was reported to increase with depth.

Data collection and analysis

To undertake this research necessary secondary data such as grain yield and other management activities of sorghum was collected from *Alamata* agricultural office and the research center. Besides, observed daily rainfall and temperature data (1980-2012) was obtained from the Ethiopian National Metrological Agency (NMA). A complete set of daily weather data (1980-2010) i.e. rainfall, maximum and minimum temperature was obtained from the global bias shifted modern era retrospective analysis for research and applications (MERRA) dataset to fill some missed observed climate data. Simple interpolations were also used to fill short data gaps from neighboring good values (free of strong outliers) on either side. Instat climate soft ware was used to determine the onset, cessation, number of rainy days, length of growing period, dry spell, annual and seasonal amount of rainfall of the study area. April first was used to determine the onset date of rainfall, when 20 mm of rainfall running over three consecutive days as well as no dry spell longer than 9 days over the next 21 days from start of rainy season was used particularly for long season growing crops like sorghum to assess the risk of crop failure due to false onset dates. Various authors used similar criteria in assessing the start of the growing season (Mamo, 2005). End of rainy season was considered any day after September five when soil water balance fall below half (50%). The soil water holding capacity was considered to be 100 mm/m. The minimum threshold value of rainfall used was 0.85 mm and below this it was considered as part of dry spell. The length of growing period was computed from the distance between the onset and cessation date of rainfall. Mann Kendall test which is the distribution free non parametric test was used to detect the trend of the different rainfall features. Moreover, the Sen's test was used to evaluate for the magnitude of the change.

Result and Discussion

Annual and Seasonal Rainfall Variability

The average annual rainfall of *Alamata wereda* varies from190 mm to about 1060 mm. The median rainfall was 762.8 mm annually with coefficient of variation (CV) of 26.2 % (Table1) which was similar to the region (28%), while in contrast to 8% nationally (Warren and Khogali, 1992). Comparing the seasonal rainfall variability of the area, *Belg* (CV=53.1%) and *meher* (CV=47.1%) rainfall were highly variable than the annual (CV=26.2%) rainfall (Table1). Hadgu et al. (2013) has also reported similar results in the same area. Considering the direct effect of *Meher* rainfall on agricultural production, high variability could tremendously affect the livelihood of the farming community in the area. For *Meher* season, the rainfall varies from 49 mm to 765 mm with a median of 370 mm. The long term rainfall data of this season demonstrates, there was a significant (p=0.05) increasing trend of rainfall. However, in the last (current) two decades, the total annual rainfall has indicated a significantly (p=0.01) decreasing trend (Table 3) from its previous decades. In the *Belg* season the rainfall varies from 31 mm to 615 mm with a median of 265 mm. The coefficient of variation of this season was very large (53.1%) similar to the *Meher* (47.1%) rainfall.

Apart from its high variability, the *Belg* rainfall has also shown a significant (p=0.05) decreasing trend in the 2nd and the last current two decades. The amount of rainfall for *Belg* (r=0.8) and *Meher* (r=0.4) seasons was positively correlated (Spearman's) with their number of rainy days, however, neither of the correlations, *Belg* (p=0.2) and *Meher* (p=0.6) was significant. This explains the amount of rainfall in the area was not necessarily dependent on number of rainy days, but its intensity seems to be what matters. According to the 33 years analyzed climate data and even farmers response, the worst historically observed drought year in the *Wereda* was in 1984 followed by 2009 with an annual rainfall of 193 mm and 286 mm respectively. Even though it was not statistically significant, the total annual rainfall generally indicates a decreasing trend. Rainfall in the study area was generally low with manifestations of high seasonal variability than the interannual variability.

Table 1. Descriptive statistics of important rainfall features of *Alamata Wereda*

Summarized descriptive statistics of important rainfall features								
Rainfall features	**Mean**	**Min**	**LQU**	**Median**	**UQU**	**Max**	**Std Dev**	**CV (%)**
JJAS (mm)	372.3	49	231.3	369.7	472.7	764.7	175.5	47.1
FMAM (mm)	257	30.6	148.3	264.5	334.8	612.7	136.3	53.1
JOND (mm)	102.3	13.7	31.3	85.7	138.3	376.7	84.7	82.7
Annual (mm)	731.6	193.1	632.2	762.8	871.6	1063	191.7	26.2
Cessation Date (DOY)	262.4	249	253.5	263	269.5	278	9.6	3.7
Onset date (DOY)	135.3	92	98	107	195	229	47.4	35.1
LGP (Days)	127.1	25	71.5	155	166.5	180	48.6	38.2
Rainy Days	56.6	11	44	59	64	112	21.1	37.3

Where: The JJAS stands for June, July, August and September, FMAM for February, March, April, May and JOND stands for January, October, November and December, while LGP refers to length of growing periods

Table 2. Correlation of yield with annual, seasonal and monthly rainfall (mm)

	Annual	**Belg**	**Kiremt**	**April**	**Sep**
Yield	.564**	0.34	0.29	.479**	.552**
Sig.(2-tailed)	0.001	0.07	0.12	0.01	0.00

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Annual and decadal trend of the rainfall of Alamata Wereda

	Mann-Kendall trend Z test and Sen's slope of rainfall				
Time series	**Annual (1980-2012)**	**1st Decade**	**2nd Decade**	**3rd Decade**	**Last_2Decades**
RF Total	-0.3	1.4	1.3	-1.2	-2.7**
Slope	-0.8	35.8	22.0	-16.4	-14.7
Meher	2.2*	1.9+	1.6	-0.3	-0.6
Slope	7.7	31.1	43.0	-3.4	-1.9
Belg	-2.6*	1.1	-2.1*	-0.8	-1.6*
Slope	-6.6	7.8	-34.7	-8.7	-8.0
Bega	-0.3	-0.3	0.7	-0.3	-1.5
Slope	-0.4	-3.9	12.5	-1.6	-5.1
Rainy days	-0.3	1.4	1.3	-1.2	-2.7**
Slope	-0.8	35.8	22.0	-16.4	-14.7
Onset date	1.9+	0.0	0.5	2.1*	1.5
Slope	0.7	0.0	0.9	7.0	1.0
Cessation date	0.8	1.3	1.1	-0.7	-1.6
Slope	0.2	1.6	1.5	-0.5	-0.5
LGP	-1.2	0.6	0.5	-2.1*	-2.0*
Slope	-0.7	1.7	1.1	-8.9	-1.4

First, second, third and last two decades represents 1980_1990, 1991_2000, 2001_2009 and 1991_2009 respectively. The symbols (*), (**) and (+) are used to indicate the significance level of the trend at 0.05, 0.01 and 0.1 levels respectively and LGP represents length of growing period respectively.

Table 4. Monthly rainfall trend analysis using Mann-Kendall Z test and Sen's slope estimation

	Mann-Kendall trend Z test and Sen's slope estimation of monthly rainfall									
	1st Decade		**2nd Decade**		**3rd Decade**		**Last two Decades**		**Annual**	
Months	Z test	Slope	Z test	slope	Z test	slope	Z test	slope	Z test	Slope
January	-0.4	-0.3	0.1	0.0	-1.8+	-4.4	-1.4	-0.9	-0.3	0
February	-0.5	-2.9	-1.9+	-11.6	-0.4	0.0	-1.5	0.0	3.4***	-2.3
March	0.2	1.3	-1.6	-7.8	-0.5	-2.4	-1.2	-2.2	-0.7	-1.1
April	1.7+	6.4	-1.1	-9.8	-1.0	-8.2	-0.7	-1.3	-1.0	-0.9
May	0.3	2.4	-0.9	-3.7	-0.4	-0.8	-2.0*	-1.8	-1.7+	-0.9
June	0.4	0.0	0.4	0.0	-1.1	-0.9	0.3	0.0	1.1	0.0
July	1.6	8.9	1.6	16.7	0.9	5.5	1.2	2.3	3.5***	4.1
August	1.9+	12.5	2.0*	26.6	-0.5	-5.0	-0.4	-1.0	2.1*	3.5
September	2.0+	4.6	-0.7	-1.4	-0.7	-2.3	-3.5***	-3.1	-0.9	-0.4
October	-0.5	-1.2	0.4	0.8	-0.4	-0.1	-1.8+	-0.8	-0.7	-0.1
November	-2.8**	-2.0	0.4	0.0	1.6	3.8	0.6	0.0	0.7	0.0
December	0.2	0.4	-1.5	-1.1	-1.8+	-2.4	-1.6	-0.2	-2.2*	-0.4

*NB: ** Indicates level of significance at 0.01 while single if for 0.05.*

On average the main rainy season (51%) contributes largely to the annual rainfall totals. *Belg* rainfall (35%) also makes a considerable contribution to the annual rainfall totals while the remaining (14%) was from the *Bega* (dry season). This demonstrates how the declining trend of *Belg* rainfall could be serious, particularly for long season growing crops like sorghum.

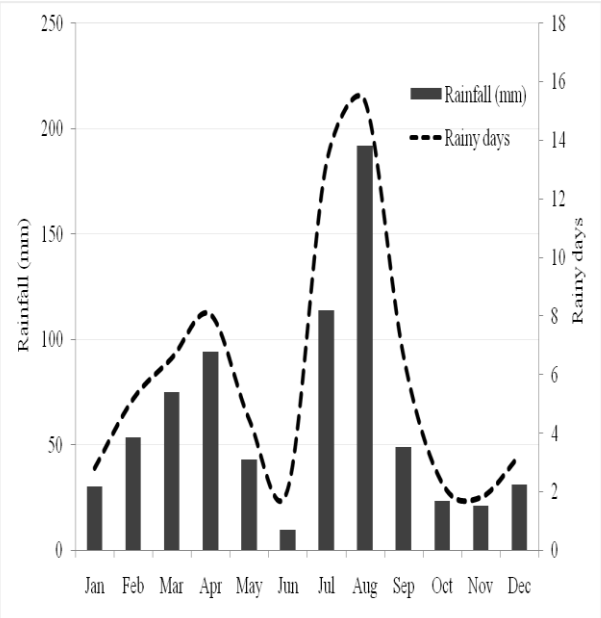

Figure 2. Long term mean monthly rainfall and rainy days

The long term average result indicates that during the *Belg* season, the rainfall reaches its peak on April while in August for *Meher* Season (Figure 2). Rainfall in *Alamata* was erratic with recurrent drought and rainfall failure especially in the *Belg* season has become common. Besides, the inter-seasonal rainfall variation was large. The correlation between amount of rainfall and number of rainy days in the *Belg* season was higher than (r=0.8) the *Meher* season (r=0.4). That is, the distribution of rainfall amount per day was uniform in *Belg* than *Meher.* The numbers of rainy days were high in July and August but the amount of rainfall was low while the reverse happens in September with few rainy days. Therefore, the rainfall intensity was high in September that leads to runoff without giving time to infiltration and hence, here is the key that we should do something. Constructing of different water harvesting structures could be very important for supplementary irrigation of crops at their critical growth stages. The number of rainy days was significantly (p=0.01) in a decreasing trend in the last two decades (Table 3), which was similar to the total annual amount of rainfall during that period and this demonstrate the direct relationship of rainy days with total amount of rainfall. The number of rainy days varies from 15 to 100 with a median of 71 days. The coefficient of variation (31.2%) of rainy days was high which reveals the interannual variability of rainy days in the area.

Onset and Cessation of rainfall

Analysing and determining the most frequent onset and cessation of rainfall using observed long term climate data is crucial to prepare and decide the appropriate sowing time with a minimum possible risk. The *Meher* onset of rainfall varies from July11 to August 19 and the median was on July 14 and this was similar to Araya (2011) findings (11-20 July) as normal sowing date in the same area. Abebe (2006) also similarly discussed the median onset of *Meher* rainfall was in the first week of July. The standard deviation for onset of rainfall was 12 days. Abebe (2006) and Hadgu et al., (2013) also indicated similar values (> 10 days of standard deviation) for *Alamata* and *Edagahamus Wereda*'s. On top of this, the coefficient of variation (5.8%) was small, which implies patterns could easily be understood for undertaking cropping decisions of this season. In the *Belg* season, the start of rainfall varies from March 17 (earliest) to May 8 (late) with a median of 107 day of the year. The coefficient of variation of *Belg* rainfall (14.3%) onset was large compare to the *Meher* onset of rainfall (5.8%). Despite the variability of the *Belg* rainfall, the onset date of this season has significantly (p=0.05) shifted to the *Meher* onset dates in the last decade (2000 -2012).

The median rainfall onset was at 107 day of the year for *Belg* crops like sorghum while it was on 195 day of the year for *Meher* crops. However, to decide the most appropriate sowing date based on the rainfall onset date, analyzing the occurrence of different dry spell lengths and frequency of onset by month is very important. From the analysis of historical years of rainfall data, 60.6% of onset date was between 90 and 120 days of the year (i.e. on April month). On the other hand, 30.3% of the onset date was between 180 and 210 days of the year (i.e. on July) while the remaining 9% was in March and August (Figure 3). This demonstrates that the onset of rainfall for the *Belg* and *Meher* season were in the first and second decade of April and July respectively.

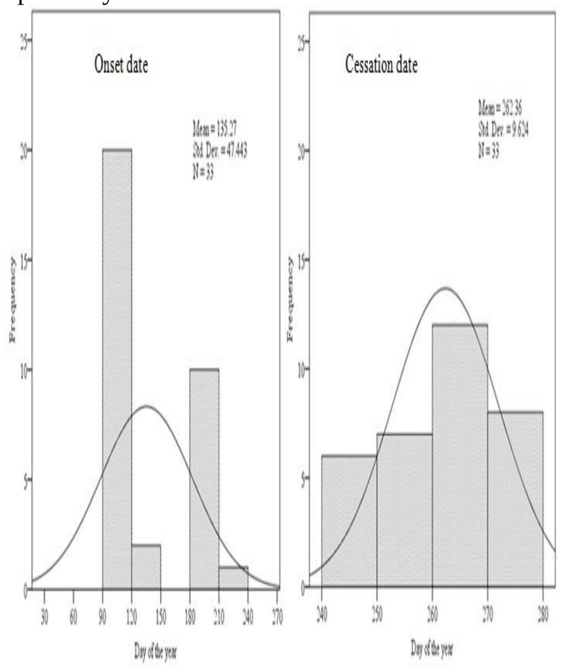

Figure 3. Distribution of onset and cessation dates of rainfall by day of the year (DOY)

The end of rainfall for *Alamata Wereda* ranges from September 5 (earliest cessation) to October 4 (late cessation) with a median cessation date on September 19. Similarly, Araya (2011) reported the most frequent cessation date between1 and 10 September in the same area.

This variability of cessation date was similar to the studies of Hadgu et al. (2013) at Edagahamus (first week of September) and Mekelle (first week of October). The median cessation date was characterized by low standard deviation (9.6 days) which was similar to the results at Adigudom, Mekelle and Adigrat (<10 days) and hence, the end of rainy season in this area was relatively stable compared to its onset date. However, it was in contrast to Hadgu et al. (2013) results at *Alamata* that showed high standard deviation (about 20 days). This difference may be due to the difference in setting of cessation rules. In the last decade, the cessation date has decreased from the previous years and indicates the shrinking of length of growing period which threatens the long season growing crops. In 76% of the years (i.e. in 25 years) the cessation of rainfall lays between 240 and 270 days of the year (i.e. on September), while in the remaining eight years (24%) the cessation date was in the first decade of October (Figure 3).

Length of growing period

Even though, what controls is climate particularly rainfall, each crop and even variety has almost a specific length of growing period requirements. Length of growing period (LGP) refers to a continuous period within a year in which neither temperature nor water makes crop growth impossible. Sorghum is mostly sown at *Belg* (locally known as *Azmera*) and hence, its LGP is longer than many crops. The LGP of the area varies from 25 days to 180 days and the median was 155 days. The coefficient of variation (38.1%) was high which reveals the interannual variability in length of growing period. The high interannual variability in length of growing period was due to the variability of *Belg* rainfall onsets. There was a very strong correlation (r=0.98) between the onset of rainfall and length of growing period which reveals, when the rainfall starts early there has been longer growing seasons and vice versa.

Knowing Length of growing period is crucial for growing of different crops based on their maturity, nonetheless, this high variability puts sowing date to be compounded by risk. Besides, the LGP of the study area has revealed a significantly (p=0.05) decreasing trend in both the third and last two current decades of the thirty three years (Table 3) and this was happened due to the threatening and shifts in onset date of rainfall at *Belg* season. More to the point, the amount of rainfall for September (p=0.01) and May (p=0.05) has significantly reduced in the last two current decades of the years (Table 3) which this shortens the growing season of sorghum. To the other side, a significant increase of annual rainfall of July (p=0.01) and August (p=0.05) was observed while decreasing in February (p=0.01). For *Meher* season the LGP varies from 21 to 79 days with a median of 55 days. The standard deviation (16 days) and coefficient of variation (29.8%) were similar to Abebe (2006) findings in *Alamata (28%) and Edagahamus (29%)*.

Length of dry spells

Daily rainfall data for each year were fitted to a simple Markov chain first order model and assessed the chance of rain given the previous day was dry, i.e. the chance that a dry spell continues, and also the chance of rain given the previous day was rainy, i.e. the chance that a rain spell continues. A threshold value of greater or equal to 0.85mm was considered as a rainy day and all below this value was considered as dry spell. The probability of dry spell lengths of 5, 10, 15 and 20 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 (Figure 4).

From the analysis of the dry spell events, the occurrence of 5 days dry spell was almost 100% in all months except in August which reduces the probability to 70% (Figure 4). The probability of being 10 days dry spell was similarly about 100% in February, May and June months. However, the probability of the same event was below 10% in August and about 65% for March and April. There was no probability of 15 days dry spell occurrences particularly in August while about 30% in March and April months. To the other side, occurrence of this event was about 90% in May and June months. The probability of 20 days dry spell occurrence was none in August while about 10% for March and April months. Nonetheless, the occurrence of this event was very high (about 75%) in the February, May and June months.

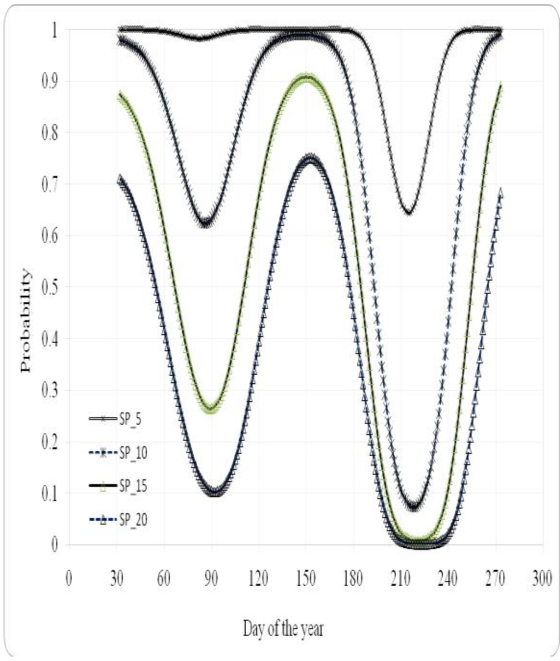

Figure 4. The probability of different length of dry spell occurrences

All dry spell probability curves converge to their minimum during the peak rain season (200 -250 day of the year) and increase again around September signaling the end of the growing season. In general, the *Belg* has higher probability of dry spells than the *Meher*. The shortest the dry spell length the most frequently observed event. The above dry spell analysis demonstrates that the onset of rainfall that fulfills the criteria were starting from the end of March to the mid April for *Belg* and July for *Meher*. This was evidenced by almost no or low probability of prolonged dry spells such as 15 and 20 days occurrences. Besides, the dry spell reveals that May and June could not be the appropriate sowing dates. This was because the probability of long dry spell occurrence was very high in these months which could lead to failure of crop at its establishment and hence, may reduce yield. However, sometimes dry sowing (a condition where no soil moisture that could affect the viability nature of the seed) could be possible.

Sorghum production is particularly related to the *Belg* rains. This is because of the fact that sorghum is sown earlier than many crops, which makes the *Belg* rainfall critically important. Favorable *Belg* rainfall conditions could allow cropping of a larger area and improve sorghum yield per ha of cultivated land. In general, for the production of sorghum which is long-cycle crop sown early from the *Meher* rains, the significance of *Belg* rainfall is quite obvious. Sorghum has a good tolerance for water stress caused by dry spell occurrences and even end of season dry spells (rainfall shortage in September), so it is more sensitive to *Belg* rainfall. Once the crop (sorghum) has sown earlier and initially established well, it may withstand even prolonged dry spells of May and June and can provide a reasonable yield. Moreover, sowing on June could give better yield than May (Table 8) because it was near to the onset of *Meher* main season that possibly reduces the spell length. Care must be taken in selecting the appropriate sowing date to avoid the coincidence of long dry spells with the flowering stage (sensitive to temperature) to reduce the impacts.

Sorghum production in Alamata Wereda

Sorghum is one of the most important crops grown in dry land areas and is almost the only crop that uses the *Belg* rainfall. *Degalit, Gigrite, Dengele, America and Kodem* are some of the sorghum cultivars grown in Alamata wereda. Farmers of the study area pointed that late maturing and high yielding cultivars such as *Degalit, Dengele and Jamuye* has abandoned (Gebremedhn, 2011). Late maturity and drought has been identified as an important factor for loss of traditional cultivars of sorghum and this was associated with the changes in rainfall and duration of the area (Meles et al., 2009).

According to office of agriculture of the *Wereda* the lowest yield in 2010 (Figure 5) was explained due to the low amount of rainfall recorded in 2009. The average yield of sorghum in *Alamata* was 30 quintal per hectare. However, the yield can vary from as low as one (during drought years) to 45 quintal per hectare when conditions are favorable and this figure may vary from variety to variety, because some are high yielding while others are less. Sorghum exhibits the largest interannual variability in terms of area cultivated and yield. This high inter-annual variability was caused mainly by the high inter-annual variability of rainfall onset.

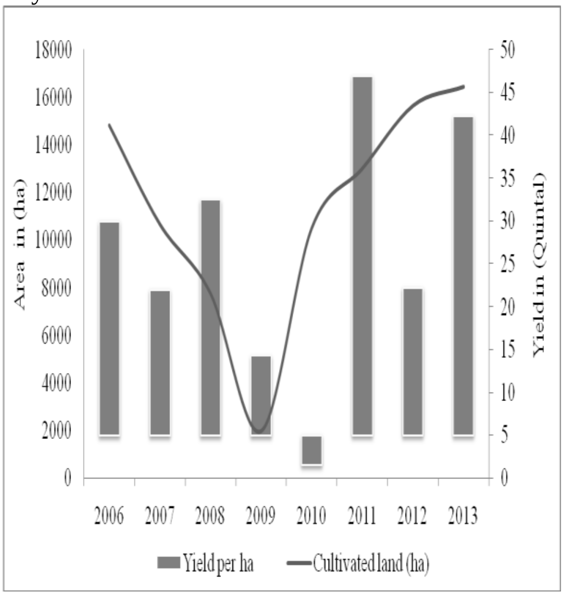

Figure 5. Interannual variability of sorghum yields (Quintal) and cultivated land (ha) in *Alamata*

Where: Quintal is a local unit which is equivalent with the conversion of 1ton = 10 Quintal

Rainfall-yield relationship

Correlation analysis was conducted taking the historical rainfall as an independent and yield as a dependent variable to estimate rainfall-crop production relationship. Though not statistically significant, sorghum production shows a positive correlation with the *Belg* (r=0.34) and *Meher* (r=0.3) rainfall (Table2). However, the total annual rainfall was significantly (r=0.56, p=0.01) correlated with yield of sorghum. Beyond the correlation, 32% of the variability in yield was explained by the total annual rainfall, while *Belg* and *Meher* rainfall explains 11.5% and 8.5% of the yield variability respectively.

In contrary to this, Ndamani (2009) reported weak correlation between annual rainfall and cereal productions, and hence, pointed as a poor predictor of yield. The reason why sorghum has significantly correlated with annual rainfall, in contrary to many other crops indicates that sorghum is less sensitive to distribution of rainfall as it is moisture stress tolerant crop. Even though the correlations between yield and monthly rainfalls was positive, only April (r=0.48) and September (r=0.55) rainfall was statistically significant. This indicates that for sorghum production, rainfall during April (for seedling establishment) and September (grain filling) appears to be particularly important.

Conclusion

The yielding ability of crops is determined by genotype and the environment where it is used to grow. Climate, particularly rainfall is the limiting environmental factor of yield in arid and semi arid areas. The variability or total shift in mean of rainfall features and other climate parameters could put its signal on the yield return of crops. Despite the characteristics of high seasonal and interannual variability, the study area has shown significantly decreasing trend of annual rainfall totals particularly in the last two decades. This was also evidenced by a significant reduction in number of rainy days. The *Belg* rainfall on which the sowing of sorghum depends was highly variable with a significant decreasing trend. Moreover, the onset of rainfall in this season was variable which was also compounded by the occurrence of prolonged dry spell probabilities. May and June, which were not preferable for sowing dates, experience the highest probability of dry spell occurrences. Using the historical thirty three climate data, 60.6% of the rainfall onset date was on April, however, a significant shift of this onset to *Meher* has been observed in the last current two decades of the years. Unlike the onset, the cessation date of rainfall in the area was more or less stable. Besides, the LGP has demonstrated a significantly decreasing trend in both the third and last two current decades of the historical years and this was happened due to the threatening and shifts in onset date of rainfall at *Belg* season. More to the point, the amount of rainfall for September and May has significantly reduced in the last two decades of the years which this shortens the growing season of sorghum and other long season growing crops.

Generally, the rainfall features has significantly been changed putting its consequences on agricultural crops, which was evidenced by the change in annual rainfall totals, rainy days, length of growing period and onset date of the current two decades of the historical years. An important implication of this analysis was that adoption of shorter duration rather than longer duration sorghum cultivars seems an important response in dealing with the main effects of rainfall variability.

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