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ANALYSIS OF RAIN FALL ONSET AND RECESSION FOR DECISION MAKING IN RAINFALL WATER MANAGEMENT IN THE WEST HARAREGAE ZONE, ETHIOPIA

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ABSTRACT

This study was undertaken to assess and characterize the onset and recession of rainy season for supporting crop production in the study area for selected station of west Hararghe Zone of Oromiya, Ethiopia, based on simple water balance model. The mean onset of the main growing season was found tooccur during the first meteorological dekade of July at Hirna, Second meteorological dekade of July at Asebe Tefer and last meteorological dekade of July at Meiso While ended during the end of September at Hirna, first meteorological dekade of October at Asebe Teferi and second meteorological dekade of September at Meiso. Similarly, though unreliable and only few occurred during the entire study period, the mean onset of Belg season was found to occur during the beginning of the last dekade of March for all study area. The length of the growing season during the main rainy season were 116days,102days and 85days at Hirna, Asebe Teferi and Meiso, with coefficient of variation and standard deviation of 9.42% 27%, 39%,and 18, 19, and 17days, with their respective orders. Similarly, the mean growing length during the Belg season was found to be 39days with a standard deviation of 32 days and coefficient of variation of 78.25% at Hirna, with mean LGP of 47 days, standard deviation of 18 days and coefficient of variation of 37% at Asebe Teferi and found to be 32days with a standard deviation of 23 days and coefficient of variation of 72.34% at Meiso.

Keywords: rainfall, decision making, water management, Ethiopia.

INTRODUCTION

Rainfall is the basic component in the hydrological cycle which plays an important role in sustaining lives and all creatures depend on water. The definition of rainy season onset/cessation is versatile (Smith *et al*., 2008). Climatologists, agronomists and hydrologists have proposed different definitions. For instance, agro climatologists usually define the onset at the rain gauge scale, using a variety of empirical thresholds (Stern *et al*., 1981; Sivakumar, 1988). They consider that the rainy season onset is the first wet day of a spell receiving a given rainfall amount and not followed by a long dry spell during the subsequent weeks. The rainfall thresholds are determined empirically in order to fit the requirements of a given crop and are adjusted to account for local-scale climatic conditions. The analysis of rainfall for agricultural purposes includes the trend, start, and end, length of the rainy season distribution of rainfall and the risk of dry and wet spells.

Ethiopia's topography is composed of massive highlands, complex mountains and dissected plateaus divided by Great Rift Valley running generally southeast to northeast. This great terrain diversity in the country determines wide variations in climate, soil, natural vegetation, and settlement patterns (Camberlin and Philippon, 2001).

As the country is located within the tropical region, it is influenced by weather systems of various scales, from mesoscale, such as thunderstorms, to large scale El Niño/ Southern Oscillation (ENSO) related phenomena. The major rain-bearing system for the main rainy season (June to September) is the Inter Tropical Convergence Zone (ITCZ). On the other hand, the eastward moving mid-latitude troughs will facilitate the interaction between the mid-latitude cold air and the tropical warm air so that unstable conditions will be created for the moisture that comes into Ethiopia from the Arabian Sea during the small rainy season, Belg (February to May) (National Meteorological Services Agency (NMSA), 1996).

Accordingly, the climate is characterized by high rainfall variability both in amount and distribution across regions and seasons. As a result, most central and eastern highlands of the country are characterized by a coefficient of variability (CV) of less than 30% values (in mm) of rainfall and this value increases to 70% or more to the lowlands of the north, northeast and southeast (NMSA, 1996). Generally, the value of CV of rainfall varies from 10% to 70% in the country. The low rainfall areas of the north, northeastern and southeastern regions are characterized by high CV values and are vulnerable to drought. This variability of rainfall in time and space causes its occurrence very difficult to predict and it is this tempo-spatial variation in the rainfall distribution that creates serious hydrological problems (Raiford *et al.*, 2007).

In semi-arid sub-saharan Africa like Ethiopia water has long been considered to be the main limiting resource for crop growth (Barron *et al*., 2003). Local

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farmers can benefit from dry spell agricultural production due to the agricultural products produced during dry spell has more value. Rainfall is highly erratic, and most rainfalls as intensive, often convective storms, of very high intensity and varies extremely spatially and temporally. Such variability is a threat to agricultural industry that relies heavily on rain-fed agriculture, since it will be very vulnerable to phenomena caused by rainfall extremes such as annual droughts and intra-seasonal dry spells as well as floods particularly in the lowland areas (FAO, 1986).

The presence of a relationship between the onset and cessation dates and between the length of the season and the onset and/or cessation dates is also very relevant for planning activities in the season. Sivakumar (1988) carried out an analysis of long-term daily rainfall data for 58 locations in the southern Sahelian and Sudanian climatic zones of West Africa. The study showed that a significant relationship exists between the onset of rains and the length of the growing season. Oladipo and Kyari (1993) investigated the fluctuation in the onset, cessation and length of the growing season in Northern Nigeria and reported also that the length of the growing season is more sensitive to the onset of the rains than to the cessation. Reliable prediction of rainfall characteristics, especially the onset, is needed to determine a less risky planting date or planting method, or sowing of less risky types/ varieties of crops in responsive farming (Stewart, 1991)

Some studies conducted in sub-Saharan Africa indicated that there is a potential opportunities for increasing crop yields in the region. An assessment made by Baron (2004) showed that the cereal crop yields could reach as high as 3.5 t ha-1 against the existing yield 1 t ha-1 yield estimated by Rockstrom (2003). This wide gap suggests that there is an enormous opportunity to raise crop yield from rainfed agriculture. This is entirely linked to focusing attention on maximizing yield per unit of water. However, the agricultural economy is highly fragile due to repeated failure of crop yield associated with irregularity in onset, temporal and spatial distribution of rain in most parts of the region during the growing season. According to Meinke (2003), rainfall water potential assessment work determined through possible estimation of rainfall onset date, end date, duration and seasonal totals and dry spell length, which together make up the overall rain feature, can provide deep insight into the rainfall variability and into the field management options through proactive responses.

The objective this paper is to present the characteristic of the onset and recession of the growing season in the West Harrragea, eastern part of Ethiopia

MATERIALS AND METHODS

The study area is located in West Hararaghe zones, Oromiya Regional State, eastern part of Ethiopia, about 405 Km east of Addis Ababa. The Harerghe highlands lying in the eastern part of the country are generally known for their rugged topography, mountainous landscapes which govern the variations in regional geomorphology, soil sequences, ecological zones, quantity and quality of plant and animal life (Tamire, 1981). The climatic conditions of the study area exist in all agro-ecological zones. The majority is covered by kola, woyena dega and Dega according to its altitudinal range from sea level.

The climate in West Hararghe is warm and temperate, there is significant rainfall. Even in the driest month there is a lot of rain. This location is classified as Cfb by Köppen and Geiger. The averages temperature of the zone is 17.1°C. On an average about 1026 mm of precipitation falls annually in its zone. It has a latitude and longitude of9°05′N and 40°52′E and an altitude of 1826 meters above sea level.

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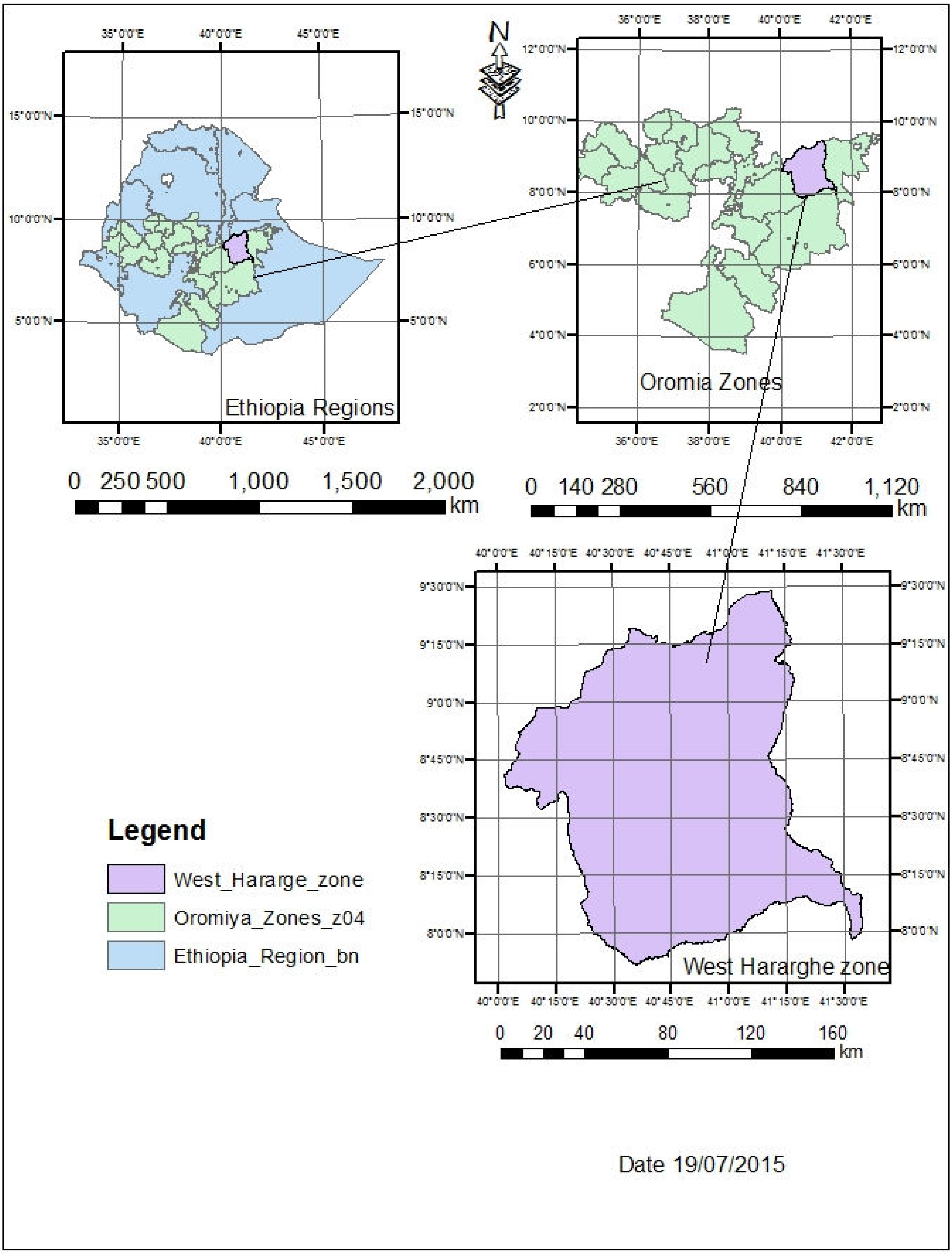

Figure-1. Location map of the study areas.

Data summary and presentation

Dekadal (ten days) rainfall amounts were computed from the daily data set of 26 years(1985-2010) of *Hirna*, 30 year (1985-2014) of *Aseb Teferi* and 18years (1991-2008),) of *Meiso*, using Standard Meteorological Dekades. The Standard or Meteorological Dekades (SMDs) were constructed in such a way that each month of a given year was divided in to three dekades and subsequently the first two ten days were considered as the

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first and second dekade for each month, respectively. The rest of days in each month again summed up to form the last or third dekade (Messay, 2006). The monthly ETo data retrieved from the Hargreave's equation (Allen *et al.,* 1998) was adjusted to daily values and again re-adjusted to the dekadal values for the appropriate analysis.

The Reference evapotranspiration data for this study was derived from minimum and maximum temperatures based on Hargreave's equation (Allen *et al.,* 1998) due to the existing limited climatic variables.

$$\mathrm{ETo} = 0.0023(\mathrm{T_m} + 17.8)(\sqrt{\mathrm{T_{max}} - \mathrm{T_{min}}})$$

Determination of the onset rainfall period

The beginning or the start of the rainy season both for *Kiremt* and *Belg* was identified based on FAO (1978) simple soil water balance model Cited (Girma, 2011) using the following formula.

$$\mathrm{P_n} \geq 0.5\mathrm{ETo}$$

Determination the cessation of rainfall period

Similarly, the end of the growing season was identified based on the same model but using the following equation (when rain is getting to recede).

$$\mathrm{P_n} \leq 0.5\mathrm{ETo} \qquad 14$$

Where:

Pn is the dekadal precipitation amount during the start and recession of the rainy season

ETo is the corresponding reference evapotranspiration during the same period

Determination length of the growing period

The beginning of growing period were occur when precipitation equals half of the reference evapotranspiration (ETo) as being sufficient to meet the water requirement for establishing crops end of the growing period were occur at the dry. The precipitation again required to half of the reference evapotranspiration after attaining wet or humid period plus the number of days required for the crop to evapotranspire 100 mm of moisture required in the soil after cessation of rainfall. The variability of LGP was analyzed using the coefficient of (CV) of the lengths over 26 years for *Hirna* and 18Years for *Meiso*.

$$\mathrm{CV} = \frac{\mathrm{SD}}{\overline{\mathrm{X}}}$$

Where,

CV is the coefficient of variation for the length of the growing period

SD is the standard deviation for the length of the growing period

RESULTS AND DISCUSSIONS

Onset, cessation and LGP of the main rainy season *(Kiremt)*

The FAO (1978) simple soil water balance model based on the mean statistical analysis of the, 26 years data for *Hirna* station,30 year data for *Asebe Teferi* station and 18 years data for *Meiso* station revealed that the main rainy season (*Kiremt*) starts during the First meteorological dekad of July (decade 19) second meteorological dekade of July (decade 20) and last meteorological dekade of July (decade 21/last decade of July) respectively and recession of rainfall was observed on last meteorological dekade of September (decade 27) at *Hirna* areas, first meteorological dekad of October(decade 28)at *Asebe Teferi* areas and on second meteorological dekad of September (decade 26) at *Meiso* area (Tables 1 and 2). The mean onset of the rainy season was observed with a standard deviation of 1.79 dekads (17 days) and coefficient of variation of 26.92%, indicating a high stability of the onset of *Kiremt* at *Hirna* area, and on *Asebe Teferi* was observed with a standard deviation of 1.9 dekads (19 days) and coefficient of variation of 9.5%, indicating a high stability of the onset, similarly, at *Meiso* area the mean onset of the rain with a standard deviation of 1.68 dekads (17 days) and coefficient of variation of 33.33% indicating high stability of onset of *Kiremt* season in the area (Table-3).

Table-1. Summary of the onset date main growing period *(Kiremt)* in the study areas.

Area	Mean onset dekad no.	SD (dekads)	CV (%)	Frequency (%)	Stability of the onset
Hirna	19	1.79	9	26.92	High
Asebe Teferi	20	1.9	9.5	16.667	High
Meiso	21	1.68	8	33.33	High

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The summarized statistics of occurrences of the onsets of the growing periods in the main seasons in different dekades and the general characteristics of the identified growing period are presented in Tables 2 and 3, respectively.

Table-2. Characteristics of the Kiremt growing period in the study areas.

Areas	Onset of rainy season			End of rainy season			Length of growing period (days)		
	Early	**Mean**	**Delayed**	**Early**	**Mean**	**Delayed**	**Mean LGP** (days)	**SD** (days)	**CV** (%)
	Standard dekad numbers								
Hirna	18	19	20	27	28	29	95	20	21.05
Asebe Teferi	19	20	21	27	28	29	102	28.06	27.39
Meiso	19	21	22	26	27	28	68	28	41.17647

The early onset and delay of start of growing were only one dekade at Hirna and Aseb Teferi while at Meiso the star of the growing period for some the years has occurred two dekades earlier than the average onset date (Table-5). Similarly, for all the study areas, the end of the growing season was only delayed by one dekade. The frequency and percentage of occurrences of the Kirmet growing season has been shown in the Table-3 below:

Table-3. Percentage occurrence of the onset date of the main growing season (*Kiremt*).

Study area		Standard dekad no.								
		15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Hirna	Number of occurrence	1	1	0	6	7	5	4	1	0
	Frequency of occurrence (%)	3.84	3.84	0	23.07	26.92	19.23	15.38	3.84	0
Asebe Teferi	Number of occurrence	0	0	2	8	5	5	3	3	4
	Frequency of occurrence (%)	0	0	6.667	26.6667	16.66	16.6667	10	10	30
Meiso	Number of occurrence	0	0	0	0	4	2	6	2	1
	Frequency of occurrence (%)	0	0	0	0	16.66	11.11	33.33	11.11	5.55

The length of growing period (LGP) in the main rainy season at *Hirna*, Asebe Teferi and *Meiso* areas ranges from 81 to 173 and 49 to 139 days with a mean of 116 and 85 days and with CV and SD of 17.55% and 32.94%, 20 and 28 days, respectively (Figures 2, 3 & 4.). The period includes the duration of the time that 100mm of soil moisture reserve has already been evapotranspired after the end of the rainy season (FAO, 1978 and Mersha, 2005). The deviation magnitude of the LGP obtained at *Hirna* area could not be regarded as high because the length of growing period even with minimum length is fairly enough to support the cereal crops (Teff and Wheat) Which are commonly grown in the areas that require not far more than 100 days of growing period to their maturity, if some soil and water conservation practices could be exercised on the agricultural lands.

However at the *Meiso* the stability of the growing period has showed relatively higher variation as compared to *Hirna* and *Aseb Teferi*.

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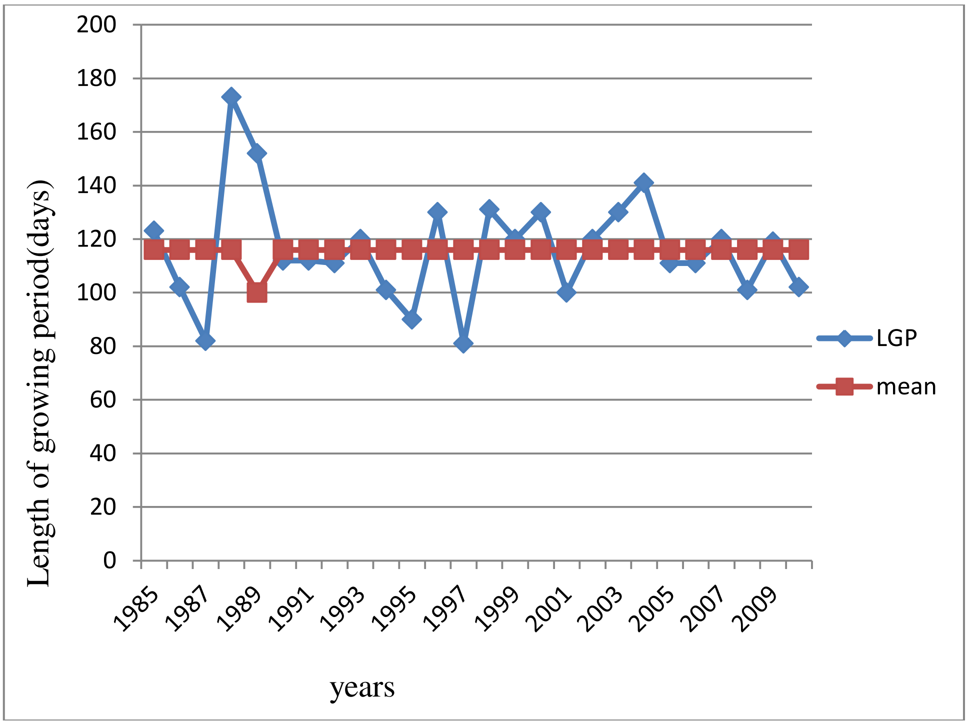

Figure-2. Length of the growing season in the *Hirna* area across years
Mean 116 day, SD 20 day and CV 17.55%.

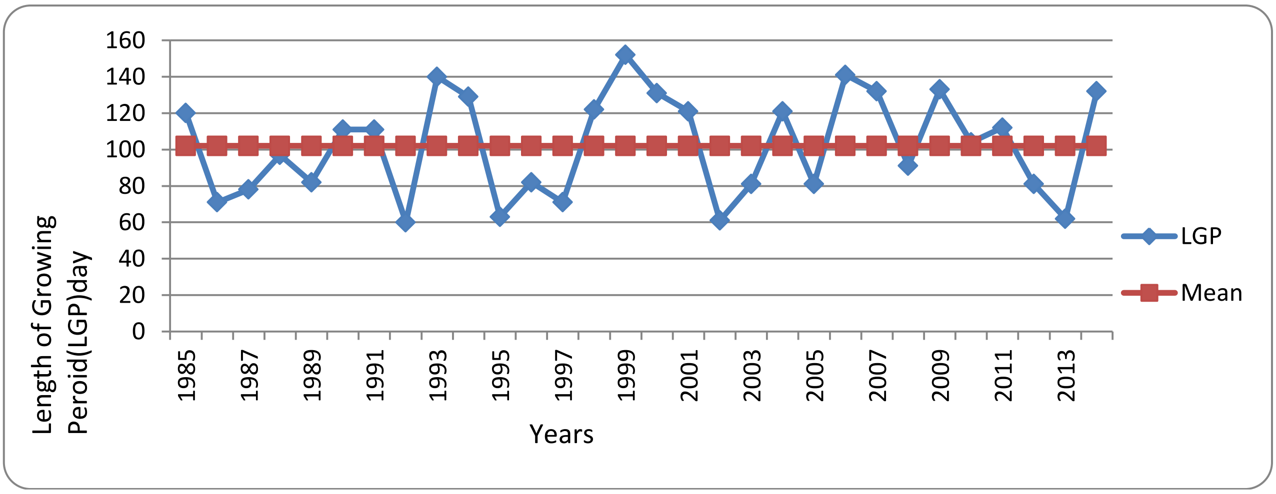

Figure-3. Length of the growing season in the *Asebe Teferi* area across years
Mean 102 day, SD 28day and CV 27.34%.

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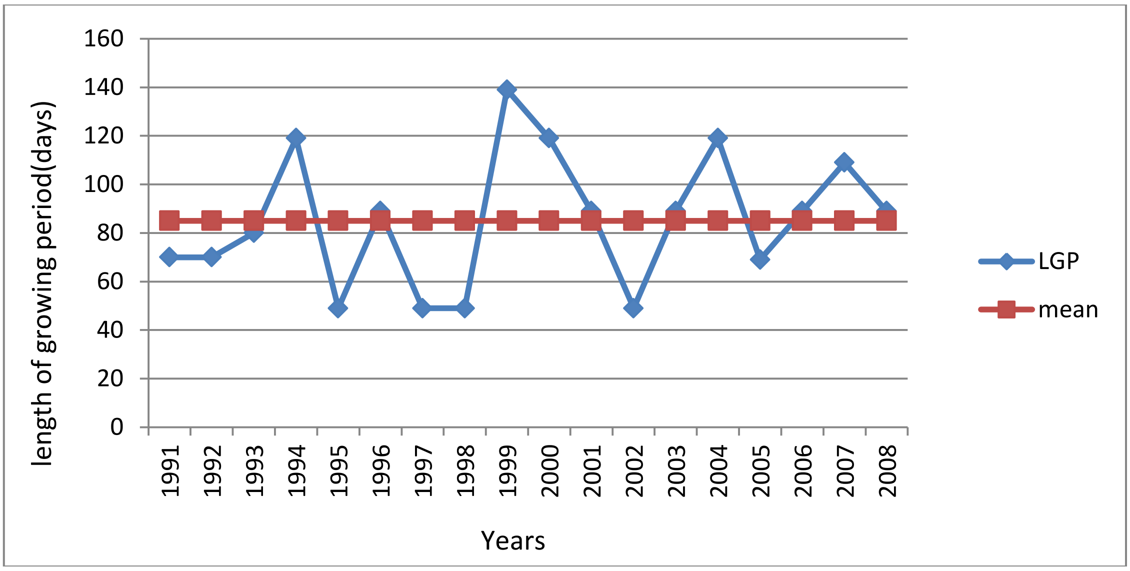

Figure-4. Length of the growing season in the *Meiso* area across years
Mean 85 day, SD 28day and CV 32.94%.

Onset, cessation and LGP on small rainy season (*Belg*)

The occurrence of the *Belg* growing season as a whole is less frequent. The mean onset of *Belg* season occurred during the last dekad of March (dekad 9) both at *Hirna* and *Aseb Teferi* areas with standard deviations of 1.7 and 1.6 dekads, i.e. on average 17 and 14 days for each and second dekad of March(dekad 8) at Meiso area with standard deviations of 1.4(14days). According to Reddy (1990), the stability of the onset of growing period is explained by the standard deviation of the average onset dekads of the seasons. Hence, the onset of *Belg* growing season is highly reliable in all areas of the study (Table-4), since standard deviation of the average onset dekads of the area are within the acceptable limits, which is less than two dekads.

Table-4. Summary of the onset date small growing period (Belg) in the study area.

Study Area dekad	**Mean onset**	**Standard deviation** (dekad)	**Coefficient of variation** (%)	**Stability**
Hirna	9	1.7	18.88	High
Aseb Teferi	9	1.6	17.77	High
Meiso	8	1.4	17.5	High

Hirna

The Length of Growing Periods (LGP) at *Hirna* area during 1985-2010 is presented in Table-5 During this period, the length of growing period in the *Belg* season varies from zero to 100 days, most of which are clustered below 80 days. Furthermore, the mean LGP of the area is 57 days with a standard deviation of 19 days having high variability of more than 100 % (Table-7). *Belg* season was observed to fail, because of no occurrence of onset dekad (availability of insufficient rain, which does not satisfy the 0.5 ET_0) without considering the intermittent rain, in about 19.23% of the time in the study area (Table-5).

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Table-5. Time series of length of growing periods in *Hirna* station Belg season.

Year	**onset dekade**	**cessation decade**	**LGP** (days)
1985	8	14	70
1986	10	15	60
1987	7	16	100
1988	10	12	30
1989	8	16	90
1990	9	14	60
1991	10	14	50
1992**	-	-	-
1993	11	16	70
1994	11	16	70
1995	8	13	60
1996*	8	-	-
1997*	9	-	-
1998	7	9	30
1999	7	11	50
2000*	11	-	-
2001*	-	11	-
2002	7	12	60
2003**	-	-	-
2004	10	13	40
2005	11	15	50
2006**	-	-	-
2007	10	12	30
2008	13	17	50
2009**	-	-	-
2010	11	16	60

* Very short and intermittent *Belg* rain ** Years with no belg season

Asebs Teferi

The period of analysis considered in *Asebe Teferi* area was 30 years (1985 - 2014) (Table-6). Results of the study revealed that the growing period varies from zero to 80 days with mean LGP of 47 days, standard deviation of 18 days and coefficient of variation of 37% and *Belg* season failed in about 23.33% at *Asebe Teferi* area (Table-6).

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Table-6. Time series of length of growing periods in *Asebe Teferi* station Belg season.

Year	Onset dekade	Cessation dekade	LGP (days)
1985	8	15	80
1986*	10	-	-
1987	8	-	-
1988**	-	-	-
1989	8	12	50
1990	9	13	50
1991	7	13	70
1992	9	15	70
1993*	11	-	-
1994	13	15	30
1995*	10	-	-
1996**	-	-	-
1997**	-	-	-
1998**	-	-	-
1999	7	9	30
2000	10	13	40
2001	8	10	30
2002	7	12	60
2003	11	13	30
2004	10	12	30
2005	7	9	30
2006**	-	-	-
2007	8	12	50
2008	10	12	30
2009	9	15	70
2010	7	-	-
2011**	-	-	-
2012	10	14	50
2013**	-	-	-
2014*	8	-	-

* Very short and intermittent *Belg* rain ** Years with no belg season

Meiso

The period of analysis considered in *Meiso* area was 18 years (1991 - 2008) (Table-7). Results of the study revealed that the growing period varies from zero to 50 days with mean LGP of 41 days, standard deviation of 10.37 days and coefficient of variation of 25, 6% as compared to *Hirna* and *Asebe Teferi* area and *Belg* season failed in about 33.33% at *Meiso* area (Table-7).

Table-7. Time series of length of growing periods of in *Meiso* station Belg season.

Years	onset dekade	Cessatio dekade	LGP (days)
1991**	-	-	-
1992**	-	-	-
1993	11	15	50
1994**	-	-	-
1995	8	13	50
1996	8	10	30
1997	8	11	40
1998**	-	-	-
1999	7	9	30
2000	13	17	50
2001	7	10	40
2002	10	12	-
2003	11	13	-
2004	10	12	30
2005	11	15	50
2006**	-	-	-
2007	8	12	-
2008	10	14	50

* Very short and intermittent *Belg* rain ** Years with no belg season

The percentage occurrence of the onset rainyseason for *Belg* in the specified dekads (Table-8) in the study areas were 7.69%, 20%, 11.11%, *Hirna, Aseb Teferi* and *Meiso* with corresponding stations, respectively. However, the season was observed to fail (no onset dekads) in about 19.23%, 23.33 and 33.33%, of the time during the period of analysis in *HirnaAseb Teferi* and *Meiso*, areas, respectively, (Table-8) and hence, farmers at these area were not able to take full advantage of the *Belg* rain for land preparation of the main rainy season. It is for this reason that planting date was some dekads later than the onset of the main growing period, which results in decreasing the period available moisture for crop growth.

Table-8. Occurrence distribution of the onset date of the small growing season (Belg).

Study area		Standard dekad no.						No onset dekade
		7	8	9	10	11	12	
Hirna	Number of occurrence	4	4	2	5	5	0	5
	Percentage of occurrence (%)	15.38	15.38	7.69	19.23	19.23	0	19.23
Asebe Teferi	Number of occurrence	5	6	3	6	2	0	7
	Percentage of occurrence (%)	16.66	20	10	20	6.6667	0	23.33
Meiso	Number of occurrence	2	4		3	3	0	6
	Percentage of occurrence (%)	11.11	22.22	0	16.66	16.66	0	33.33

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Results of the analysis using the water balance model (FAO, 1978) revealed that the *Belg* rain generally does not provide enough moisture to support crop production in the study area. The maximum mean LGP of 57 days (*Hirna*) and a minimum mean LGP of 40 days (*Meiso*) have been observed (Table-5) and the wet (humid) period was rarely observed at both area during the season. This implies that the rainfall is not reliable for rainfed agriculture in *Belg* season and cannot support long duration crops (common cereals like *tef*, maize, and sorghum, which require a minimum of 3 months to maturity).

In this season, most of the dekads, the depth of rainfall is less than half of the reference but the rainfall could serve for land preparation activities that can save time and take full advantage of the moisture from the main growing season (Engida, 2003). In other words, the moisture from this could help farmers start land preparation and hence they can plant soon the main rainy season starts so that there would be no waste of moisture.

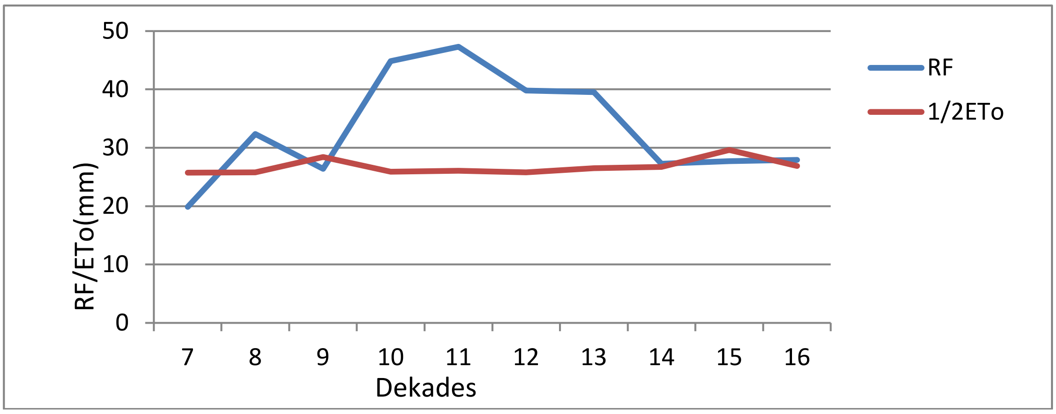

Figure-5. Growing season pattern during Belg (1985-2010) of *Hirn*a area.

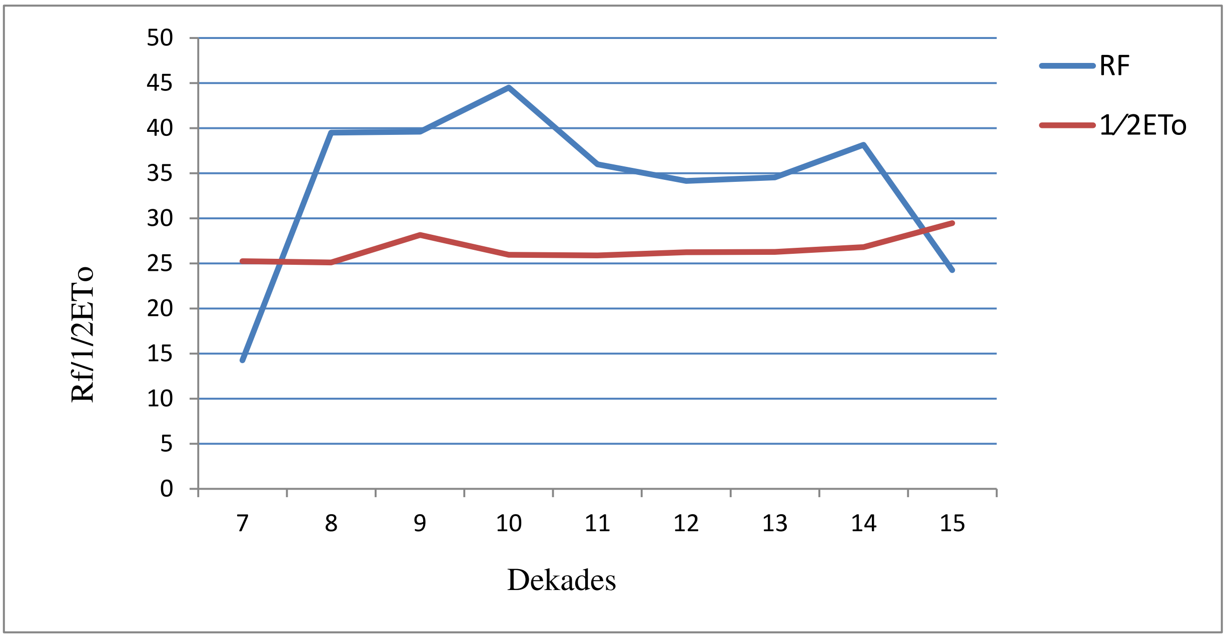

Figure-6. Growing season pattern during Belg (1985-2014) of *Aseb Teferi* area.

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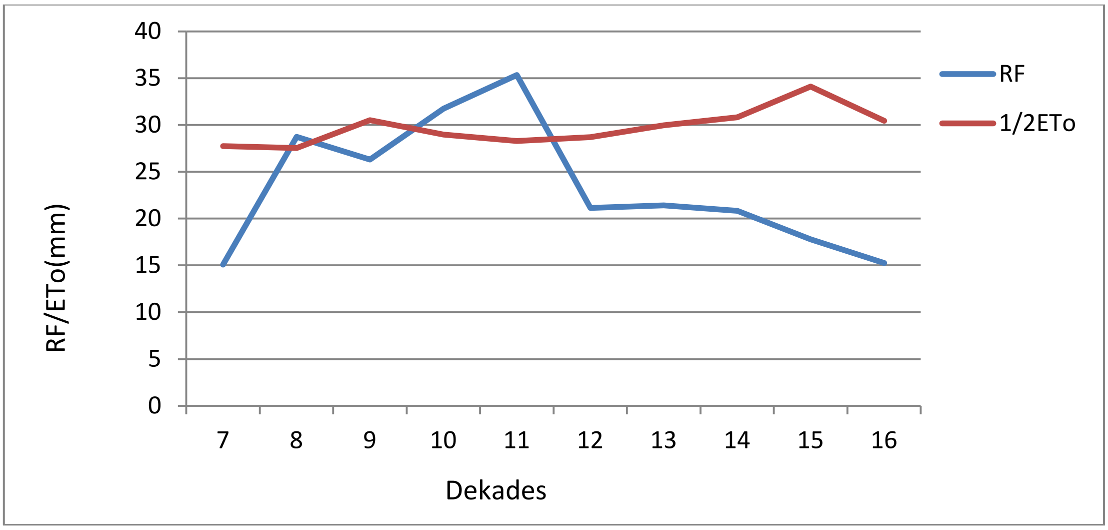

Figure-7. Growing season pattern during Belg (1991-2008) of *Meiso* area.

CONCLUSIONS

The major objective of the study was to assess the potential of rainy season for supporting crop production in the study area using standard rainfall statistical descriptors or models. The onset, end and length of growing periods were analyzed using the FAO water balance (FAO, 1978). Meanwhile, the length of growing periods were assessed by considering the soil moisture reserve (the readily available water) that can be utilized by the crops after cessation of the rainfall. Rainfall data of above 26 years for *Hirna,* 30 years for *Asebe Teferi* and 18years for *Meiso* station were used for analyzing the initial and conditional probabilities of wet and dry spells using Markov Chain model. The assessments were made for both *Belg* (small rainy season) and *Kiremt* (main rainy season) seasons.

The mean onset dekad of the main growing season (*Kiremt*) for an ideal crop starts on First meteorological dekad of July (decade 19) at *Hirna*, second meteorological dekad of July (decad 20) at *Asebe Teferi* and as late as last meteorological decade of July (decade 21/last decade of July) at *Meiso*. The onset of rain during the *Kerimt* season was found at *HirnaAsebe Teferi* and *Meiso* to be less variable with a CV value of (9% 9.5%and 8%) respectively. The lower coefficient of variation of starting of the season implies that patterns could be more understood and hence decisions pertaining to crop planning and related activities could be made more easily. It can also be noted that planning of agricultural activities is fairly simple and involves less risks in and around the study area during the main rainy season because of the stability of the onset dates of the main rainy season. However, the onset of rain during the *Belg* season was found *Hirna*, *Asebe Teferi* and *Meiso* to be more variable with a CV value of (18.88%, 17.77% and 15.55%), respectively. Meanwhile, the end of the main rainfall period is observed during the last dekad of September (dekad 27) at *Hirna,* first dekadof October (dekad 28) at *Asebe Teferi* and on second meteorological dekad of September (decade 26) at *Meiso*.

The mean lengths of main growing periods were 116days 102days and 85days at *HirnaAsebe Teferi* and *Meiso,* and coefficient of variation and standard deviation of 9.42% 27%, 39%,and 18, 19, and 17days, respectively. However, it was found that the variability of length of growing period in *Belg* season is extremely high (CV = 73.067%, 98.47% and 67.83%) implying difficulties associated with its prediction.

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