The Onset, Cessation and Dry Spells of the Small Rainy Season (Belg) of Ethiopia

By

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Abstract

An objective determination of the onset and cessation of the Belg rains of Ethiopia is important for agricultural applications as well as to enhance our understanding of the interannual variability of the rains of the season. Based on a quantitative study of daily rainfall data for 80 stations, we developed, the mean onset and cessation dates, and dry spells. The spatial and temporal variability of the onset and cessation dates are assessed and examined by testing different onset and cessation definitions for sample stations from the Belg -growing areas.

The study shows that there is more variability in the onset of the Belg rains than in its cessation. The highest variability in the onset was over the Northeastern and some places of central Ethiopia. The cessation dates of the Belg season have highest coefficient of variation over western, southwestern and west part of central Ethiopia.

The dry spell analysis shows that eastern, southeastern, northeastern and northwestern Ethiopia have long dry spell lengths in the Belg season.

1. Introduction

1.1. Rainfall Seasons of Ethiopia

Ethiopia is characterized by three distinct seasons. These are locally known as Bega (October to January), Belg (February to May) and Kiremt (June to September). The rainfall pattern is also named according to their rainfall distribution as Region A, Region B, Region C and Region D. (NMSA, 1996)

These classifications don't encompass the southern and southeastern lowlands of the country, which have a bimodal rainfall with rainfall periods from March to May and from September to October. The southwestern part of the country also doesn't follow the three-season pattern, because there it rains from February to November.

Bega

Bega is the dry season. It covers the period from October to January. It is mostly associated with hot dry days and cool nights. It is chilly in early mornings accompanied by occasional frost over most of the highland areas (Tesfaye Haile, 1986).

Kiremt

Kiremt is the main rainy season in which about 85% to 95% of the food crops of the country are produced (Workneh Degefu, 1987). It covers the period from June to September following the Belg rains and is associated with frequent

rains and homogeneous temperatures mainly in July and August. The magnitude of rainfall is higher as compared to the other seasons for many parts of the country. (NMSA, 1996)

Belg

Belg is the small rainy period. It covers the period from February to May. Rainfall during the season is highly variable in time and space and high maximum temperature values are common. (NMSA, 1996)

In this project, the primary goals of this study are to determine the onset and cessation of this season (Belg) on the basis of objective criteria and also to identify its dry spell characteristics.

1.2. The Contribution of Belg Rainfall to the annual rainfall amount

The amount of Belg rainfall is more than that of Bega and Maximum value occur over southern and southwestern regions (i.e. Bale, Gamo Gofa). They are important for long duration crops like maize and sorghum (Workneh Degefu, 1987).

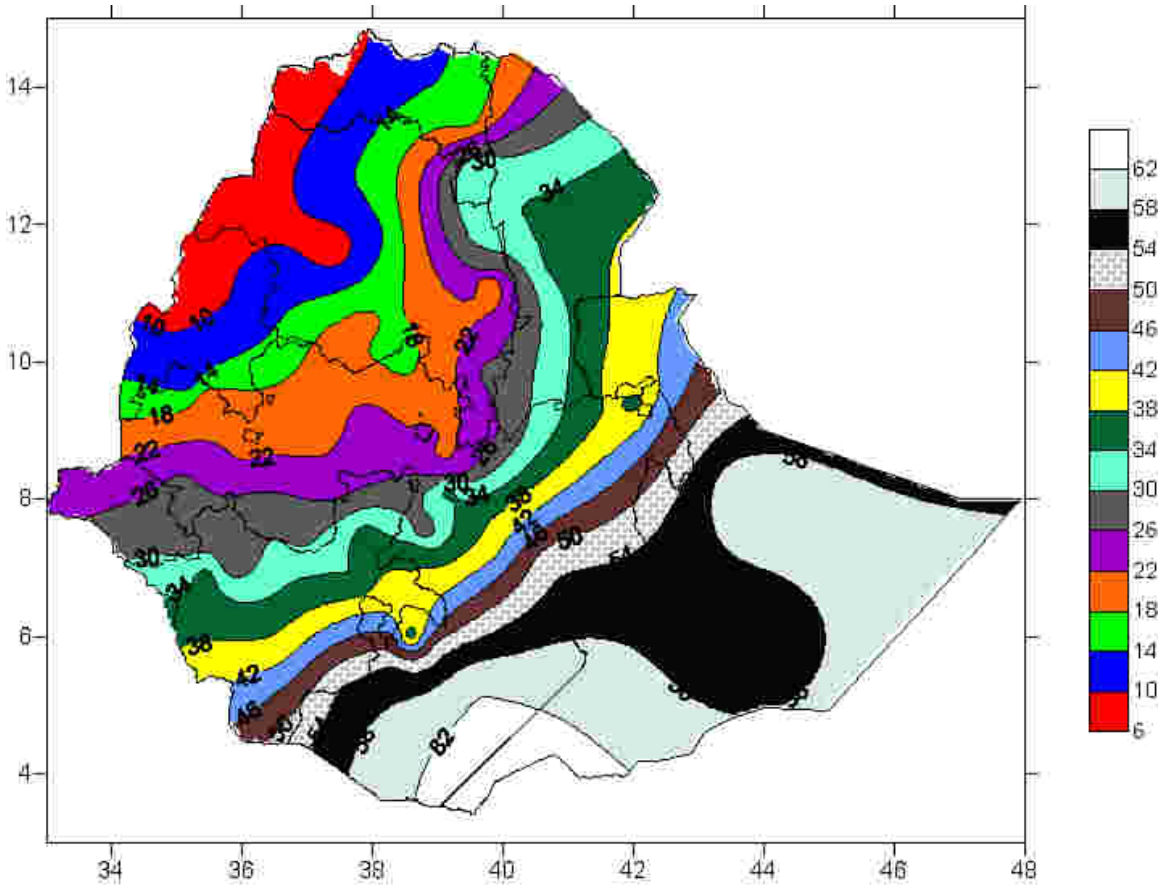


Fig.1 Contribution of Belg Rainfall to the annual rainfall amount over Ethiopia

During this season the major synoptic features that influence the weather of Ethiopia include easterly wave (EW), sub-tropical jet stream (STJ) extra-tropical troughs, Red sea convergence Zones (RSCZ), anticyclone over the Indian Ocean and the Mediterranean depression. The rains have their origins partly from Congo forest basin and partly from the Indian Ocean. Moreover, the intensity and areal coverage of the rain is associated, to a great extent with the intrusion and passage of the north -south oriented mid- latitude trough in the westerly wind field. When the trough deepens and its extension approach

equator, it interacts with ITCZ and cause widespread rains over most places particularly along the highlands. When the trough becomes weaker much of the rainfall activity concentrates, but not limited to, over southwest Ethiopia.

1.3 The socio-economic benefits of Belg Rains

Mostly, the agricultural activities fit the length of the two rainy seasons. Hence, the output of the agricultural activities depends on the performance of these seasons. The small rainy season is used for sowing short and long cycle crops. The short cycle crops are called Belg crops. The crops, which their growing season extends throughout the main rainy season, are called Meher Crops. (Endalkachew.B, 2000)

Information about the start of the rains is important for appropriate agricultural decision making so that reduction in yield of the crops is avoided by taking appropriate action.

During this season, much of the country receives shorter –lived but agriculturally important rains. A delay or deficient Belg rain means absence of water and pasture, which may result in deaths of thousands of animals. (Workneh Degefu, 1987)

Belg rain is extremely important from agricultural as well as hydrological point of view. This rain produces Belg crop, which accounts for about 5-15 % of the national food crop. Apart from this, long season crops like maize and Sorghum that constitute a major food crop of the country are planted during this season.

Small rivers, ponds and water reservoirs, which usually dry-up during the Bega season rain, will start to re-generate. A delay of Belg rain usually means the absence of water and pasture, which inform result in death of thousands of animals. (Workneh Degefu, 1987)

1.4. Characteristics of the Belg Rainfall

In tropical areas like Ethiopia the rainfall activity is mainly associated with convective activities of various scales, depending on the type of seasons. In almost all months of the small rainy season as well as in the beginning and end months of the main rainy season, thundery showers associated with convective activity are common in many parts of Ethiopia. Generally, in tropical areas including Ethiopia, each rainy day is associated with relatively intensive rainfall.

1.5. Literature Review on Onset, Cessation and Dry Spell Length

The first attempt of producing onset and cessation of the small and the main rainy season of Ethiopia were made by Mr. Tesfaye Haile in 1989E.C on pentad basis. In the work cumulative curve approach integrated with running mean and direct statistical analysis were applied to determine the time of onset and cessation of the rains.

To reach in a more critical result, in 2002, Zewdu T. Segele and P.J. Lamb did a more comprehensive work on the onset and cessation of the kiremt season. Similarly, in this work attempt is made to make Mr. Tesfaye Haile's Onset and Cessation maps more comprehensive by making use of the recent approaches and the latest statistical packages currently available.

2. Data

Daily rainfall data for 100 stations (fig.1) were obtained from the National Meteorological Agency of Ethiopia. After computerizing the data, extensive data quality control has been made to ensure research quality data by visually inspecting the original data with the soft copy. Of the 100 stations, 78 stations are used in determining the onset and cessation of the small rainy season (Belg) on the basis of objective criteria and identifying the dry spells. The data recorded in this study encompasses data from 1971-2004. Seventy two percent of the stations have data record of at least 30years from (1971-2004).Other twenty eight percent of stations, which have data from 1981-2004 were included in order to improve the spatial coverage of the study.

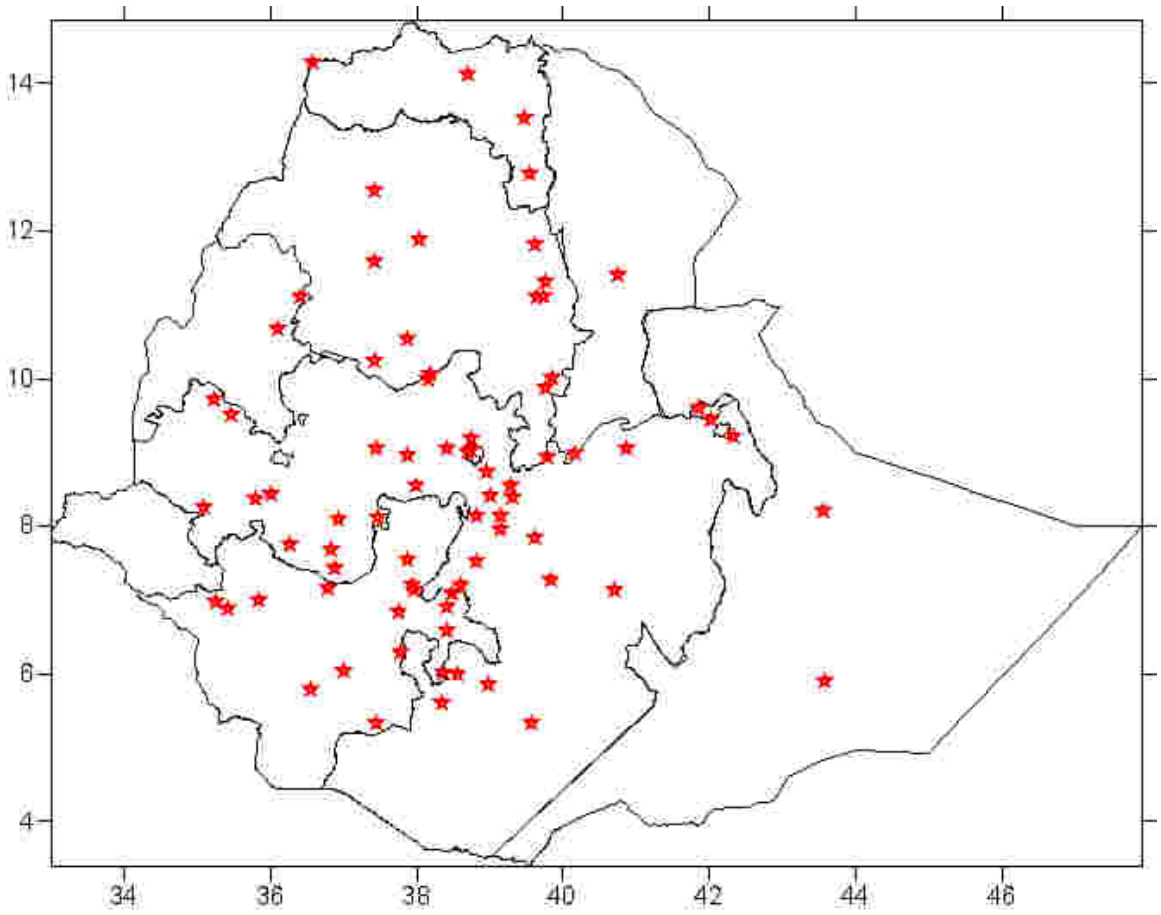


Fig.2 Location of Stations used in this study

3. Methodology

Time series of rainfall versus month is a basic technique to determine or state the criteria for onset and cessation of the Belg rains. We selected some stations from Belg growing areas to check /test /the characteristics of the number of rains within each month.

Dry/wet spell series was determined for selected stations from Belg-growing areas for each year.

In addition to the minimum rainfall requirement for agriculture, the duration and total rainfall amount of the wet-spells and the length of the dry spells for the selected stations were examined and analyzed to obtain the most appropriate empirical threshold values for onset and cessation criteria(Fig .13 A-E). Accordingly, the following criteria were set:

3.1 Onset

Onset dates for all stations should satisfy;

-Rainfall total of 10 mm or more and a length of 3 days or more:

- No dry spell of duration of 9 days or no more in the next 30 days:

- should occur with an earliest starting day of February 1:

- A threshold value of 1 mm (a rainy day is a day with 1mm or more rainfall).

3.2 Cessation

The Cessation of Belg satisfies the following conditions;

Based on water balance the end of this Belg season occurs when the water stored in the soil has been used, rather than when the rainfall the rainfall stops. The definitions used for estimating the end of the Belg seasons are based on Denneth et al.(1982) with an earliest possible day of May 1, the capacities of soils to persist precipitation with a water balance equal to zero is 100mm.

A standardized evaporation data is another tool to determine the cessation of the season, by getting the monthly evaporating data from the site:- http://www.fao.org/ag/agl/aglw/aqast/gis/index3, FAO (2004), interpolating it to the daily format with the help of Instat software.

3.3 Dry Spell

The occurrences of dry spells within the Belg season and for each months of the season were identified for a threshold of less than 1mm per day within a Belg season's months.

4 Results and Discussion

4.1. Climatology of Onset, Cessation and dry spells of Belg

4.1.1. Mean dates of Onset and Cessation of Belg

The Onset of Belg gradually advances northeastward from south western regions. The rains start in the last dekad of February over southwestern Ethiopia and cover much of the Belg-growing areas in the succeeding dekads.

The onset of Belg is highly variable, with standard deviation across the country ranging from 12 to 65.

Southwestern regions, which have onset in February and March, have the highest variability having standard deviation of 17.2 to 48.2, while northern and north eastern regions, which have a short growing season and a late start in April, have onset variability with standard deviations from 31.9 to 46.1.

The rains in March over Southwestern regions and in April over eastern and southeastern regions are associated with the seasonal southward advance of the equatorial trough /inter tropical Convergence Zone (ITCZ). The rains over the southwestern region in most part of the year are intense, persistent and widespread to fulfill the demand of Belg growing areas. Most of central Ethiopia

can start their Belg season in the second dekad of March where as east of central Ethiopia begin in the late April.

During this Belg season the major synoptic features that influence the weather of Ethiopia include easterly wave (EW), sub-tropical jet stream (STJ) extra-tropical troughs, Red sea convergence Zones (RSCZ), anticyclone over the Indian Ocean and the Mediterranean depression. The rains have their origins partly from Congo forest basin and partly from the Indian Ocean. Moreover, the intensity and areal coverage of the rain is associated, to a great extent with the intrusion and passage of the north -south oriented mid- latitude trough in the westerly wind field. When the trough deepens and its extension approach equator, it interacts with ITCZ and cause widespread rains over most places particularly along the highlands. When the trough becomes weaker much of the rainfall activity concentrates, but not limited to, over southwest Ethiopia.

The Belg rains leave from northeastern and central regions early in the first and second dekad of May, and cease over southwestern regions by late July (fig.6). The lowest variability of the cessation of Belg is over northern, northeastern and eastern regions, which have standard deviation of less than 15 days, while the highest variability is over western, southwestern, northwestern and central Ethiopia where standard deviation in cessation date range from 55-85 days.

In the western and south ward the retreat of the rains is too late; rather it merges with the main rainy season. The southward movement of an ITCZ

associated with the systems that bring the rainfall in the small rainy season. During late May much of the lowland areas of central Ethiopia and the north/northeastern regions are dry.

To illustrate the spatial and temporal variability of the onset and cessation of the rains, (fig. 21) provides the time series of mean daily rainfall along with the climatology of the onset and cessation dates for selected stations from Belg growing areas.

The Rift valley regions generally have short growing seasons ,which are manifested as late onset dates (fig. 3) and early cessation dates (fig.6) that run along southwest-northeast axes along the main rift valley.

On the other hand, the highlands of central Ethiopia have their Belg onset in the first and second dekad of April (Fig 3). The relatively high standard deviation of onset ranging from 40-44 over central Ethiopia is partly a reflection of the relatively short distinct dry period.

Even though the rain withdraws by early may from the northern Belg growing areas, some pocket areas over the Majete and Debresina region (fig.6) have late cessation in the first dekad of June (Fig. 6).

The normally delayed cessation of the season over the western and southwestern parts of the country may be attributed to the enhancement of systems which bears the main rainy season.

The highlands of eastern and southern Ethiopia are not addressed in this work to show its onset and cessation characteristics of the small rainy season,

since these areas aren't consider as the Belg growing area and the station coverage over that area is not more than 2 stations.

The high standard deviations of onset dates in this study are due to the determination of onset dates based on daily rainfall data on an individual station basis. The magnitudes of the interannual variability are comparable to results of studies that employ daily rainfall data for individual stations in determining the onset of the rains.

Generally, the rainfall condition, its onset and cessation characteristics are observed over Belg growing areas of central, south and southwestern Ethiopia including south and southeastern lowlands are analyzed in this work.

This information might have significant contributions mainly for land preparation. Besides it could be helpful to start sowing activity in some isolated areas of Belg growing areas.

4.1.2 Dry Spells

The analysis of dry spells is important in understanding the performance of a season and the variability of rainfall within a season. In addition, a simple empirical analysis of long-term rainfall data for dry spells could provide information for different agricultural applications (Sivakumar, 1992) fig.8 gives the mean dry spells over Ethiopia.

The average dry spell length determined based on a 1 mm threshold for the Belg season varies from 20 to 70 days (fig.8).

Central and Western Ethiopia have the shortest average dry spell length ,ranging between 20to 30 days, while the dry regions of north to south Rift valley have a moderate average value ranging from 40 to 50 days. The south east and Northwest regions have the longest average value from 60 to 70 days within a season.

The maximum length of dry spell events in the Belg seasons are computed based on a 1 mm threshold ,which varies from 65 days in the southern and north central to northwestern regions up to 95 days(fig. 18). The western and south western regions have maximum dry spells ranging from 30 to 35 days.

Areas which have little total length of dry spell when compared with an average dry spell length are indications of where dry spells are not so more significant, for instance south western Ethiopia (Fig. 8).

The western and south western regions have mean dry spell in February month ranging from 14 to 16 days. Central Ethiopia has 18 to 20 days of mean dry spell in February month. Highest numbers of mean dry spell are occurred in the region of north western, northern and eastern up to 28 days.

The mean dry spell during March month ranges from 8 to 20 days .Similar with others the western and south western regions have a maximum of 12 days dry spell.

During the months of April and May the dry spell ranges from 8 to 14 days. The western and southwestern areas have a maximum 10-12 dry days within a month (Fig.18).

In general, the dry spell analysis showed that during the Belg season 20-50 days from the total days have no rains above the criteria threshold of 1mm.On the other hand a maximum dry spells exceeding 65 days are extended to the northern, north western and eastern/northeastern regions (Fig.18). The highlands over central and western /southwestern Ethiopia are the least likely places to have an insignificant extended dry days ; even at the 20% and 50% probability level, the most extended breaks does not exceed 30 days (Fig19&20).

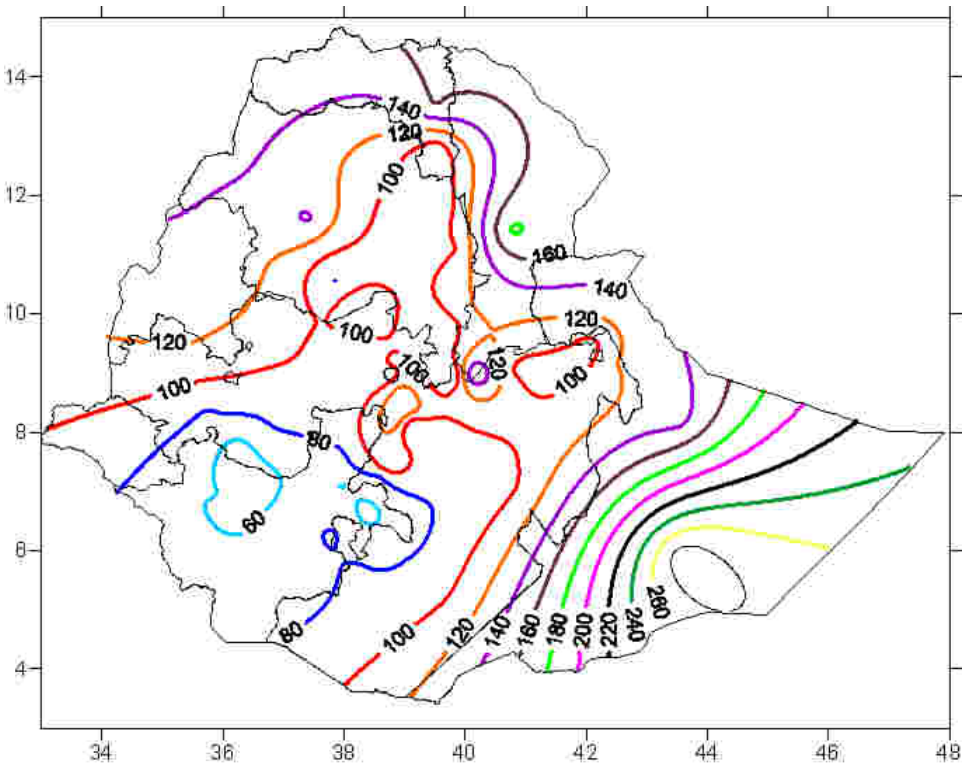


Fig.3 Mean Onset of Belg Season over Ethiopia

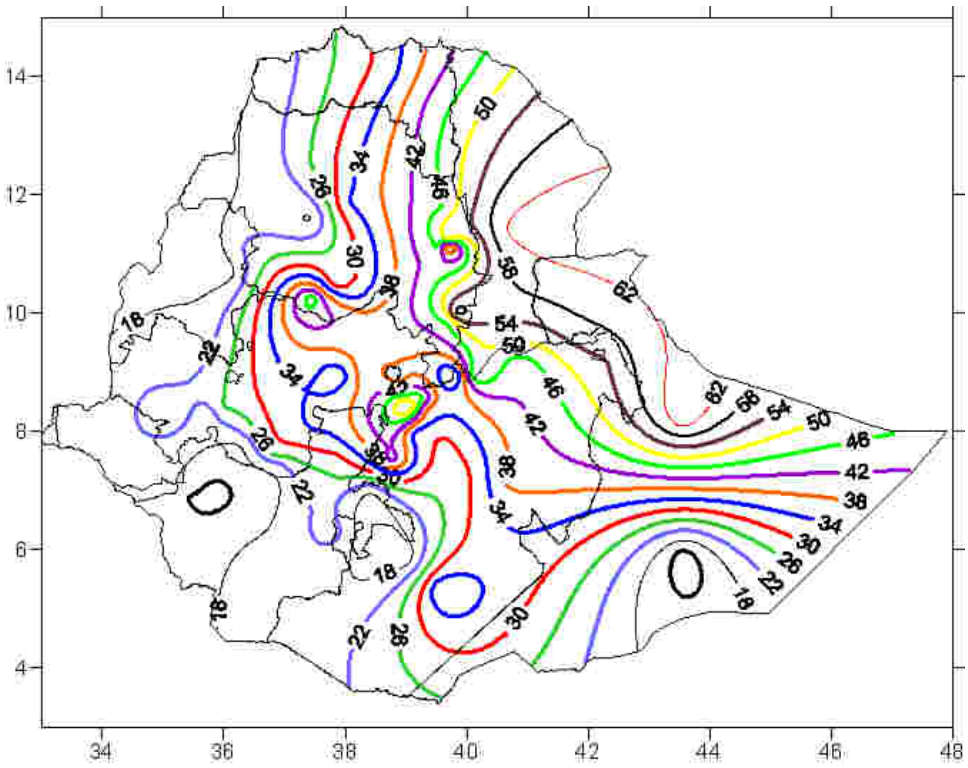


Fig.4 Standerd Deviation of Belg Onset dates

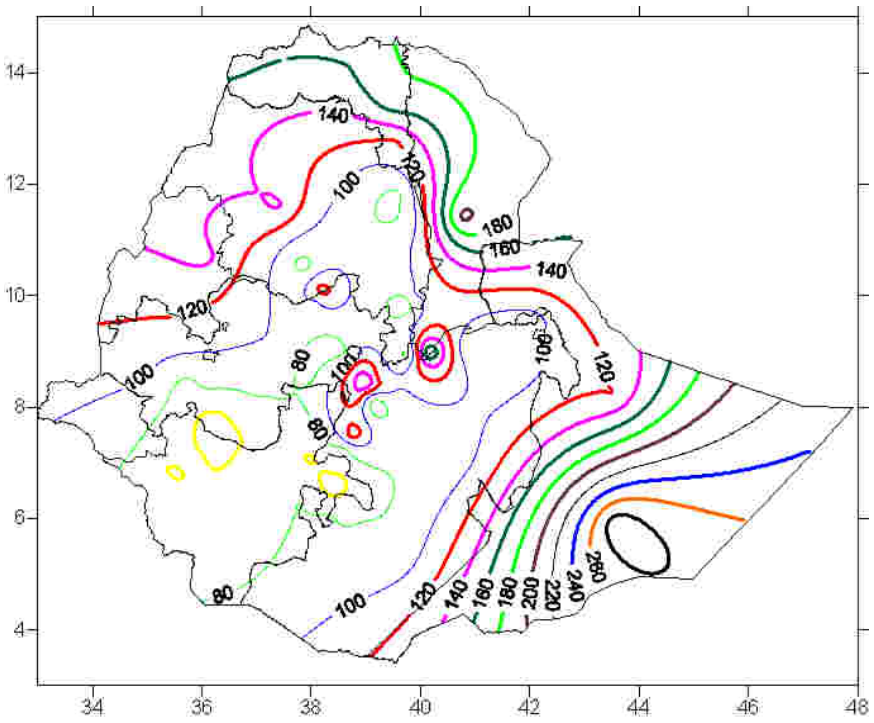


Fig. 5 Median Onset Days of Belg Season over Ethiopia

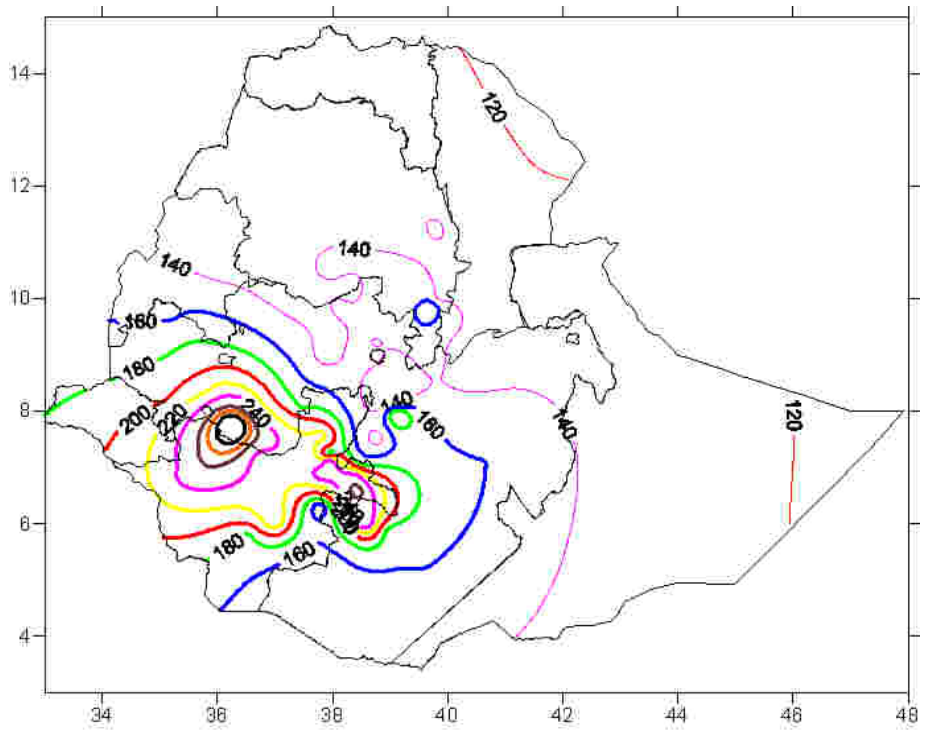


Fig. 6 Mean Cessation dates of Belg Season

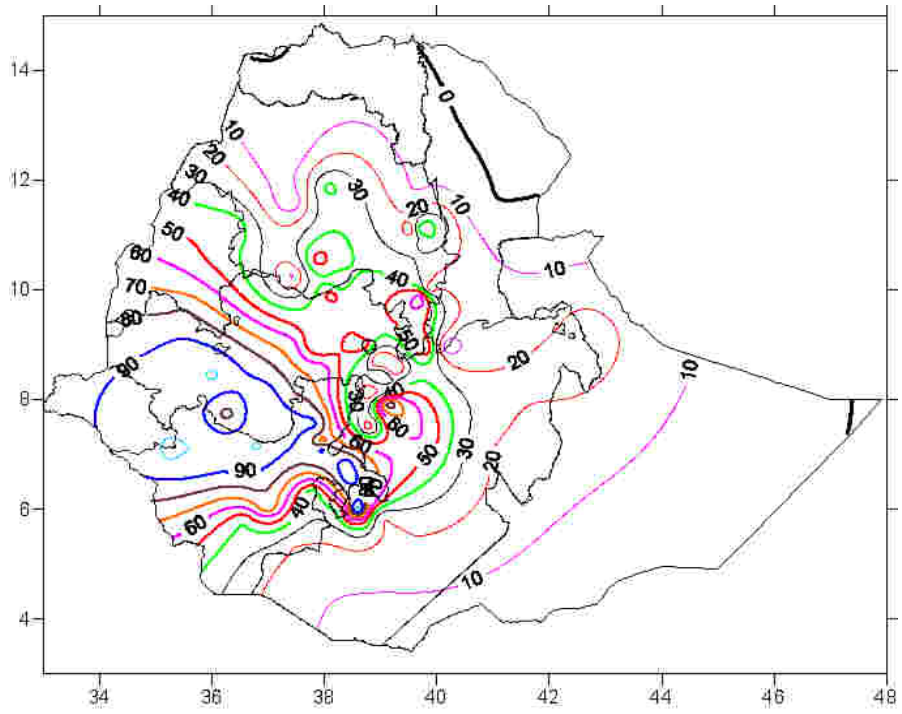


Fig.7 Standard deviation of Belg Cessation dates

Table.1

Day of the Month	Day of the year
1-Jan	1
15-Jan	15
1-Feb	32
15-Feb	46
1-Mar	61
15-Mar	75
20-Mar	80
1-Apr	92
15-Apr	106
29-Apr	120
1-May	122
15-May	136
19-May	140
1-Jun	153
15-Jun	167
1-Jul	183
15-Jul	197
1-Aug	214
15-Aug	228
1-Sep	245
15-Sep	259
1-Oct	275
15-Oct	289
1-Nov	306
15-Nov	320
1-Dec	336
15-Dec	350

From the analysis there could be many dry spell events within the months of February, March, April ,May and within the Belg season ,the maximum ,the average and the total lengths of dry spells were computed to capture the main characteristics of these events in a season. Furthermore, these same parameters were determined at 20%, 50% probability levels for each station.

All computations were performed and the results were graphically examined using Excel, Surfer and Instat Software. This combination enabled us

to clearly show the objectively determined dry spells, onset and cessation dates that best fit the daily rainfall pattern in all years.

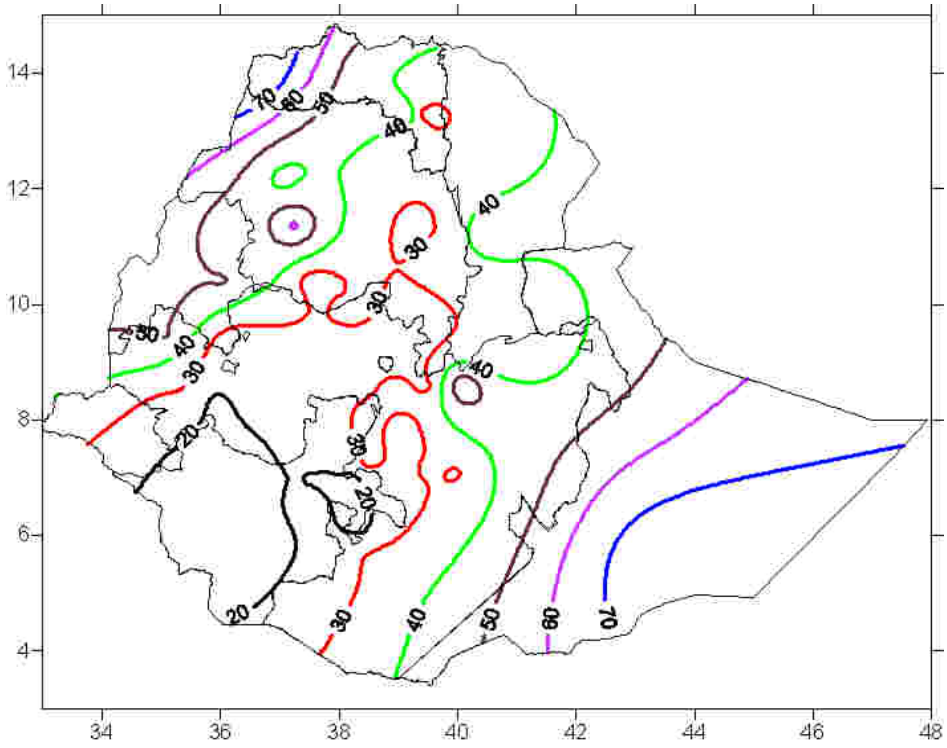


Fig.8 Mean Dry spells of Belg Season over Ethiopia

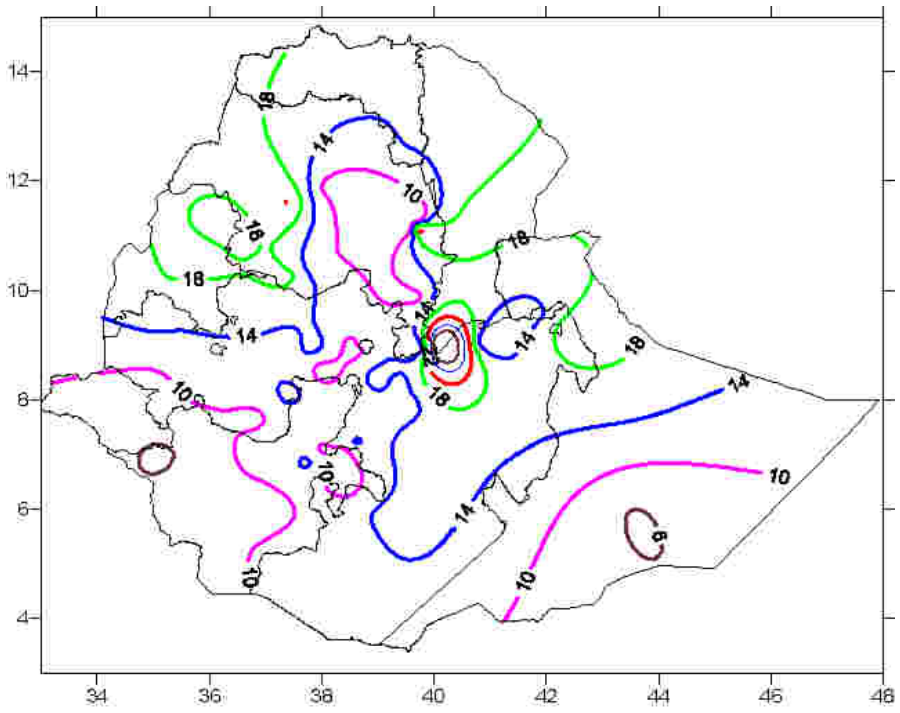


Fig.9 Standerd deviation of belg's dryspell over Ethiopia

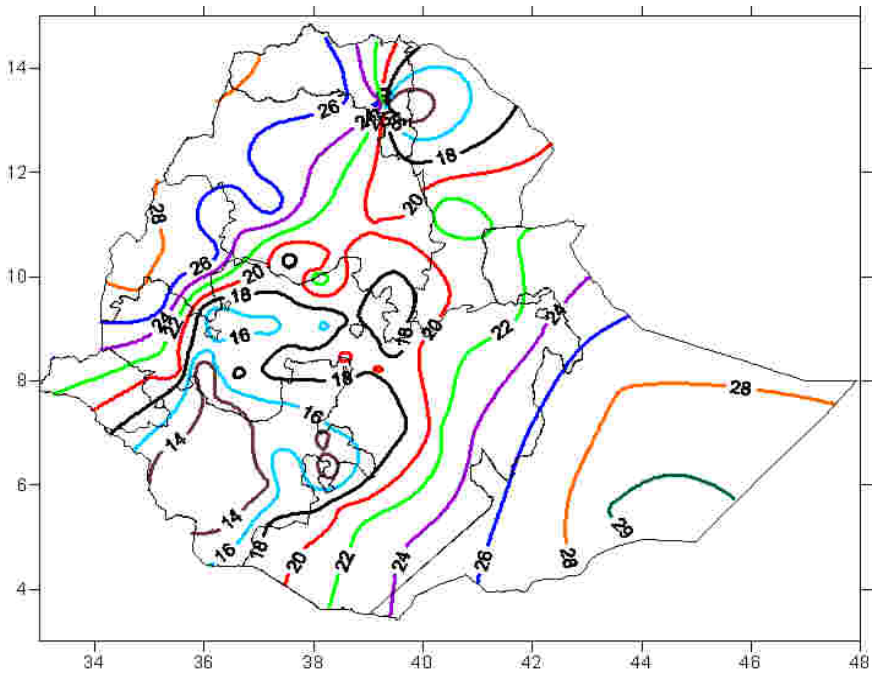


Fig. 10 Mean Dry spells of February Month Over Ethiopia

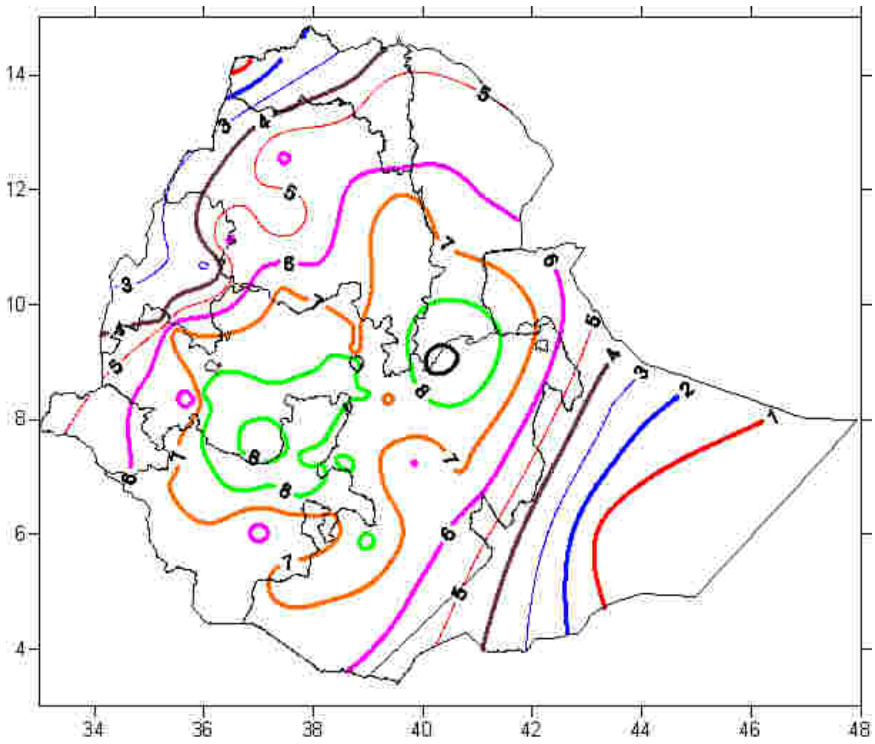


Fig.11 Standard deviation of February Month dryspell over Ethiopia

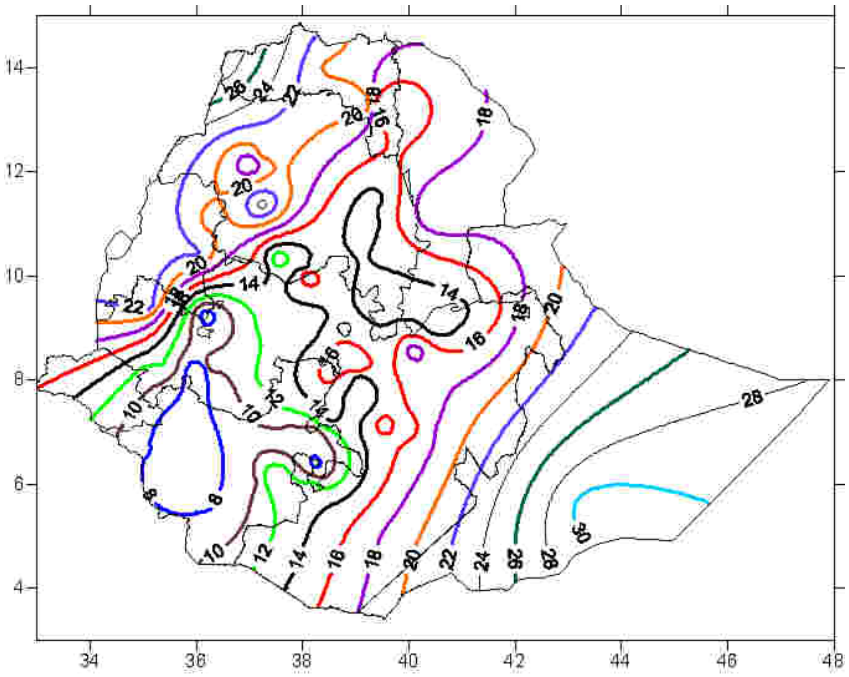


Fig. 12 Mean Dry spells of March Month Over Ethiopia

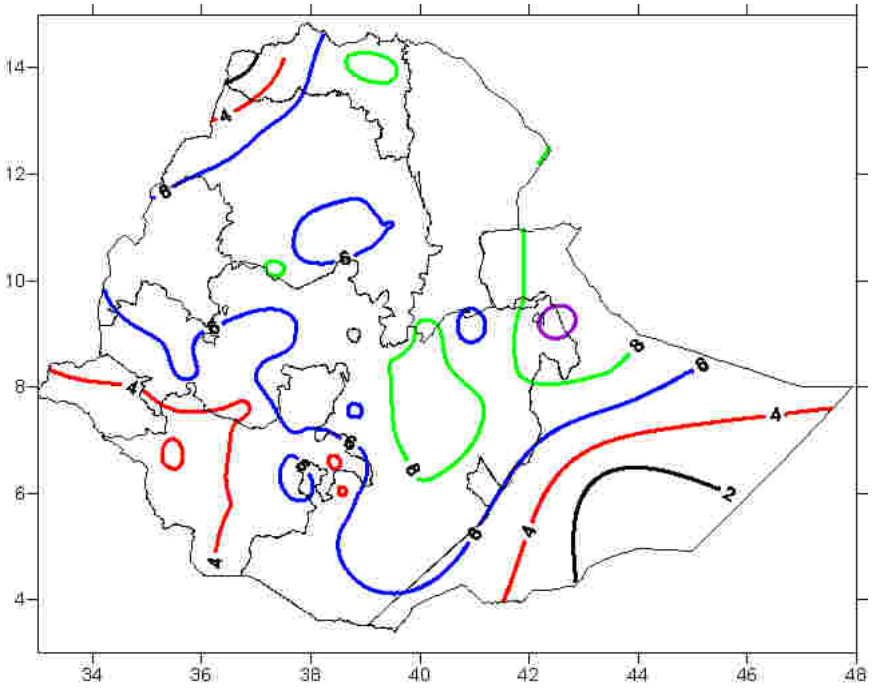


Fig.13 Standard deviation of March month dryspell over Ethiopia

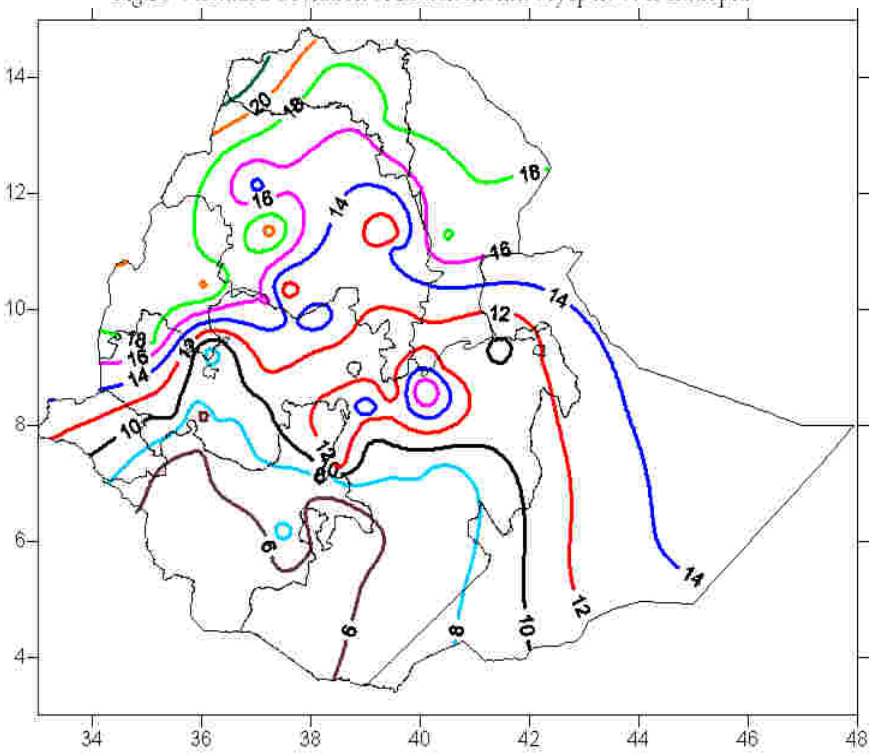


Fig. 14 Mean Dry spells of April Month over Ethiopia

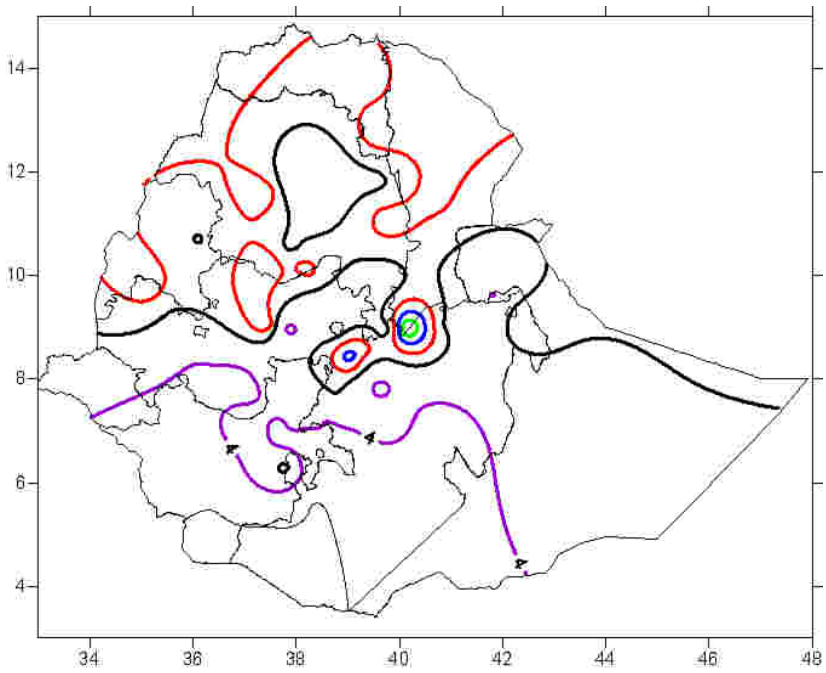


Fig. 15 Standard deviation of April Month dryspell over Ethiopia

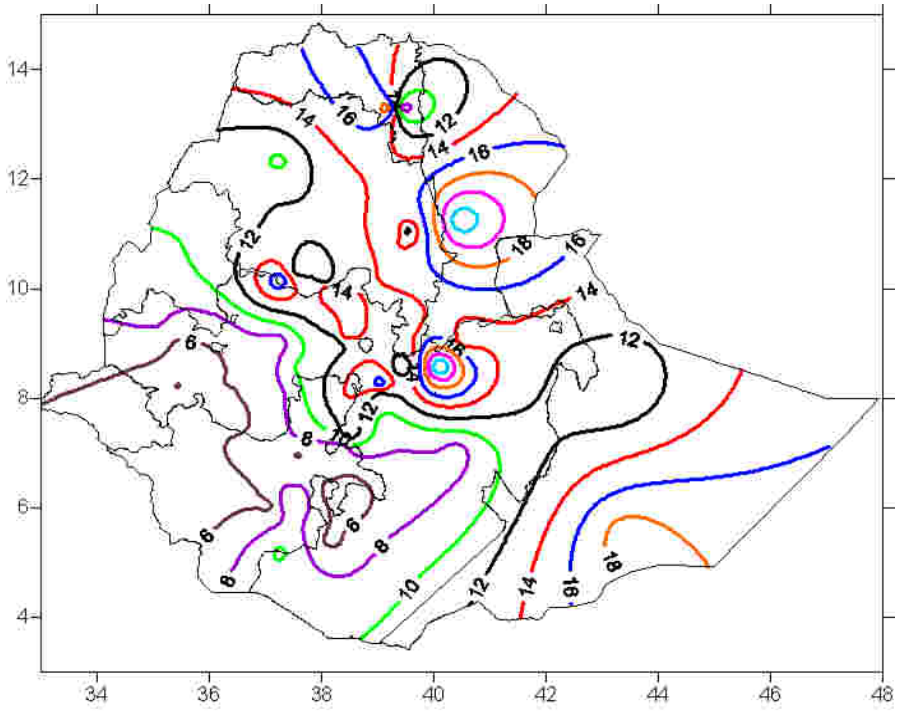


Fig. 16 Mean Dry spells of May Month Over Ethiopia

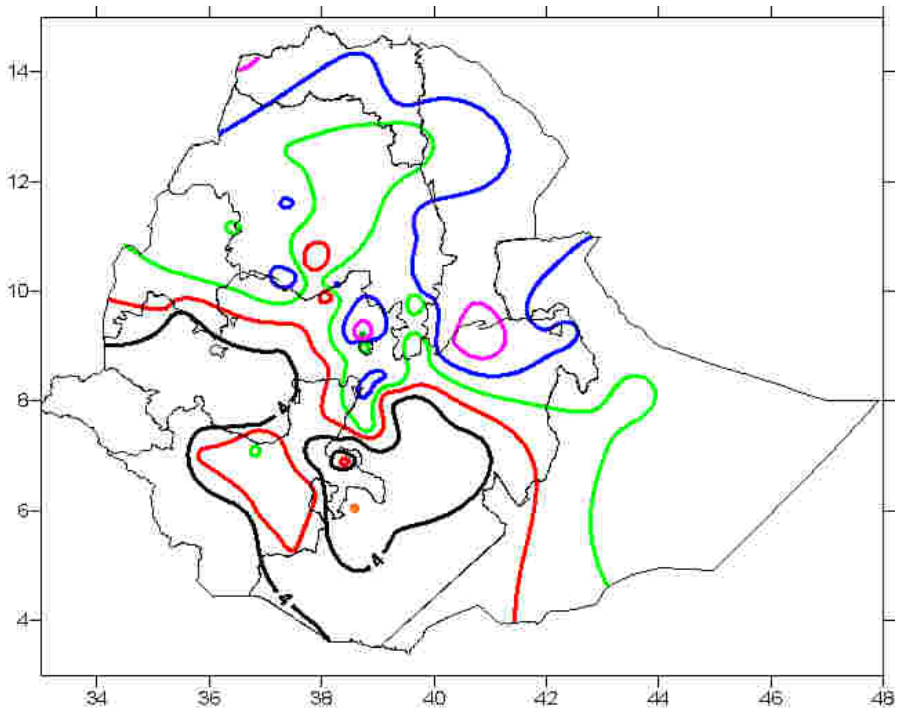


Fig 17 Standard deviation of May Month dryspell over Ethiopia

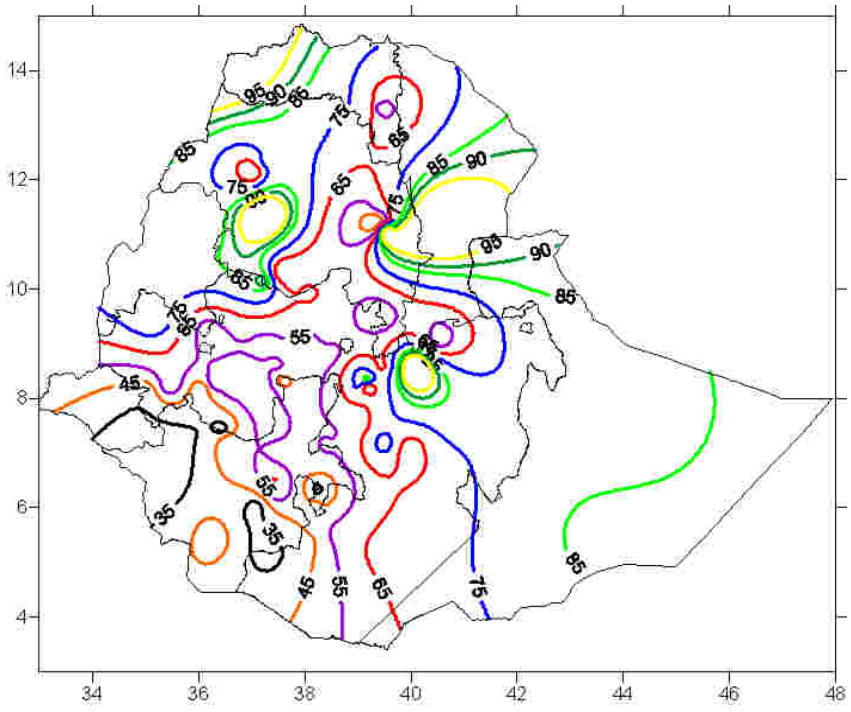


Fig.18 Maximum Dry spells of Belg Season

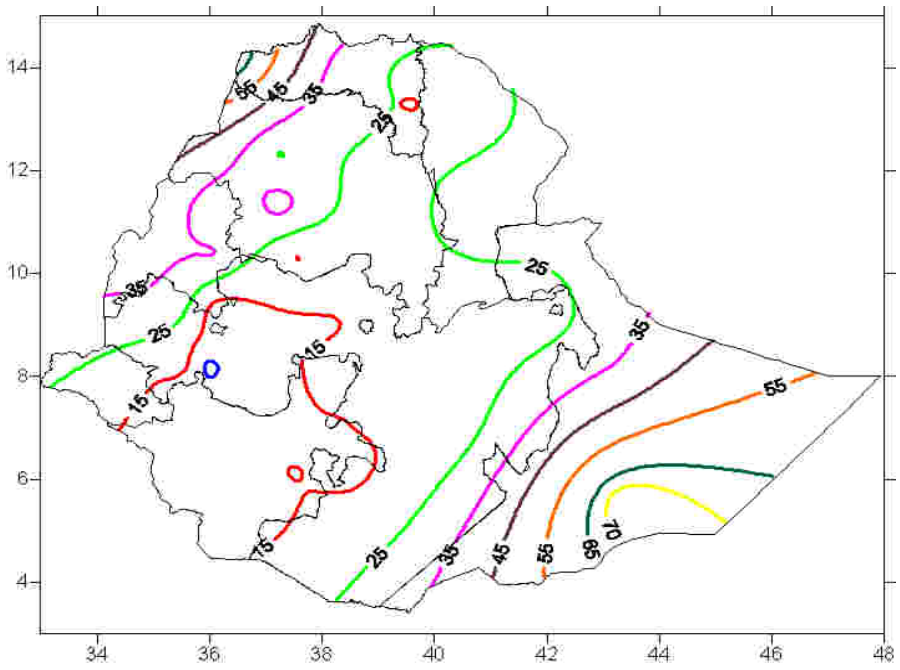


Fig.19 20th Percentil Dry spell of Belg season over Ethiopia

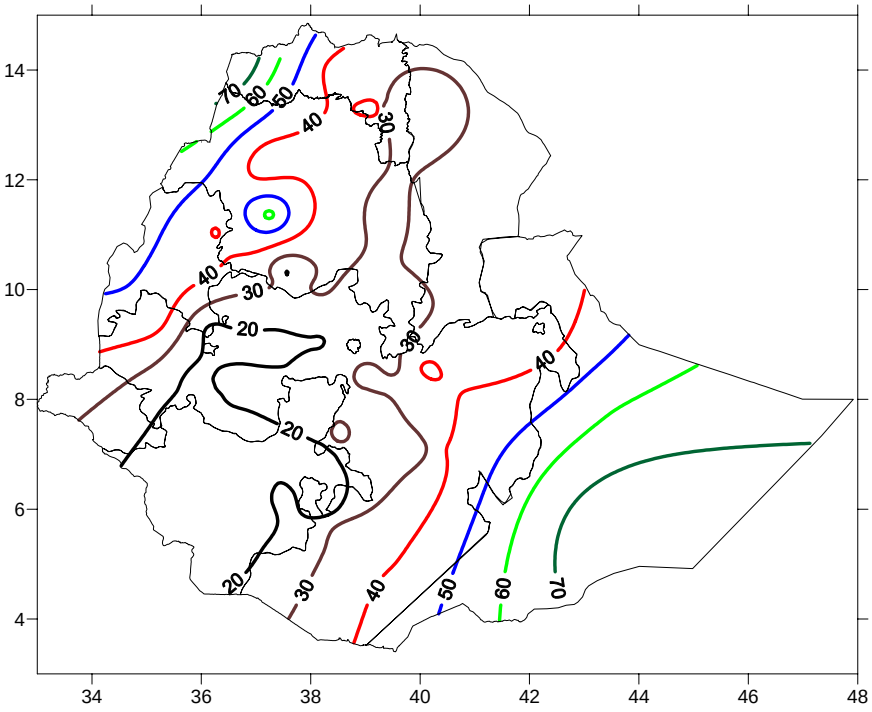
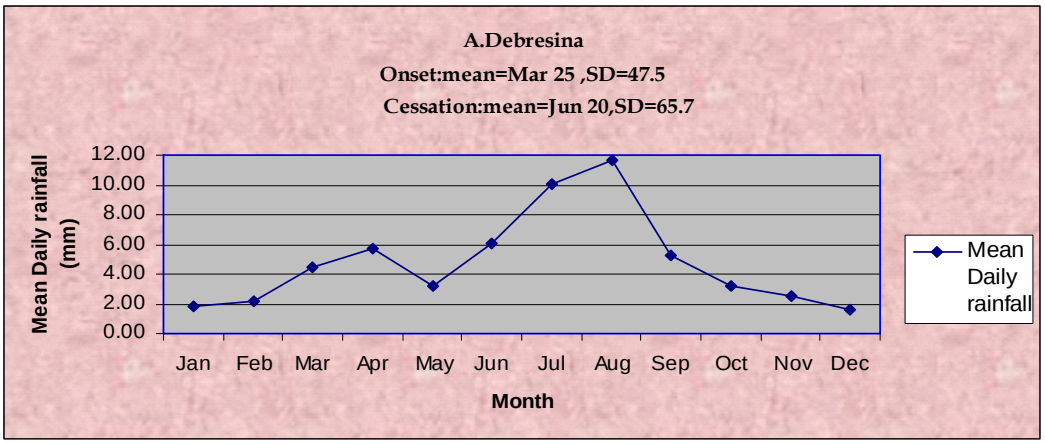
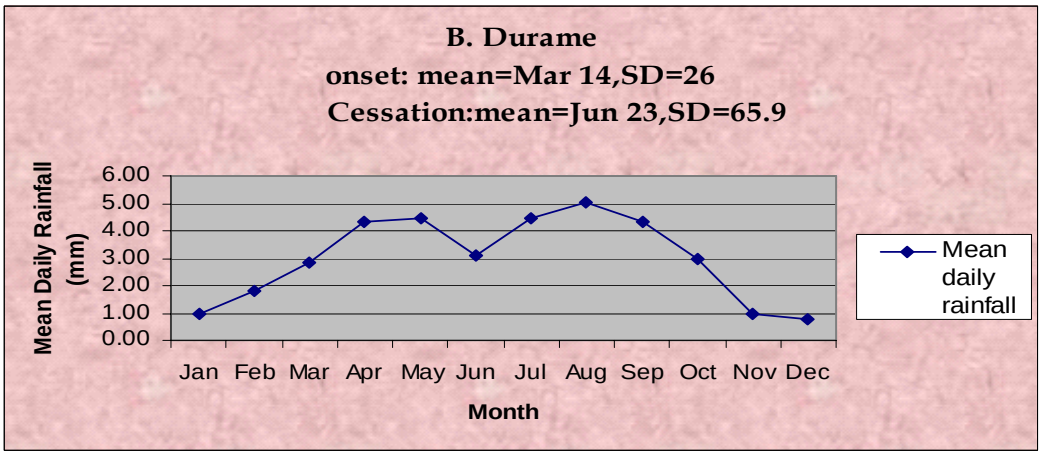
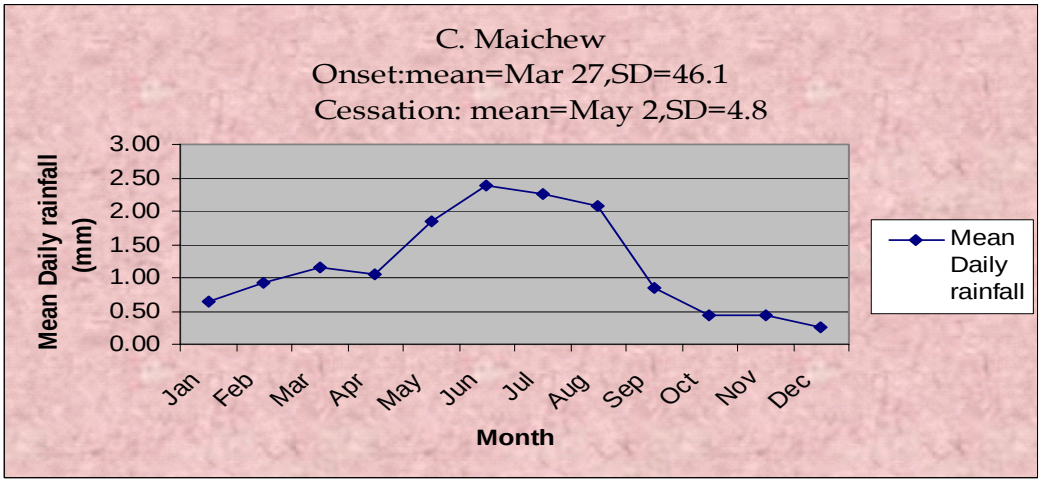


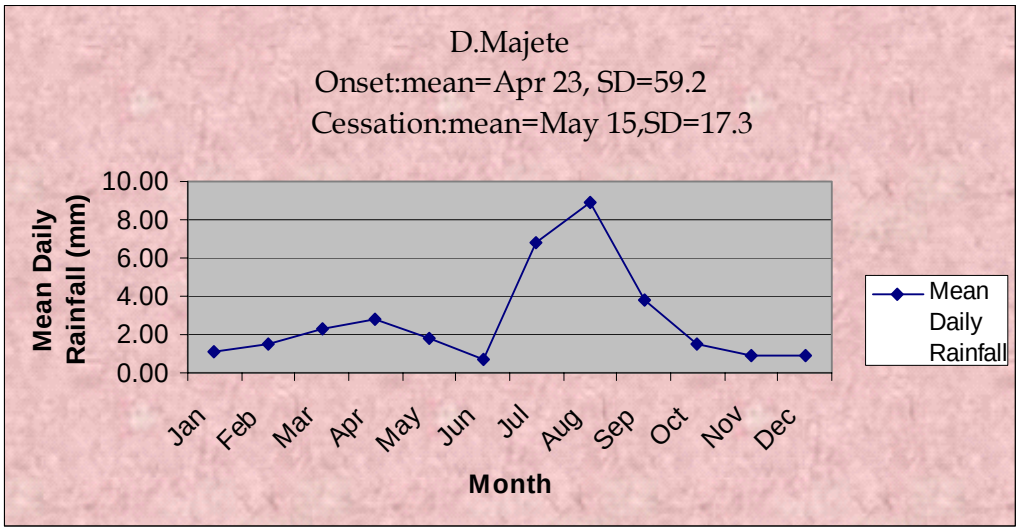
Fig. 20 50th percentil dryspell of belg season over Ethiopia

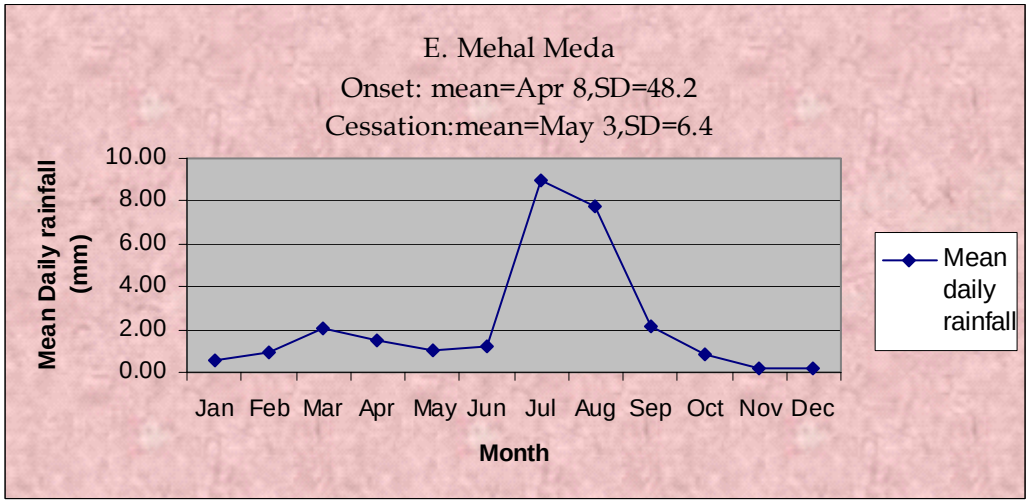
Fig. 21 Selected stations from Belg growing areas








D.Majete
Onset:mean=Apr 23, SD=59.2
Cessation:mean=May 15,SD=17.3
Mean Daily Rainfall (mm)
10.00
8.00
6.00
4.00
2.00
0.00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Mean Daily Rainfall


E. Mehal Meda
Onset: mean=Apr 8,SD=48.2
Cessation:mean=May 3,SD=6.4
Mean Daily rainfall (mm)
10.00
8.00
6.00
4.00
2.00
0.00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Mean daily rainfall

5. Conclusion

After a thorough examination of the daily rainfall patterns for 78 stations, we have been able to objectively determine the onset and cessation of the Belg rains of Ethiopia. It was found that there is more variability in the onset of the Belg rains than the cessation, and the highest variability was in regions where the rains start early in the year. During Belg, more than 5 continuous days of no rain are common over most parts of the country, especially over Belg growing areas, while extended breaks a total of exceeding 30 days are familiar out of the Belg growing areas.

Various atmospheric systems affecting Ethiopian rainfall, the temporal and spatial variations of rainfall discussed above could be the result of the topography and the geographical location of the country.

The great east African Rift valley (which runs northeast to south west across Ethiopia), the mountains and highlands to the right and left of this Rift valley, and the lowlands surrounding these mountains and highlands in every direction can be described as the country's main topographic features. The ENSO episode is strongly linked with the various atmospheric systems and rainfall distribution over Ethiopia. Hence, all these complicated factors directly or indirectly contribute to the complex nature of the onset, cessation and dry spell characteristics of the season.

From this complex nature of onset, cessation and dry spell characteristics of the Belg season, we can conclude that Belg is not suitable for rain-fed agriculture.

6. Recommendation

Critical and specific studies on the characteristic of onset and cessation of Belg season with respect to ENSO, NAO and blocking events is highly recommended, since the interannual variability of Belg season is so sophisticated.

Reference:

1) Endalkachew Bekele, 2000 "Daily Rainfall Analysis for Agricultural planning in central Ethiopia."

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3) NMSA, 2004 "Climate of Ethiopia Series Vol.I, No1; Rainfall"

4) Tesfay.H, 1989 "Onset and Cessation of Rains in Ethiopia."

5) Zewdu.T.Segele a, b and P.J.Lamb b, 2002" Characteristics of the main rainy season (Kiremt) in Ethiopia; Onset, Dry spell, End of main rainy system."

6) Evaporation data,

http://www.fao.org/ag/agl/aglw/aquastat/gis/index3.stm

7) Monthly Agro meteorological Bulletin Feb, Mar, 2006

List of Figures

Appendix

A Mean, Median, 20th and 80th percentile Onset of Belg Season

Stations	Lon	Lat	mean	median	20th	80th
A.A bole	38.75	9.03	1-Apr	29-Mar	1-Mar	13-May
A.A obse	38.70	9.00	20-Mar	17-Mar	7-Feb	1-May
A.Alem	38.40	9.05	21-Mar	11-Mar	11-Feb	21-Apr
Agarfa	39.82	7.27	22-Mar	23-Mar	25-Feb	8-Apr
Alemaya	42.02	9.43	23-Mar	23-Mar	23-Mar	23-Mar
Aleta Wondo	38.42	6.58	24-Feb	19-Feb	10-Feb	10-Mar
Ambo Agri	37.87	8.97	23-Mar	17-Mar	26-Feb	21-Apr
Arsi Robi	39.62	7.85	29-Mar	25-Mar	4-Mar	21-Apr
Assebe Teffer	40.87	9.07	4-Apr	20-Mar	4-Mar	9-May
Assela	39.13	7.95	21-Mar	12-Mar	27-Feb	22-Apr
Awash Sheleko	40.15	8.98	10-Jun	28-Jun	18-Apr	21-Jul
Awassa	38.48	7.08	10-Mar	11-Mar	14-Feb	24-Mar
Axum	38.70	14.13	29-May	8-Jun	28-Apr	25-Jun
B_Dar	37.42	11.60	21-May	21-May	4-May	9-Jun
Babile	42.33	9.22	26-Apr	13-Apr	10-Mar	10-Jul
Bedelle	36.00	8.45	27-Mar	28-Mar	4-Mar	21-Apr
Bore	38.55	6.00	12-Mar	15-Mar	23-Feb	28-Mar
Bullen	36.10	10.68	15-May	23-May	25-Apr	30-May
Bure	35.08	8.27	30-Mar	4-Apr	5-Mar	23-Apr
Chelelektu	38.37	6.02	17-Mar	22-Mar	3-Mar	28-Mar
Chena	35.85	7.00	1-Mar	3-Mar	17-Feb	13-Mar
Chida	36.78	7.17	26-Feb	2-Mar	5-Feb	13-Mar
Chira	36.27	7.75	23-Feb	22-Feb	5-Feb	6-Mar
Combolcha	39.73	11.12	2-Apr	29-Mar	29Feb	5-May
D.dawa	41.85	9.60	16-Apr	2-Apr	6-Mar	29-Jun
D.habour	43.55	8.22	12-May	30-Apr	8-Apr	24-Jun
D.Tabour	38.03	11.88	25-Apr	24-Apr	17-Mar	26-May
D.Zeite	38.95	8.73	4-May	13-May	18-Mar	13-Jun
Dangla	36.42	11.12	3-May	10-May	12-Apr	26-May
Debre Sina	39.75	9.87	25-Mar	10-Mar	11-Feb	17-Apr
Dejen	38.15	10.00	18-Apr	14-Apr	10-Mar	8-Jun
Dessie	39.63	11.10	6-Apr	29-Mar	5-Mar	9-May
Durame	37.95	7.20	14-Mar	17-Mar	13-Feb	3-Apr
Filiklike	38.17	10.05	4-May	14-May	23-Mar	12-Jun
Gedo	37.43	9.05	6-Apr	7-Apr	4-Mar	8-May
Ginir	40.70	7.13	2-Apr	29-Mar	15-Mar	10-Apr
Gode	43.58	5.90	19-Oct	19-Oct	10-Oct	27-Oct
Gonder	37.42	12.55	6-May	9-May	15-Apr	30-May
Guder	39.78	8.95	17-Mar	17-Mar	20-Feb	15-Apr
Hagere Mariam	38.33	5.60	22-Mar	29-Mar	10-Mar	1-Apr

Hossana	37.87	7.55	12-Mar	5-Mar	12-Feb	4-Apr
Humer	36.58	14.28	8-Jun	14-Jun	20-May	22-Jun
Hurumum	35.78	8.37	19-Mar	8-Mar	2-Mar	13-Apr
Jimma	36.83	7.68	7-Mar	5-Mar	9-Feb	24-Mar
Jinka	36.55	5.80	3-Mar	5-Mar	7-Feb	25-Mar
Kemba	37.00	6.05	7-Mar	7-Mar	16-Feb	26-Mar
Kibre Mengist	38.97	5.87	19-Mar	22-Mar	10-Mar	30-Mar
Kiltukara	35.22	9.72	5-May	1-May	19-Apr	28-May
Koka Dam	39.00	8.42	21-May	7-Jun	16-Mar	5-Jul
Konso	37.45	5.33	15-Mar	21-Mar	16-Feb	30-Mar
Kulumsa	39.13	8.13	25-Mar	15-Mar	17-Feb	4-May
Kumbi	37.47	8.12	25-Mar	20-Mar	23-Feb	7-May
Langano	38.80	7.52	3-May	11-May	15-Mar	17-Jun
Limu Seka	36.92	8.10	22-Mar	17-Mar	24-Feb	18-Apr
Maichew	39.53	12.77	27-Mar	27-Apr	6-Feb	2-May
Majete	39.85	10.01	23-Apr	6-Apr	1-Mar	8-Jul
Mehal Meda	37.43	10.25	8-Apr	3-Apr	2-Mar	15-Jun
Mekele	39.48	13.52	8-Jun	23-Jun	27-May	4-Jul
Meki	38.82	8.15	9-May	9-May	19-Mar	22-Jun
Melkassa	39.32	8.40	26-Apr	29-Apr	15-Mar	11-Jun
Metesso	36.88	7.43	1-Mar	1-Mar	10-Feb	21-Mar
Mille	40.75	11.42	1-Jul	23-Jul	20-Jun	6-Aug
Mirab Abay	37.78	6.30	23-Mar	20-Mar	4-Mar	14-Apr
Mizan Teferri	35.42	6.88	1-Mar	28-Feb	15-Feb	13-Mar
Morecho	38.42	6.92	2-Mar	5-Mar	11-Feb	18-Mar
Nazaret	39.28	8.55	25-Apr	18-Apr	10-Mar	12-Jun
Nedjo	35.45	9.52	30-Apr	27-Apr	17-Apr	17-May
Negelle	39.57	5.33	2-Apr	26-Mar	15-Mar	9-Apr
Rob Gebeya	37.87	10.55	16-Mar	11-Mar	27-Feb	28-Mar
Shashemene	38.60	7.20	15-Mar	12-Mar	13-Feb	9-Apr
Shone	37.97	7.13	29 Feb	25-Feb	8-Feb	15-Mar
Sululta	38.73	9.18	10-Apr	2-Apr	3-Mar	3-Jun
Teppi	35.25	6.98	8-Mar	10-Mar	16-Feb	21-Mar
welaita Sodo	37.75	6.85	8-Mar	12-Mar	12-Feb	28-Mar
Werebabu	39.75	11.32	9-Apr	25-Mar	22-Feb	27-Jun
Woldia	39.62	11.82	29-Mar	17-Mar	29Feb	18-Apr
Woliso Ghion	37.98	8.55	21-Mar	16-Mar	8-Feb	26-Apr

B. Mean, Median, 20th and 80th Percentile cessation of Belg Season

Stations	Lon	Lat	mean	median	20th	80th
A.A bole	38.75	9.03	25-May	6-May	1-May	24-May
A.A obse	38.70	9.00	30-May	6-May	1-May	1-Jun
A.Alem	38.40	9.05	23-May	2-May	1-May	21-May
Agarfa	39.82	7.27	11-Jun	20-May	4-May	23-Jun
Alemaya	42.02	9.43	7-May	1-May	1-May	10-May
Aleta Wondo	38.42	6.58	27-Sep	14-Nov	1-May	13-Dec
Ambo Agri	37.87	8.97	11-May	1-May	1-May	4-May
Arsi Robi	39.62	7.85	9-Jun	16-May	1-May	16-Jun
Assebe Teffer	40.87	9.07	16-May	3-May	1-May	9-Jun
Assela	39.13	7.95	28-Jul	3-Jun	1-May	11-Nov
Awash Sheleko	40.15	8.98	2-May	1-May	1-May	3-May
Awassa	38.48	7.08	15-Jun	12-May	1-May	30-Jun
Axum	38.70	14.13	3-May	1-May	1-May	2-May
B_Dar	37.42	11.60	2-May	1-May	1-May	1-May
Babile	42.33	9.22	15-May	1-May	1-May	29-May
Bedelle	36.00	8.45	9-Aug	22-Jun	1-May	2-Dec
Bore	38.55	6.00	18-Sep	29-Nov	1-May	16-Dec
Bullen	36.10	10.68	10-May	1-May	1-May	1-May
Bure	35.08	8.27	14-Jul	7-May	1-May	22-Nov
Chelelektu	38.37	6.02	1-Aug	19-Jul	3-Jul	20-Aug
Chena	35.85	7.00	16-Sep	16-Nov	5-May	30-Nov
Chida	36.78	7.17	12-Aug	5-Jul	1-May	3-Dec
Chira	36.27	7.75	29-Oct	18-Nov	29-Oct	14-Dec
Combolcha	39.73	11.12	21-May	1-May	1-May	10-May
D.dawa	41.85	9.60	12-May	6-May	1-May	20-May
D.habour	43.55	8.22	8-May	1-May	1-May	16-May
D.Tabour	38.03	11.88	13-May	1-May	1-May	4-May
D.Zeite	38.95	8.73	4-May	1-May	1-May	8-May
Dangla	36.42	11.12	14-May	1-May	1-May	5-May
Debre Sina	39.75	9.87	20-Jun	28-May	1-May	28-Jun
Dejen	38.15	10.00	23-May	1-May	1-May	20-May
Dessie	39.63	11.10	14-May	7-May	1-May	28-May
Durame	37.95	7.20	23-Jun	28-May	1-May	15-Jul
Filiklike	38.17	10.05	11-May	1-May	1-May	12-May
Gedo	37.43	9.05	30-May	1-May	1-May	27-May
Ginir	40.70	7.13	8-Jun	12-Jun	14-May	2-Jul
Gode	43.58	5.90	4-May	1-May	1-May	9-May
Gonder	37.42	12.55	2-May	1-May	1-May	1-May
Guder	39.78	8.95	2-Jun	4-May	1-May	29-May
Hagere	38.33	5.60	21-Jun	17-Jun	2-Jun	21-Jul

Mariam						
Hossana	37.87	7.55	16-Aug	23-Oct	1-May	8-Nov
Humer	36.58	14.28	1-May	1-May	1-May	1-May
Hurumum	35.78	8.37	3-Aug	16-Jun	1-May	29-Nov
Jimma	36.83	7.68	6-Sep	2-Nov	2-May	27-Nov
Jinka	36.55	5.80	25-Jun	15-Jun	25-May	24-Jul
Kemba	37.00	6.05	25-Aug	5-Aug	21-Jun	6-Dec
Kibre Mengist	38.97	5.87	20-Jun	23-Jun	5-Jun	4-Jul
Kiltukara	35.22	9.72	3-Jun	1-May	1-May	9-May
Koka Dam	39.00	8.42	19-May	1-May	1-May	21-May
Konso	37.45	5.33	28-May	26-May	2-May	19-Jun
Kulumsa	39.13	8.13	14-May	4-May	1-May	31-May
Kumbi	37.47	8.12	24-Jun	8-May	1-May	23-Oct
Langano	38.80	7.52	8-May	1-May	1-May	13-May
Limu Seka	36.92	8.10	29-Jul	1-Jun	1-May	11-Nov
Maichew	39.53	12.77	3-May	1-May	1-May	1-May
Majete	39.85	10.01	15-May	8-May	1-May	29-May
Mehal Meda	37.43	10.25	3-May	1-May	1-May	4-May
Mekele	39.48	13.52	2-May	1-May	1-May	1-May
Meki	38.82	8.15	6-May	1-May	1-May	12-May
Melkassa	39.32	8.40	9-May	1-May	1-May	5-May
Metesso	36.88	7.43	7-Sep	3-Nov	7-May	25-Nov
Mille	40.75	11.42	2-May	1-May	1-May	3-May
Mirab Abay	37.78	6.30	24-May	2-May	1-May	25-Jun
Mizan Teferri	35.42	6.88	5-Sep	19-Oct	1-May	14-Dec
Morecho	38.42	6.92	22-Aug	12-Aug	8-May	30-Nov
Nazaret	39.28	8.55	3-May	1-May	1-May	3-May
Nedjo	35.45	9.52	21-Jun	2-May	1-May	28-Oct
Negelle	39.57	5.33	10-Jun	15-Jun	5-Jun	25-Jun
Rob Gebeya	37.87	10.55	26-May	2-May	1-May	22-May
Shashemene	38.60	7.20	9-Jun	10-May	1-May	27-Jun
Shone	37.97	7.13	3-Sep	29-Oct	4-May	21-Nov
Sululta	38.73	9.18	18-May	1-May	1-May	24-May
Teppi	35.25	6.98	23-Aug	17-Oct	3-May	30-Nov
welaita Sodo	37.75	6.85	2-Sep	5-Oct	17-May	23-Nov
Werebabu	39.75	11.32	22-May	11-May	1-May	3-Jun
Woldia	39.62	11.82	8-May	4-May	1-May	16-May
Woliso Ghion	37.98	8.55	2-Jun	6-May	1-May	22-May

C. Standard deviation of dry spells in Belg season

Stations	Lon	Lat	Feb	Mar	Apr	May	Belg
A.A bole	38.75	9.03	**8.2**	**6.4**	**5.1**	**5.5**	**14.2**
A.A obse	38.70	9.00	**8.6**	**8.6**	**4.6**	**6.1**	**8.6**
A.Alem	38.40	9.05	8.2	6.5	5.9	6.6	10
Agarfa	39.82	7.27	5.9	8.9	5.2	3.9	16.9
Aleta Wondo	38.42	6.58	7.1	3.6	1.7	1.9	7.1
Ambo Agri	37.87	8.97	7.3	6.7	3.3	5.1	15.9
Arsi Robi	39.62	7.85	7.4	8.6	3.4	2.8	12.5
Assebe Teffer	40.87	9.07	8.8	4.9	5.9	8.9	11.1
Assela	39.13	7.95	7.8	6.6	5.7	4.4	12.9
Awash Sheleko	40.15	8.98	9.44	9.5	10.3	7.7	44.1
Awassa	38.48	7.08	7.4	5.9	4.2	3.3	9.9
Axum	38.70	14.13	3.5	8.2	6.7	6.8	16.6
B_Dar	37.42	11.60	3.9	6.7	7.7	7.2	22.5
Babile	42.33	9.22	6.2	10.8	6.9	7.2	20.2
Bedelle	36.00	8.45	8.2	4.9	4.2	3.4	11
Bore	38.55	6.00	7.2	3.4	2.6	1.8	10.42
Bullen	36.10	10.68	2.8	7.7	5.9	7.1	19
Bure	35.08	8.27	6.6	4.4	5.1	3.4	8.2
Chelelektu	38.37	6.02	6.7	5.5	2.8	2.9	11.7
Chena	35.85	7.00	7.3	2.9	2.11	5.3	7.5
Chida	36.78	7.17	9.1	4.5	4.8	6.1	11.93
Chira	36.27	7.75	9	4.33	3.5	3.2	9.9
Combolcha	39.73	11.12	7	7.6	7.8	7.4	24.9
D.dawa	41.85	9.60	7.5	7.8	3.8	6.6	12.9
D.habour	43.55	8.22	2.8	7.8	5.6	5.8	16.7
D.Tabour	38.03	11.88	5.4	6.6	4	5.6	9.2
D.Zeite	38.95	8.73	7.4	6.7	6.8	6.5	11.6
Dangla	36.42	11.12	6.2	7.7	6.3	5.8	15.5
Debre Sina	39.75	9.87	7.8	6.9	5.2	5.5	9.3
Dejen	38.15	10.00	7.6	7.8	6.6	4.3	12.2
Dessie	39.63	11.10	7.7	6.1	7.4	6.6	9.9
Durame	37.95	7.20	7.6	5.9	4.2	3.4	10.6
Filiklike	38.17	10.05	6.1	6.7	7.7	7.5	13.5
Gedo	37.43	9.05	7.4	4.3	7.7	4.1	12.2
Ginir	40.70	7.13	7.1	8.6	3	3.5	15.1
Gode	43.58	5.90	0	0	5.6	6.8	5.5
Gonder	37.42	12.55	6.2	7.1	6.4	5.9	17
Guder	39.78	8.95	7.9	7.3	5.6	5.3	11.7
Hagere	38.33	5.60	7.2	5.5	1.92	3.4	10.2

Mariam							
Hossana	37.87	7.55	8.12	7.1	4.4	4.8	12.3
Humer	36.58	14.28	0.35	0	7.7	8.3	18.8
Hurumum	35.78	8.37	5.5	7.3	4.3	3.8	13.1
Jimma	36.83	7.68	7.3	3.8	2.9	2.9	8.5
Jinka	36.55	5.80	6.7	4	2.2	2.8	9.9
Kemba	37.00	6.05	5.6	4.6	3.7	5.9	7.4
Kibre Mengist	38.97	5.87	8.3	7.2	2.6	3.8	14.9
Kiltukara	35.22	9.72	3.9	7.6	7.6	5.2	17.5
Koka Dam	39.00	8.42	8.2	6.5	8.5	7.3	17.4
Konso	37.45	5.33	7.3	5.1	2.2	5.1	11.3
Kulumsa	39.13	8.13	7.4	7.2	6.7	4.8	13.5
Kumbi	37.47	8.12	8.2	7.7	4.7	3.9	15.2
Langano	38.80	7.52	7	5.5	5.9	6.7	12.3
Limu Seka	36.92	8.10	8.2	5.8	3.6	3.8	12.9
Maichew	39.53	12.77	5.2	6.5	7.7	5.13	14.6
Majete	39.85	10.01	7.8	6.4	5.5	7.5	11.9
Mehal Meda	37.43	10.25	7.1	8.4	7.6	7.7	18.9
Mekele	39.48	13.52	6	7.9	6.8	7.4	14.5
Meki	38.82	8.15	7.5	7.1	6.8	7.4	12.6
Melkassa	39.32	8.40	6.7	7.8	6.8	6.8	12.3
Metesso	36.88	7.43	7.3	4.1	4.4	5.4	10.4
Mille	40.75	11.42	6.3	7.4	7.2	7.2	19.5
Mirab Abay	37.78	6.30	6.9	7	6.5	5.6	10.9
Mizan Teferri	35.42	6.88	7.2	4.9	3.6	2.9	6.3
Morecho	38.42	6.92	7.8	4.4	3.4	5.8	8.7
Nazaret	39.28	8.55	7.7	7.8	7.8	6.7	16.3
Nedjo	35.45	9.52	7.3	6.7	6.3	3.5	14.8
Negelle	39.57	5.33	6.5	8	2.8	4.2	14.7
Rob Gebeya	37.87	10.55	6.2	5.1	5.7	3.9	10.8
Shashemene	38.60	7.20	8.6	7.5	3.9	3.1	14.6
Shone	37.97	7.13	8.6	5.9	4.5	2.73	9.6
Sululta	38.73	9.18	6.9	7.2	4.7	9.1	11.3
Teppi	35.25	6.98	6.3	2.9	2.8	2.1	5.5
welaita Sodo	37.75	6.85	8.6	5.9	3.1	4.2	14.9
Werebabu	39.75	11.32	7.7	7.9	6.9	7.3	6.8
Woldia	39.62	11.82	7.2	6.1	5.7	6.5	10.5
Woliso Ghion	37.98	8.55	9	6.7	5.7	4.4	8.4

D. Maximum Dry spells of Feb, Mar, April, May month and Belg Season

Stations	Lon	Lat	Feb	Mar	Apr	May	Belg
A.A bole	38.75	9.03	29	31	21	31	75
A.A obse	38.70	9.00	28	27	22	31	42
A.Alem	38.40	9.05	29	27	27	31	52
Agarfa	39.82	7.27	29	31	27	19	81
Aleta Wondo	38.42	6.58	29	19	9	11	30
Ambo Agri	37.87	8.97	29	28	18	22	57
Arsi Robi	39.62	7.85	29	31	16	15	55
Assebe Teffer	40.87	9.07	29	20	30	31	46
Assela	39.13	7.95	29	31	24	23	60
Awash Sheleko	40.15	8.98	29	31	30	31	121
Awassa	38.48	7.08	29	31	22	15	47
Axum	38.70	14.13	29	31	29	31	82
B_Dar	37.42	11.60	29	31	30	31	121
Babile	42.33	9.22	29	31	30	31	81
Bedelle	36.00	8.45	29	29	20	15	58
Bore	38.55	6.00	29	16	11	8	42
Bullen	36.10	10.68	29	31	30	22	84
Bure	35.08	8.27	29	22	21	15	37
Chelelektu	38.37	6.02	29	23	11	11	52
Chena	35.85	7.00	27	12	10	23	29
Chida	36.78	7.17	29	19	20	23	48
Chira	36.27	7.75	29	16	11	14	36
Combolcha	39.73	11.12	29	31	30	31	121
D.dawa	41.85	9.60	29	31	20	31	72
D.habour	43.55	8.22	29	31	30	31	76
D.Tabour	38.03	11.88	29	31	21	29	53
D.Zeite	38.95	8.73	29	31	30	30	61
Dangla	36.42	11.12	29	31	28	19	78
Debre Sina	39.75	9.87	29	30	27	30	46
Dejen	38.15	10.00	29	31	30	23	60
Dessie	39.63	11.10	29	28	30	31	52
Durame	37.95	7.20	29	31	17	14	50
Filiklike	38.17	10.05	29	31	30	31	69
Gedo	37.43	9.05	29	22	30	17	51
Ginir	40.70	7.13	29	31	14	16	71
Gode	43.58	5.90	29	31	28	31	88
Gonder	37.42	12.55	29	31	30	27	78
Guder	39.78	8.95	29	31	25	27	61

Hagere Mariam	38.33	5.60	29	25	9	13	43
Hossana	37.87	7.55	29	31	17	18	58
Humer	36.58	14.28	29	31	30	29	119
Hurumum	35.78	8.37	29	31	19	16	64
Jimma	36.83	7.68	29	19	16	15	30
Jinka	36.55	5.80	29	23	11	14	52
Kemba	37.00	6.05	29	20	16	30	30
Kibre Mengist	38.97	5.87	29	29	12	13	58
Kiltukara	35.22	9.72	29	31	30	22	84
Koka Dam	39.00	8.42	29	31	30	31	76
Konso	37.45	5.33	29	20	10	19	30
Kulumsa	39.13	8.13	29	31	30	25	70
Kumbi	37.47	8.12	29	31	24	23	64
Langano	38.80	7.52	29	26	28	28	53
Limu Seka	36.92	8.10	29	27	14	16	56
Maichew	39.53	12.77	21	28	29	20.00	49
Majete	39.85	10.01	29	31	30	31	73
Mehal Meda	37.43	10.25	29	31	30	31	93
Mekele	39.48	13.52	29	31	30	31	71
Meki	38.82	8.15	29	31	30	31	59
Melkassa	39.32	8.40	29	31	30	31	57
Metesso	36.88	7.43	29	18	23	31	54
Mille	40.75	11.42	29	31	30	31	116
Mirab Abay	37.78	6.30	29	31	30	27	58
Mizan Teferri	35.42	6.88	29	20	19	14	25
Morecho	38.42	6.92	29	15	15	31	44
Nazaret	39.28	8.55	29	31	30	31	90
Nedjo	35.45	9.52	29	31	30	16	79
Negelle	39.57	5.33	29	31	14	19	68
Rob Gebeya	37.87	10.55	29	25	27	20	54
Shashemene	38.60	7.20	29	31	21	15	61
Shone	37.97	7.13	29	31	22	15	46
Sululta	38.73	9.18	29	29	22	31	58
Teppi	35.25	6.98	25	14	14	10	25
welaita Sodo	37.75	6.85	29	31	17	21	67
Werebabu	39.75	11.32	29	30	28	31	37
Woldia	39.62	11.82	29	30	25	27	59
Woliso Ghion	37.98	8.55	29	28	24	23	41