Analysis of Rainfall Variability in Rwanda for Small-scale farmers Coping Strategies to Climate Variability

Author: Frederic Ntirenganya

Corresponding Author: fredo@aims.ac.za/ntfredo@gmail.com

Affiliation: University of Lay Adventists of Kigali

Abstract

In this study we analysed rainfall data to assess rainfall variability in Rwanda for small scale farmer's strategies to climate variability and to determine the annual and seasonal trends of both rainfall and dry spells in Rwanda using 15 stations. The stations divide roughly into two groups. Some started from the 1930s, while others, including Kigali, started in the 1970s. Three stations, Rulindo, Rwaza and Save, had even earlier records, but no data was available from 1920 to 1929, so these early records were not used. The statistical methods used include time series. Instat + Version 3.37 and R programming were used to determine the annual and seasonal rainfall totals, annual and seasonal number of rain days, ploughing and planting date, maximum spell length, crop water requirement and end of the season. GIS Software was used for data visualisation in the maps. The observation of rainfall and number of rain days totals show that there is no visible trend. The results shows that we did not find a conclusive evidence of climate change in the rainfall data analysis and this should be investigated further by making a statistically significant difference between the different types of years. The maximum dry spell was found in March 1985 with dry spell length of 21 days in Butare. It was observed that the trend of dry spells increases seasonally in the results of the analysis. The evidence from this study shows that long dry spell length will lead to poorer yields of the crops due to stressed plants which experience dry spell in their growing season. From the results, seasonal dry spell has clear impact in crop production and good yield is obtained by accurate timing of ploughing and planting period in order to plant the seeds on time which gives opportunity to use available water for each rainy season. The application of irrigation will help in maintaining crop water requirements for farmers in various areas and if irrigated areas are expanded, the total crop yields will increase.

We suggest that further study could be carried out to find out the effect of dry spell in water requirement for crop factor according to the growth stages: initial stage, crop development stage, mid-season stage and late season stage). We also suggest further study to investigate the extent to which the pattern of rainfall is the same in El Ni~no, La Ni~na and normal years.

Keywords: *Rainfall Variability, Small Scale Farmers, Coping Strategies*

1. INTRODUCTION

Rwanda is a developing country, where most of the population is dependent on climate sensitive rainfed agriculture affecting about 61.8% small scale farmer's population and wage farm 9.9 % (NISR, 2011). Rainfed agriculture is very important for the economy of Sub-Sahara Africa (SSA). Some countries of SSA are leading in grain food (CROPS, CEREALS) rainfed agriculture, in the world.As an example, the rainfed agricultural sector accounts for more than 95% of farmed land in Sub-Sahara Africa while it is 90% for Latin America, 60% for East Asia and 75 % for the Near East and North Africa. Moreover, it is the source of the everyday life (daily) food for the poor communities in most of the developing countries (Wani et al., 2009). Unfortunately, despite all the recent progresses achieved in (attempts in) improving productivity and environmental conditions in many developing countries, a large number of families in Africa and Asia, where rainfed agriculture is the main agricultural activity, are still facing poverty, hunger, food insecurity and malnutrition (Wani et al., 2009).

Rwanda is situated in Eastern Africa and it shares the borders with Tanzania in the East, the Democratic Republic of Congo in the West, Uganda in the North and Burundi in the South. The country covers an area of 26 338 square kilometers and among it 1390 km is covered by water dominated by lakes. It is highly elevated known as the country of a ``thousand hills". The fourth national population and housing census conducted in August 2012 in the country shows that the total population of Rwanda was 10 515 973 persons. This gives an estimated population density of about 415 individuals per square kilometers, making Rwanda one of the most densely populated countries in the World and the most populated in Africa (NISR, 2014).

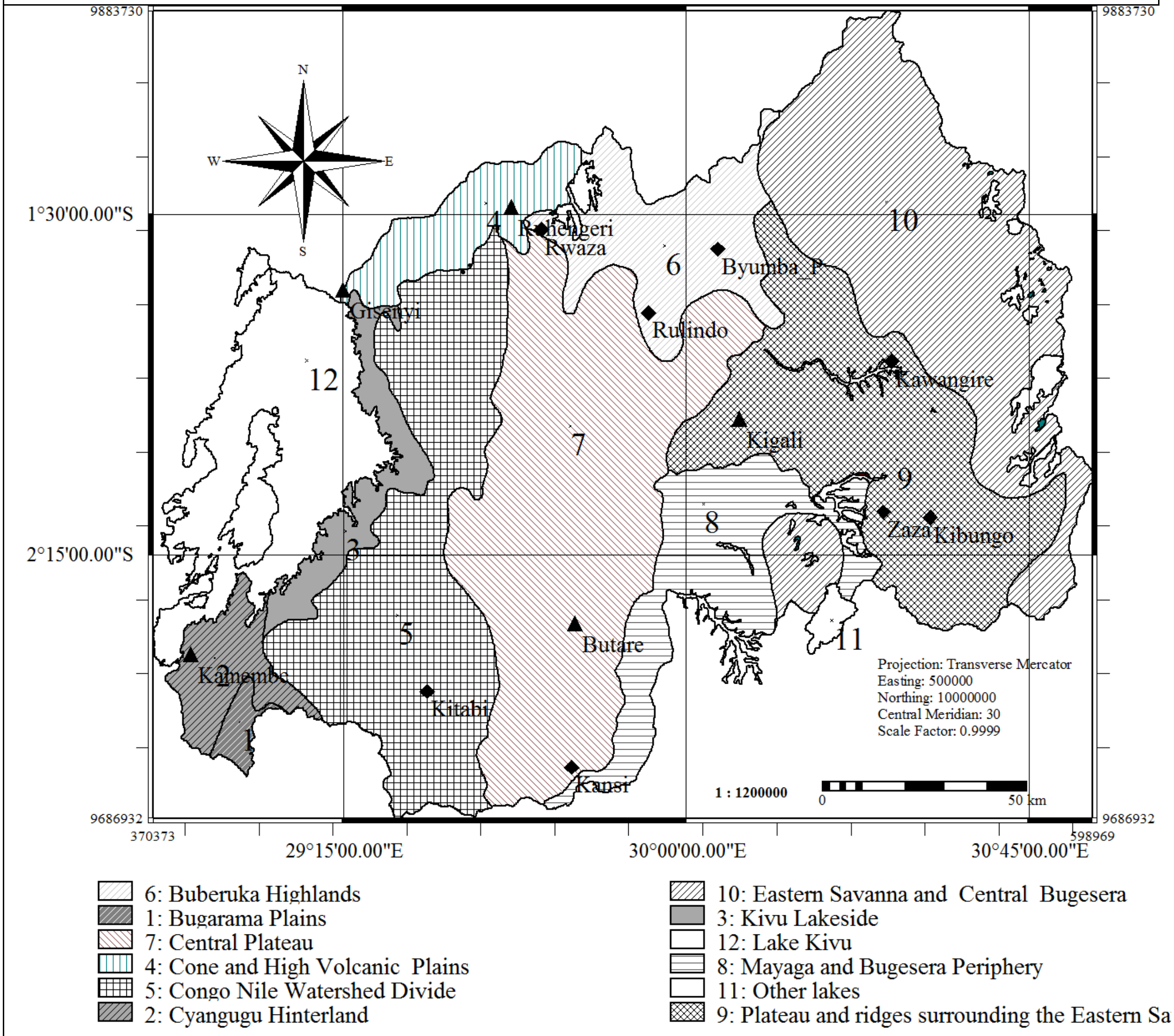
Rwanda has a moderate climate with an annual average temperature of 19 degree Celsius. It is divided into three agro-climatic zones which are a high-altitude region, central plateau, and plateau of eastern lowlands and the west (FAO, 2005).It has two main rainy seasons that are a short rainy season (mid-September to mid-December) locally known as ``Umuhindo`` which is characterised by a heavy precipitation in November and a long rainy season (March to May) locally known as ``Itumba``, which is characterized by a higher heavy precipitation in April compared to that in November.Rwanda is a country dominated by a complex topography, with terrain including mountains, hills, lakes and lowland savannah. The terrain can be classified into two broad topographic regions: (i) the mountainous terrain in the West (by the edge of Lake Kivu and the Congo-Nile divide) and (ii) the East characterized by the Central plateau and Eastern lowland plateau. This complexity in terrain leads to a complex climate and extremely diverse cropping practices, with maize (Zea Mays), plantain (Musa ssp), cassava (Munihotesculenta), potato (Solanum tuberosum), climbing and bush beans (Phaseolus vulgaris), wheat (Triticum aestivum) and rice (Oryzaglaberrima or Oryzasativa) all cultivated in different parts of the country (FAO, 2005).

In comparison to other countries in East Africa, there have been relatively few attempts to study Rwanda's historical rainfall data. UNEP (2011) suggests that "Rwanda is experiencing more irregular and unpredictable rainfall patterns, with less weather predictability for farmers as a result". However, it should be noted that these conclusions were based on an analysis of one climate station situated in Kigali city, which has a relatively short time-series of data starting from 1971. The climate of Kigali is also not representative of the entire country. Other literature about the rainfall in Rwanda has focussed on agricultural applications or on an understanding of large scale drivers of climate. Ilunga et al. (2004) used inter-monthly pluviometrics to differentiate rainy seasons. The paper found influences on Rwanda's rainfall from both the ITCZ and from the Atlantic monsoon. Ilunga and Mugwaneza (2008) used historical rainfall data to determine the best planting date for the September-January agricultural season. They found that the last decade of September is the period the most favourable for planting in almost the whole country except in the region of Eastern low plateau where the favourable sowing period is from 13th to 24th of October. The paper also suggested that the start of the rains would be seen as a failure if there was a period of 7 consecutive dry days in the month after the season began.

2. METHODS

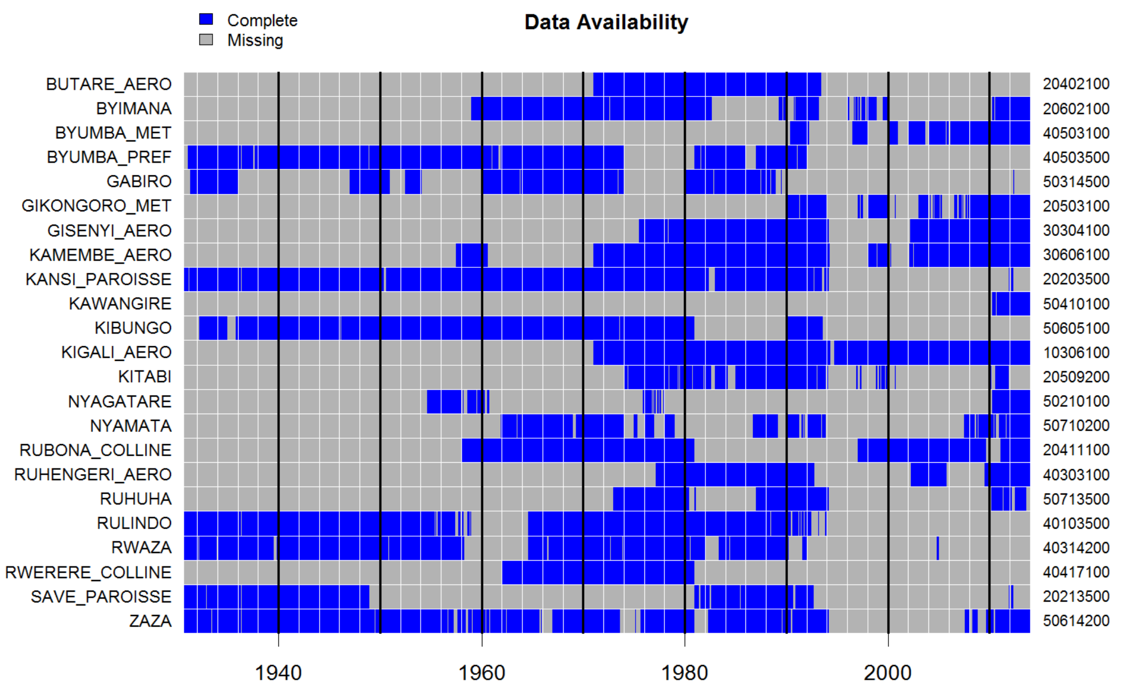
The study is concerned with Rwandan climate where the choice of our analysis has been drawn at the some stations representing others based on data availability (gaps) in data recording as shown in fig. 2. The daily rainfall data used in the analysis was taken from 1971 to early 2014. The secondly data used were provided by the Rwanda Meteorological Office. A major portion of data from 1994 is missing data. The data count 568 gaps (3:5%) missing values due to the Genocide against Tutsi in 1994 where most of meteorological stations of Rwanda were unattended for many days. The Figure 1 shows the location of the main climatic stations in Rwanda. Figure 2 indicates the length and completeness of the rainfall records at each site. Their climatic data are managed by a system called CLIMSOFT Version 4.1 and an initial version of the information in Fig. 2 was used by them to identify some data that was available in their paper archive, but that had not yet been computerised.

Fig. 1 –The main climatic stations location in Rwanda



These data were entered to produce Fig. 2.GIS software was used for maps visualization. Instat Plus Version 3.37 and R programming were used to determine the annual and seasonal rainfall totals, annual and seasonal number of rain days, ploughing and planting date, maximum spell length, crop water requirement and end of the season.

Fig. 2 Data availability for the Rwandan stations (available data is shown in blue). There is a gap from 1994 for most stations, due to the genocide against the Tutsi.



From the information in Fig. 2 the stations divide roughly into two groups. Some started from the 1930s, while others, including Kigali, started in the 1970s. Three stations, Rulindo, Rwaza and Save, had even earlier records, but no data was available from 1920 to 1929, so these early records were not used.

The information from Fig. 2, together with the locations of the stations, shown in Fig. 1, was used to determine the stations for

the analyses. Table 3 lists these sites in order of increasing altitude. In Rwanda there are two seasons each year, with "Season A" from about September to December and "Season B" from February to June. July and August are the driest months. In each case the records were therefore re-arranged to start the year in August. In graphs the year 2014 is defined as the "year" from August 2013 to July 2014.

Table 1 Stations used in the analyses

Station	Alt(m)	Lat	Long	Start[1]	End[2]	Years[3]	OND[4]	MAM[4]	Rain(mm)[5]
Nyamata	1428	-2.150	30.450	1962		11	24	23	997
Kawangire	1473	-1.824	30.448	1931		44	60	56	994
Zaza	1515	-2.155	30.431	1931		48	64	60	1083
Gisenyi	1554	-1.667	29.250	1976		26	30	29	1191
Kigali	1567	-1.950	30.117	1971		40	43	42	990
Kamembe	1591	-2.467	28.917	1958		34	37	40	1404
Kibungo	1600	-2.167	30.533	1933		49	53	54	1001
Kansi	1670	-2.717	29.750	1931	1994	57	62	61	1159
Rubona	1706	-2.460	29.760	1958		36	38	39	1182
Butare	1760	-2.610	29.730	1971	1993	21	22	23	1234
Rulindo	1800	-1.717	29.917	1931	1993	43	52	52	1242
Rwaza	1800	-1.533	29.683	1931	1992	39	49	49	1311
Ruhengeri	1878	-1.483	29.617	1978		20	22	21	1310
Kitabi	2262	-2.550	29.433	1974	1994	11	15	18	1675
Byumba	2276	-1.577	30.069	1991		7	14	15	1166

[1] The start of the record from August. Hence for example 1931 is a start from August 1930 to July 1931
[2] Where no end is given, the station is continuing. Data were available to December 2013
[3] The number of complete years, i.e. from August to July, with no missing values
[4] The number of years with no missing values in the October to December or march to May periods
[5] The mean annual rainfall (August to July) for the years where there were no missing values

With the large number of missing observations the decision was made to analyse the data for all years or seasons where there were no missing values. Hence, there is a risk that some apparent differences between stations could partly be due to differences in the years for which data are available for those stations in the interpretation of the results.

This paper concentrates on the variability of the rainfall data and the first results are general. They give summary statistics for the rainfall totals, the number of rain days and the length of the longest dry spell, for each of the two rainy seasons. October to December is defined as the period for season A and March to May as season B. A threshold of 0.85mm was used to calculate the number of rain days and the dry spells. This threshold was used to facilitate a fair comparison between the stations as small rainfalls are sometimes recorded inconsistently between stations and for different periods within a station. Also, trace amounts of rainfall are not easily detectable in climatology analysis. We choose a slight higher threshold to avoid any complications for the recording of very small values of rainfall data.

The results are presented as tables for the set of stations and as graphs for examples of the individual stations. For extension staff, Non-Government Organisation (NGO) staff and others who liaise with farmers and for farmers themselves the results are shown as time-series graphs. They have the years on the x-axis and the required data (totals, number of rain days, and lengths of longest dry spells) on the y-axis. These graphs serve two key purposes. The first is to give users the long-term perspective. It always shows that there is considerable year-to-year variability and usually shows little or no evidence of a trend. Farmers remember the recent years and are usually very keen to see the long-term perspective, provided by the graphs.

The second purpose of the graphs is for intermediaries and farmers to be able to quantify this variability themselves. This is often done simply by them putting a strip of paper over part of the graph and counting the number of points that remain visible. They then use this to calculate the corresponding risks. Our experience is that farmers are well able to do, and understand these calculations, irrespective of their level of formal education.

The tables provide examples of the risks for all the stations analysed. Here one aspect of considerable interest is the relative risks within a site of the two seasons.

Results are then provided on the start and end of the rains. For season A the start of the rains was defined as follows: The first planting was the first occasion from 10 September with 20mm or more, within a 3-day period. And the successful planting used the definition above, with the additional condition of no dry spell of 10 days or longer within the subsequent 21 days.

The results are again presented as time-series graphs for examples of the stations, and in tabular form for all the stations.

For selected stations, a second graph shows the risk of a dry spell of 10 days or more, in the following 21 days, for alternative planting dates from 1st September for Season A and from 1st February for Season B. Information from this type of graph can inform users of the smaller risk from delayed planting. This risk must be balanced by a consideration of the loss of season length.

For Season B the end was defined as follows: the end of the rains was defined as the last occasion before 1st June with more than 10mm on a single day. And the end of the season was then the day on which a simple water balance dropped to zero, after the end of the rains. For this component we took the soil capacity as 60mm and the evaporation as 5mm per day.

For selected stations, we present the results as time-series graphs. They are also summarised in tabular form for all the stations. These results are also used to describe the length of the two seasons together.

In this general section, we do not present results on the length of the individual seasons. This is because the January and February period between the two seasons remains fairly rainy. Hence the distinction between these seasons depends on the farmer's cropping strategy. Hence we first consider the crops and then return to a discussion of the individual seasons for particular cropping strategies. The second part of the results provides tables of some of the common crops grown in Rwanda.

Examples are taken from these crop tables to show how they can be used in conjunction with the rainfall data to compare risks for different cropping strategies. These comparisons are then used to show how risks can be compared by the farmers themselves and used as part of discussions by them to identify their preferred cropping strategies.

The methods used in this study have the advantage of being simple enough to be completely transparent for farmers, and of being simpler to consider for scaling-up exercise for the whole country.

3. RESULTS

The rainfall data contained the mixture of zero records (dry days) and those of rain (wet days). The problem with rainfall data is to choose an optimal threshold level needed for the threshold method for measuring rainfall from space with a satellite. The smallest amount recorded for this study is 0.1mm and the largest is 106 mm. The precipitation which is less than 0.01 inches is called trace amounts of rain and it is recorded in some countries. Trace amounts of rainfall are not easily detectable in climatology analysis. We choose a slight higher threshold, 0.85 mm to avoid any complications for the recording of very small values of rainfall data. i.e. The use of 0.85 mm as the threshold was to eliminate errors that can occur while recording small rainfall values with Climate Research Unit and Global Precipitation Climatology Centre gridded-gauge analyses respectively in the interannual variability of the Africa-wide mean monthly rainfall as modified on 20 September 2018.

Fig. 3 shows the total rainfall for stations, namely Butare and Kigali. These were chosen partly because of data availability for the Rwandan stations (available data is shown in blue) in fig.2.

There is a gap from 1994 for most stations, due to the genocide against the Tutsi. .

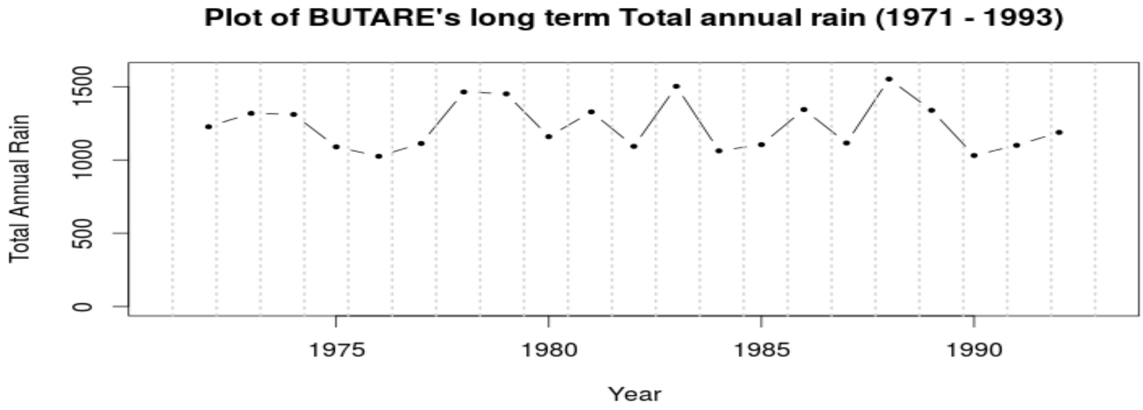


Fig. 3Annual rainfall total for Butare

Fig.3 shows that the maximum rain amount in Butare records from 1972 to 1993 is 1578.3mm per year (occurred in 1989) and the minimum is 482.9 mm per year (occurred in 1972). The 1971 and 1994 years were not considered in the analysis because of the missing values. The annual rainfall totals does not show any obvious visible trend, therefore the data do not yet provide climate variability for this region.

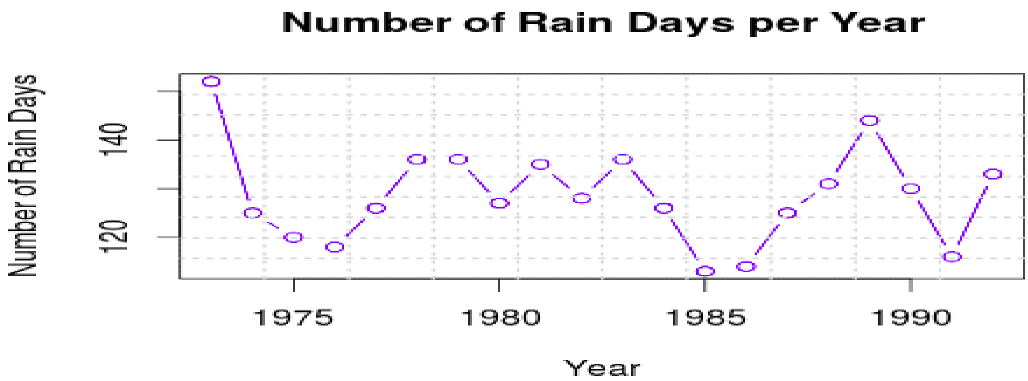


Fig.4 Numberof rain days for Butare station (1972-1993)

In Fig. 4 we analysed the number of rain days per year for Butare station. The minimum and maximum number of rainy days per year is 113 days and 152 days recorded in 1992 and 1973 respectively. There is no visible trend in annul rainy days total in Butare. Hence, there is no climate change in total of rainy days.

Seasonal rainfall totals.

OND season.

Fig.5 shows that the highest amount of rain was 532.1 mm recorded in 1976. The smallest was286.8 mm which occurred in

1983. There is no visible trend, hence no indication of climate change.

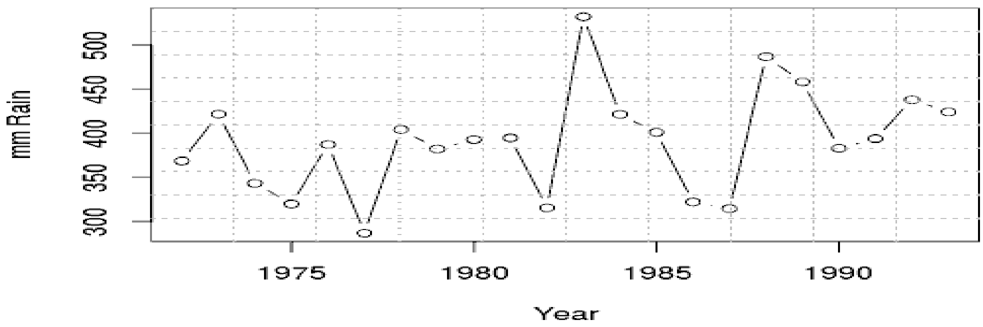


Fig. 5 Seasonal rainfall totals (October to December) for Butare (1972-1993).

Fig.6 shows that the highest amount of rain was 671.7 mm recorded in 1984. The smallest was 203.5 mm which occurred in 1981. There is no visible trend, hence no indication of climate change.

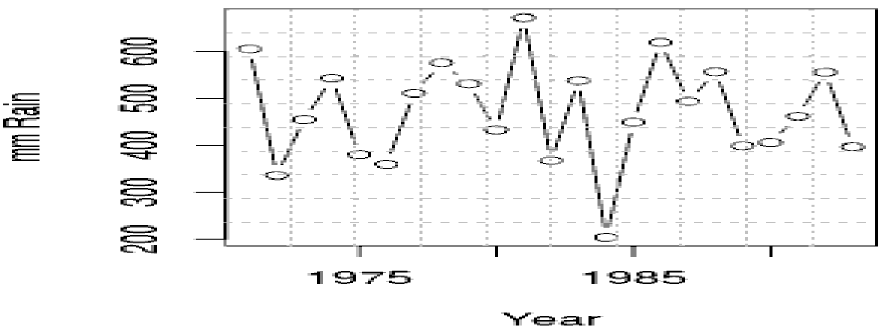


Fig. 6 Seasonal rainfall totals (March to May) for Butare (1972-1993).

3.2 Number of rain days for Butare

Fig.7 shows that the highest rain count was 65 days recorded in 1983. The smallest was 50 days which occurred in 1988. There is no visible trend; hence no indication of climate change experienced in seasonal rainy days totals.

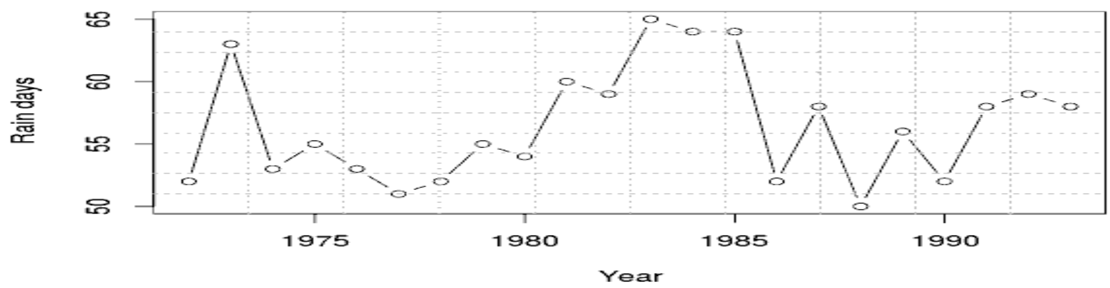


Fig.7 Number of rainy days for the OND season in Butare (1972-1993)

Fig.8 shows that the highest rain count was 65 days recorded in 1983. The smallest was50 days which occurred in 1998. There is no visible trend, hence no indication of climate change.

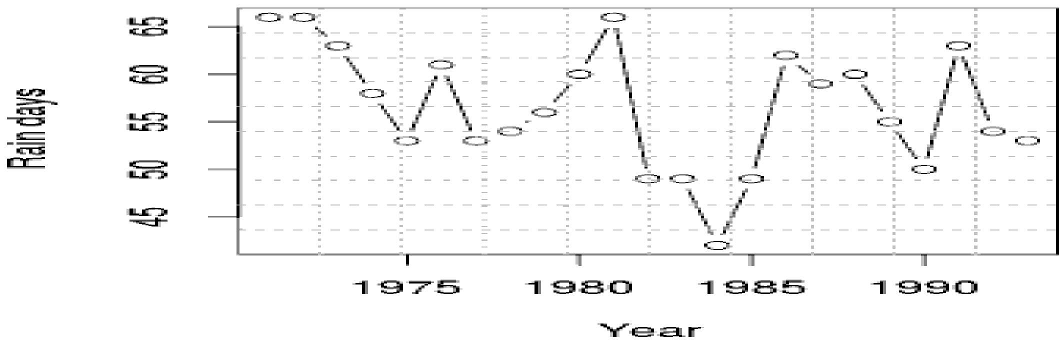


Fig. 8 Number of rainy days for MAM season in Butare

Fig.9 shows that the highest rain count was 66 days recorded in 1972. The smallest was 42 days which occurred in 1984. There is no visible trend, hence no indication of climate change.

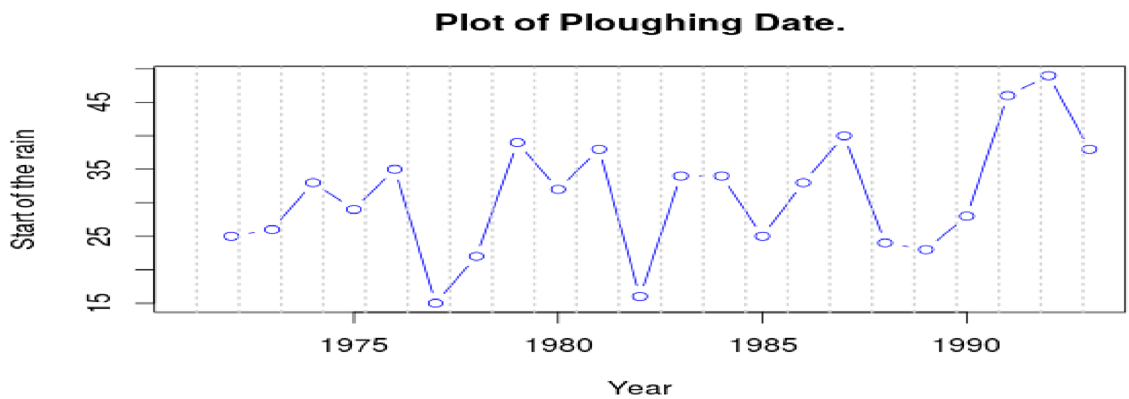


Fig. 9 Ploughing date for Butare Station (1972-1993)

Fig.10 shows that the earliest date for ploughing was fifth day of the year occurred in 1977 and the longest ploughing date was forth ninth (49^{th}) day of the year occurred in 1992. Record that in this study the year has been shifted to start from 1^{st} August to end of July. There is no visible trend, hence no indication of climate change.

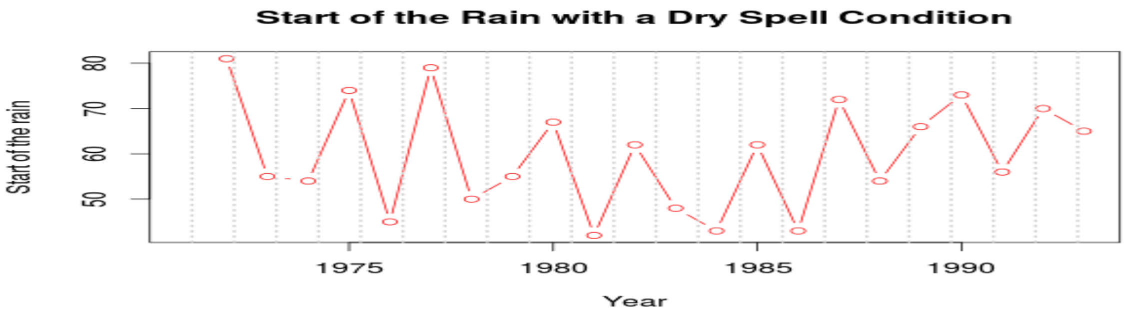


Fig. 10 Start of the rain with dry spell for Butare Station (1972-1993)

Fig. 10 shows the start of the rain with dry spell in Butare. It shows the risk of a dry spell of 10 days or more, in the following 21 days, for alternative planting dates from 1^{st} September for Season A. The longest start of the rain was 80^{th} day of the year and the shortest start of the rain with dry spell was 45^{th} day of the year. It informs the smaller risk from delayed planting.

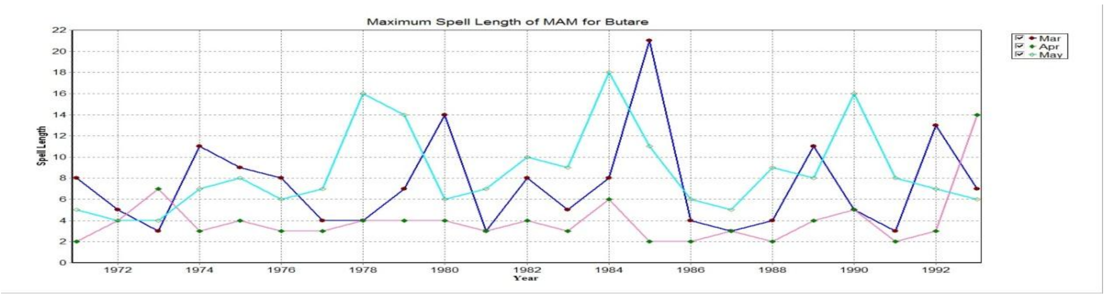


Fig. 11 Maximum spell length of March to May season in Butare(1972-1993)

The trend of dry spell lengths increases with time. The longest dry spell length was 21 days occurred in March 1985 for season B in Butare as shown in fig.11 and the smallest spell length was 2 days occurred in April 1972, 1985, 1986, 1988 and 1991. It was observed that the length of dry spells increases exponentially from March to May. The 4 day long dry spell having the high chances of occurrence than any other counterpart day long dry spell.

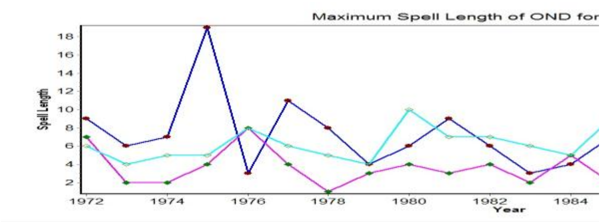


Fig. 12 Maximum Spell length for October to December rainy season in Butare(1972-1993). The longest dry spell length was 20 days occurred in October 1975 for season A in Butare as shown in fig.12 and the smallest spell length was 1 day occurred in November 1978. It was observed that the length of dry spells increases exponentially from October to December. The 4 day long dry spell having the high chances of occurrence than its counterpart 7 day long dry spell.Table 2. Seasonal rainfall totals (mm)

Station	Season A – October to December			Season B - March to May		
	20 %	Median	80%	20%	Median	80%
Nyamata	240	308	409	299	363	461
Kawangire	250	311	394	342	381	454
Zaza	307	361	417	322	395	505
Gisenyi	332	337	429	280	378	437
Kigali	259	317	354	292	363	445
Kamembe	412	457	559	375	414	504
Kibungo	230	301	371	327	385	479
Kansi	289	349	428	348	448	529
Rubona	280	381	470	353	471	550
Butare	321	393	431	390	461	566
Rulindo	279	355	426	386	490	596
Rwaza	318	441	532	409	497	569
Ruhengeri	350	404	456	418	460	612
Kitabi	417	499	601	608	641	726
Byumba	250	357	433	320	444	522

Apart from Kamembe, Season B, i.e. March to May usually has more rain than Season A.

Table 3 Number of rain days

Stations	Season A – October to December			Season B - March to May		
	20%	Median	80%	20%	Median	80%
Nyamata	27	33	46	25	36	46
Kawangire	26	34	41	31	35	42
Zaza	31	39	43	32	40	46
Gisenyi	45	48	54	38	47	51
Kigali	34	39	44	35	39	42
Kamembe	53	56	60	44	49	54
Kibungo	27	32	42	33	38	44
Kansi	26	36	43	26	37	45
Rubona	35	41	48	39	44	49
Butare	37	45	50	41	45	47
Rulindo	31	38	47	37	45	51
Rwaza	40	45	52	43	50	57
Ruhengeri	46	52	57	48	55	58
Kitabi	49	52	59	50	56	60
Byumba	31	43	48	39	47	51

In the two seasons, the median number of rain days is similar in some of the stations, for example, in Gisenyi there was an average of 48 rain days in Season A, and 47 in Season B. This average is roughly 15 days per month, i.e. half the days have rain.

The 48 rain days at Gisenyi produced the 337mm of rain, (Table 1) i.e. a mean rain per rain day of 7mm. Rainfalls had a slightly higher mean, of 8mm in Season B.

Table 4: Length of the longest dry spell

Stations	Season A – October to December			Season B - March to May		
	20%	Median	80%	20%	Median	80%
Nyamata	7	10	15	9	13	16
Kawangire	8	11	16	8	10	13
Zaza	6	9	14	8	10	15
Gisenyi	5	7	9	6	9	12
Kigali	6	8	11	8	10	13
Kamembe	4	6	7	6	8	11
Kibungo	8	11	17	7	11	15
Kansi	8	10	15	7	10	16
Rubona	7	9	14	7	9	12
Butare	6	8	9	7	9	14
Rulindo	6	10	14	8	10	13
Rwaza	5	9	12	5	8	12
Ruhengeri	6	8	10	5	7	10
Kitabi	6	7	8	6	8	11
Byumba	6	10	19	6	9	11

In the two seasons, the median Length of the longest dry spell is similar in some of the stations, for example, in Rubona there was an average of 9 Length of the longest dry spell in Season A and in Season B.

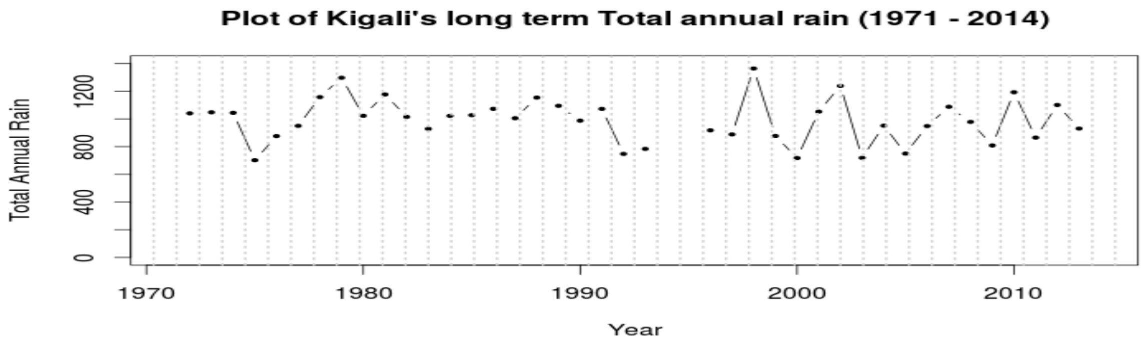


Fig. 13 Annual rainfall total for Kigali (1970-2014).

The Fig. 13 shows that the maximum rain amount in Kigali records from 1970 to 2014 is 1357 mm per year (occurred in 1978) and the minimum is 687.2 mm per year (occurred in 1991). The red line shows the average amount rainfall of 981.5 mm. The annual rainfall totals does not show any obvious visible trend, therefore the data do not yet provide climate variability for this region.

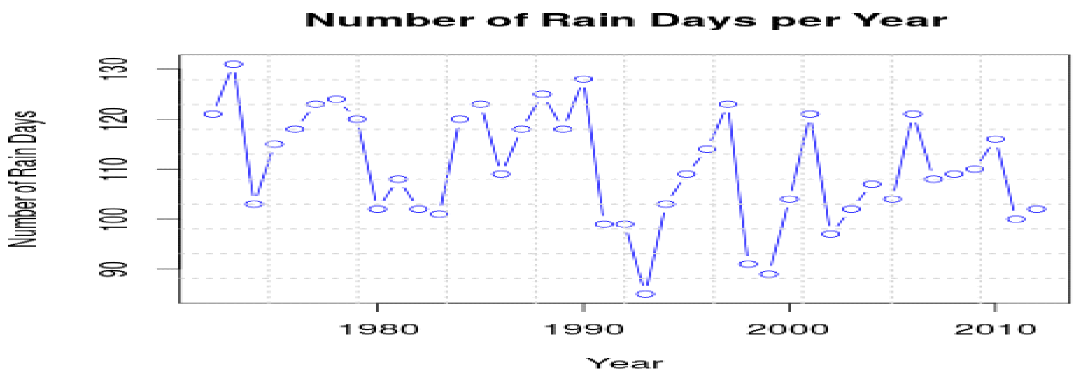


Fig. 14 Number of rainy days for Kigali (1970-2014)

In Fig.14 we analysed the number of rain days per year for Kigali station. By looking at the curve, we observed that there is a small step change after in 1993. This change might be due to missing values or to other observing staff. Therefore for the number of rain days, the graph also looks as though an alternative model could be used for a small "step change"after 1993. The minimum and maximum number of rainy days per year is 85 days and 131 days recorded in 1993 and 1973 respectively.

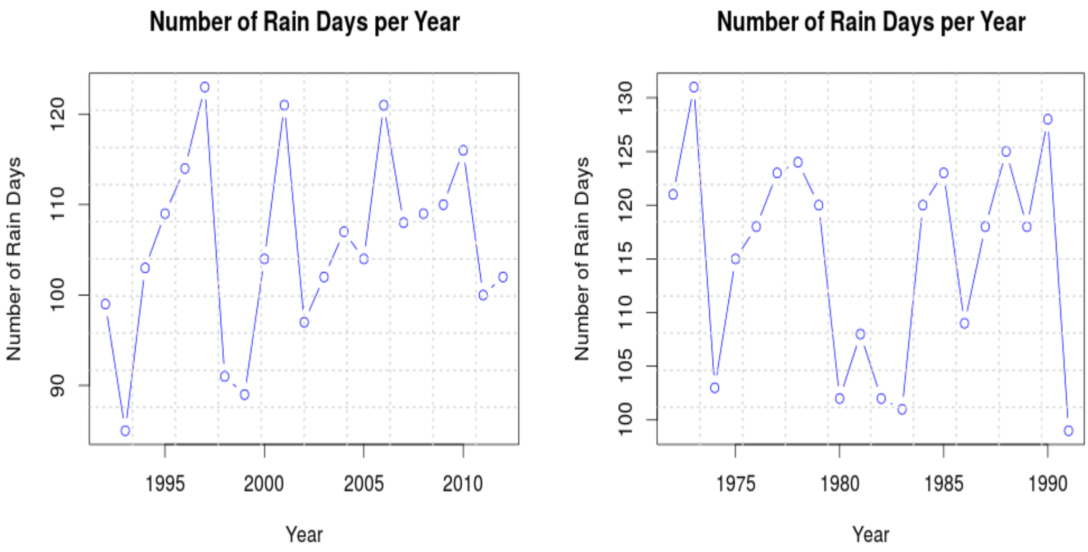


Fig. 15 Number of rain days for Kigali (1971-2014)

The Fig. 15 shows the annual rain count before and after 1993. Both fig. 15 shows that there is no visible trend in annul rainy days total for this region. Hence, there is no climate change in rain count totals.

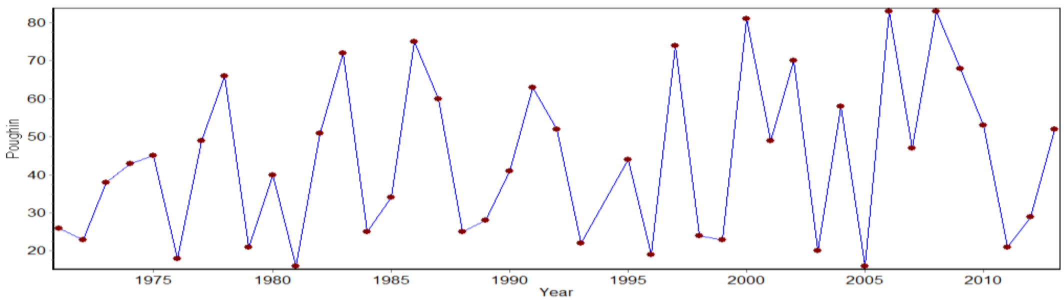


Fig.16 Ploughing date for OND season in Kigali

Fig.16 shows that the earliest date for ploughing was fifteen(15) day of the year occurred in 1980 and 2005; and the longest ploughing date was eighty fifth (85th) day of the year occurred in 2006 and 2008. In this study the year has been shifted to start from 1st August to end of July. There is no visible trend, hence no indication of climate change in the region.

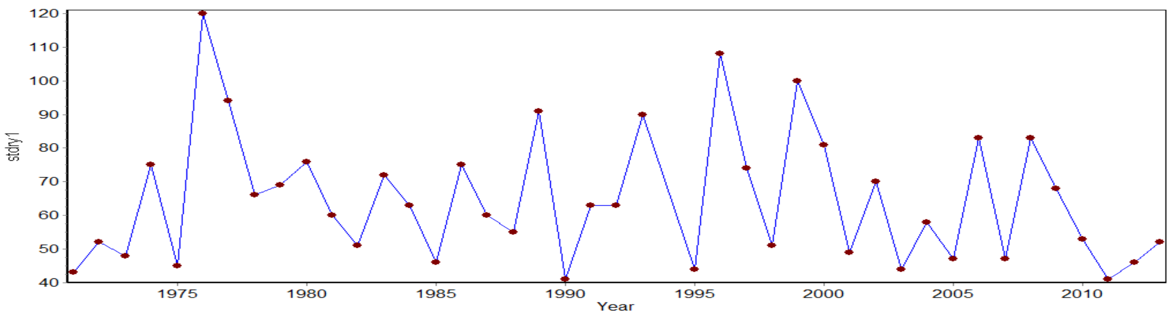
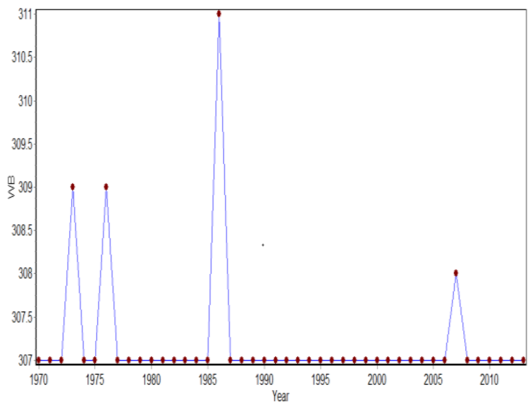


Fig. 17 Planting date with dry spell in OND season Kigali

Fig. 17 shows the start of the rain with dry spell in Kigali for the season A. It shows the risk of a dry spell of 10 days or more, in the following 21 days, for alternative planting dates from 1st October for Season A. The longest start of the rain was 120th day of the year and the shortest start of the rain with dry spell was 40th day of the year. It informs the smaller risk from delayed planting.



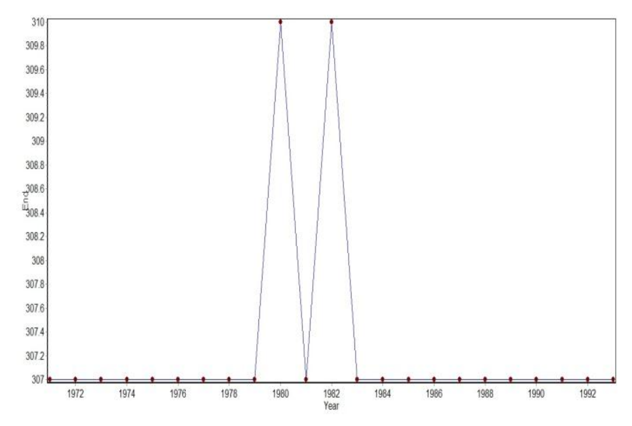


Fig. 18 End of the second season (MAM) in Kigali (1970-2014) and Fig. 19 End of the second season (MAM) in Butare(1972-1993)

It was observed that the end of the season was 307 day of the year for Season B. It shows that the longest end of the season was 311 day of the year occurred in 1986 in Kigali and 310 day of the year occurred in 1980 and 1982 in Butare as shown in fig.18 and fig.19. This conclude that the end of the season was at 307 day of the year. Record that the year has been shifted to start from 1st August and end in July for each year in the analysis for this study.

Table. 5 Crops' Water requirement Table

Crop	Date	Crops' Water Requirement(CRW) in KIGALI after successful planting		Crops' Water Requirement(CRW) in BUTARE after successful planting	
Maize		**120 days**	**90 days**	**120 days**	**90 days**
	01/09	**374 mm**	**295 mm**	**398 mm**	**310 mm**
	11/09	**366 mm**	**285 mm**	**390 mm**	**302 mm**
	21/09	**362 mm**	**277 mm**	**385 mm**	**295 mm**
	01/09	**360 mm**	**271 mm**	**381 mm**	**290 mm**

Due to clear gaps in data for most of climatic station as shown in fig.2 for data availability, we choose to use two stations which have less missing data. The table.5 shows an example of crop water requirement for maize in both Kigali and Butare. It shows an example of the risks for a 90 and 120 day maize compared by looking at the risks of a long dry spell in the 90 or 120 days after a successful planting. The crop water requirement (CRW) is defined as the amount of water that needs to be supplied for crop to grow in normal condition without diseases and other external factors. The length of total growing season is 120 days. It was observed that there is a slight decrease of need for each 10 days of the growth stage of the crop. The application of irrigation will help in maintaining these crop water requirements for farmers in various areas and if irrigated areas are expanded, the total crop yields will increase.

4. DISCUSSION

In this study we focused on precipitation because climatological precipitation events are most important in rainfed agriculture, and because even slight changes in precipitation can have significant perturbation in agriculture crops production. We also focused on assessment of the trend and intensity of dry spells and its impact on crops. From the results of the analysis, it was observed that the trend of dry spells increases seasonally. A threshold of 0.85mm was used to calculate the number of rain days and the dry spells. The precipitation which is less than 0:01 inches is called trace amounts of rain and it is recorded in some countries. Trace amounts of rainfall are not easily detectable in climatology analysis. We choose a slight higher threshold in order to avoid any complications for the recording of very small values of rainfall data. Rwanda's famers receive rainfall during mid-September to December rainy season and March to May rainy season. The amount of water received during rainy season should be well distributed as it is important growing season for the plants. In the two seasons, the median length of the longest dry spell is similar in some of the stations, for example, in Rubona there was an average of 9 length of the longest dry spell in Season A and in Season B.

Butare and Kigali almost experience long dry spell of 4 and more days. The maximum dry spell was found in March 1985 with dry spell length of 21 days in Butare. Annual rainfall totals, seasonal rainfall totals, number of rainy days time series were plotted. The observation of time series shows that there is no visible trend, hence no indication of climate change. (R.D Stern and P.J.M Cooper, 2011) showed that there was no clear evidence that the trend was dependent seasonally in assessing climate risk and climate change using rainfall data in Zambia. In the two seasons, the median number of rain days is similar in some of the stations, for example, in Gisenyi there was an average of 48 rain days in Season A, and 47 in Season B. This average is roughly 15 days per month, i.e. half the days have rain. The 48 rain days at Gisenyi produced the 337mm of rain, (Table 1) i.e. a mean rain per rain day of 7mm. Rainfalls had a slightly higher mean, of 8mm in Season B. A successful good yield is obtained by good timing of ploughing and planting period in order to plant the seeds on time which gives opportunity to use available water for each rainy season.

The evidence from this study shows that long dry spell length will leads to poorer yields of the crops due to died plants which experienced dry spell in their growing season. From the results, seasonal dry spell has clear impact in crop production.

6. RECOMMEDATION

We recommend that further study could be carried out to find out the effect of dry spell in water requirement for crop factor according to the growth stages: initial stage, crop development stage, mid-season stage and late season stage). And also considering the effect of other factors like fertilizers and type of diseases with water satisfaction index.

7. ACKNOWLEDGEMENTS

Special thank goes to whoever contributed on this research, including Rwanda

Meteorology Agency that provided rainfall data. We wish to thank the colleagues for their constructive discussion during this research study period.

5. REFERENCES

S. P. Wani, J. Rockestrom, and T. Oweis, editors. Rainfed Agriculture: Unlocking the Potential,volume 7. CAB International, 2009.

NISR, 2011. The Third Integrated Household Living Conditions Survey (EICV3), Main Indicators Report

NISR, 2012. Population and Housing Census, 2012

UNEP (2011).Annual Report 2011

Ilunga et al. (2004). Pluviometric seasons and rainfall origin in Rwanda

Ilunga and Mugwaneza (2008). Probable sowing period in Rwanda

D. C. Edwards and T. B. McKee. Characteristics of 20th century drought in the United States at multiple time scales. Technical Report 634, Colorado State University, 1997.

FAO. Information system for water and agriculture. Technical report, Food and Agriculture Organisation (FAO) of the United Nation., 2005.

G. J. Husak, J. Michaelsen, and C. Funk. Use of gamma distribution to represent monthly rainfall in africa for drought monitoring applications. International Journal of Climatology, 2006.

O. Munyaneza, S.Uhlenbrook, S.Maskey, U. G. Wali, and J. Wenninger. Hydrological and climatic dataavailability and preliminary analysis in Rwanda. In Poster Presentation (Proceedings of the hydrology, 10th International WATERNET/WARFSA/GWP-SA Symposium , Entebbe, Uganda, 28-30 October 2009), 2009.

NISR. Population size, structure and distribution. Technical report, National Institute of Statistics of Rwanda, 2014.

Rwanda. Green grownth and climate relience. National strategy for climate change and low carbon development. Technical report, Kigali, 2011.

C. J. Schreck and F. H.M.Semazzi. Variability of the recent climate of Eastern Africa. International Journal of Climatology, 2003.

R. Stern and P. Cooper. Assessing climate risk and climate change using rainfall data- a case study from Zambia. Experimental Agriculture, 47(2), 2011.