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Rainfall Variability and Its Impact on Rain-Fed Crop Production in Rwanda

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Abstract

The changes on the rainfall intensity and frequency greatly affect the agricultural production, and the most impacted are poor societies practicing rain-fed agriculture. This study assessed the impact of rainfall variability on maize production during the agricultural season B of 2015 and 2016 in the Eastern Rwanda. The input data were the seasonal maize cropland, production and monthly maximum rainfall analyzed with use of Origin Pro. Software for Statistical Analysis. The results indicated decreasing rainfall in 2015, specifically at the Kibungo-Kazo (from 273.4 to 81.3 mm), Nyagatare (from 105.8 to 52.2 mm) and Kabarondo meteorological stations (from 214.9 to 70.6 mm) in March and April, respectively. Similar rainfall decreasing trends were recorded in 2016. These rainfall scenarios disturbed the normal rainfall calendar, which usually starts from end of March and keeps on increasing in April up to the mid-May. And consequently, early dry season started in May instead of June in 2016 as normal. In addition, it was noted that these rainfall patterns occurred during the maize water requiring period (April-May) for its growth and production, and were associated to the recorded maize production failure, which reduced from 57,695 to 20,967Mt in season B of 2015 and 2016, respectively. This expresses that the sector is still rain-fed and suggests, for the adaptation to (1) introduce drought tolerant crops, (2) the Rwanda Meteorology Agency should work closely with farmers and spread climatic data in advance to alert farmers, and (3) exploring the available ground and surface water can take over the rainfall shortage experienced in the area.

Keywords

Agriculture, Eastern Province, Maize, Rainfall, Rwanda

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1. Introduction

The world is under pressure of its rapid human population growth and global warming, both considerably affect agricultural sector and cause food insecurity. This is recorded in most cases by farmers in poor countries, who still practice a subsistence rain-fed agriculture [1, 2, 3, 4]. Over the last 100 years, the global average temperature has risen by 0.75°C, and is predicted to increase by 2°C while precipitation will likely increase by 1 to 2% in the next decades, and as a result, wet place will become much wetter while dry places will be much drier [5, 6, 7]. In addition, it is predicted that under global warming, some parts of the equatorial East Africa, will likely record 5 to 20% increase of rainfall between December and February, while about 5 to 10% of low rainfall will be registered between June and August [8, 9].

Moreover, the Sub-Saharan Africa population is projected to be about 1.5 billion by 2050, requiring a food increase of about 360% [10, 11, 12] and this, likely may not be achieved unless

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appropriate mitigation and adaptation measures to global warming are regarded. Since 1990, the precipitation records in Rwanda have been changing, the mean annual rainfall in 1990 was 97 mm falling to 95 mm in 2000, and then increased up to 110 mm in 2015. While the mean annual temperature was 19.3°C in 1990 increasing up to 19.8°C in 2015 [13, 14, 15]. The above changes have impacted on water availability, where some regions received high rainfall intensity and frequency than others, which in turn, led to water scarcity and caused crop failure, hunger and poverty [16, 17].

The Government of Rwanda, for the agricultural development, has initiated an agricultural policy known as: "Land Use Consolidation" where each area is specifically prioritized with one or two crops depending on its soil type and fertility, along with agricultural inputs provision, where for example the chemical fertilizers increased from 2,149 to 68,749 tons in 1990 and 2015, respectively along with technical staff to assist the farmers [18-20]. However, since the time when the program started, the Eastern province growing maize and soya has been recording failures, primarily due to water scarcity exacerbated by its rainfall shortage [19, 21, 22]. The consequences of rainfall failure in the eastern province of Rwanda can be revealed by, for example, the defeat occurred between 2014 and 2016, which led to prolonged drier periods, and damaged over 23,000 ha of cropland and 2,000 livestock killed [23, 14]. However, much is invested in crop irrigation, and today the province is the largely irrigated area countrywide, which spaced from 15,939 ha in 2014 to about 21,338.5 and 25,512 ha in 2015 and 2016, respectively [24].

Although, irrigation is expanding within the area, the crop productivity is still impacted by rainfall shortage [25], since the total available ground and surface water is not adequately explored due to lack of and/or limited human capital and financial capabilities. The above phenomena express how the eastern province is impacted by rainfall variability, while its specific grown seasonal crops (maize and soya) require much water, despite its abundant but unexploited water sources. This expresses that, understanding how water scarcity affects the maize production can strengthen the adaptation capabilities to policy makers and farmers. Therefore, the objective of this study is to assess the impact of rainfall variability on seasonal maize production and propose appropriate measures for the adaptation and agricultural development in the eastern province of Rwanda.

2. Methods and Materials

2.1. Description of the Study Area

The Eastern Province occupies a total surface of 9,813Km^2, and has seven districts namely Bugesera, Gatsibo, Kayonza, Kirehe, Ngoma, Nyagatare, and Rwamagana. The province is bordered by Uganda in North, Tanzania in East, Republic of Burundi in South, while in the West it is bordered by the City of Kigali, Northern and Southern Provinces. The Eastern province is a relatively lowland and flat with a dry and warmer climate, and is known for its fertile land and pastoral area. However, the province is recognized by its water shortage mainly due to low rainfall frequency and intensity compared to other provinces of Rwanda [15, 26].

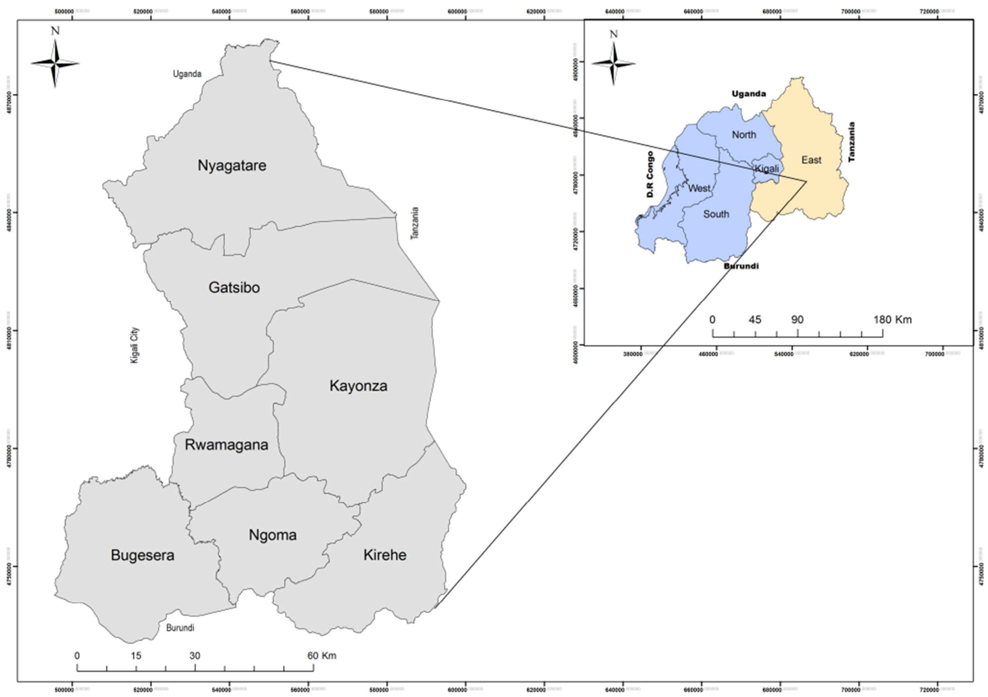

Figure 1. Map showing the location of the Eastern Province of Rwanda.

2.2. Data Collection and Analysis

To evaluate the impact of rainfall variability on maize production, a seasonal grown crop in the Eastern province of Rwanda, authors considered the seasonal maize cropland and production of the season B and monthly maximum rainfall of the years 2015 and 2016, respectively. The rainfall data considered by this study were collected by meteorological stations located within the districts of the Eastern province as illustrated in Table 1 below.

Table 1. Meteorological Stations considered by the study.

Name of Stations	District	Latitude	Longitude	Elevation
Kawangire	Kayonza	-1.49	30.27	1,473 m
Nyagatare	Nyagatare	-1.33	30.33	1,377 m
Kibungo-Kazo	Ngoma	-2.15	30.5	1,604 m
Kabarondo	Kayonza	-2.01	30.56	1,635 m
Kalama-Kilimbi	Nyagatare	-2.26	30.28	1,347 m
Gahara	Kirehe	-2.33	30.5	1,516 m

Although, agricultural production is controlled by several factors such as the soil types, inputs, crop seeds, etc., the authors recognized the efforts made by the government of Rwanda to develop the agriculture sector as well as the land fertility of the eastern province [26, 27], which can easily increase the production. Then the authors investigated on the fact that, the area suffers from water shortage and examined how rainfall variability impacts of the maize production, as the largely grown crop in this area. The other reason of only considering the rainfall was that Rwandan agriculture is still a subsistence rain-fed sector.

The rainfall data were analyzed in comparison with the production of maize. The primary data on the seasonal maize production, planted and harvested area (agricultural season B of 2015 and 216) were collected from the Rwanda Agriculture Board (RAB) and the monthly maximum rainfall data were provided by Rwanda Meteorology Agency from the meteorological stations located in the Eastern province as shown in Table 1.

Table 2. Season B Maize growing schedule in Rwanda.

Period (month)	Activity
Late February-Early March	Land preparation and Sowing
April-May	Growing, fertilizers application and much water requirement
Late May-June	Harvest

The above Table 2 shows that the used data related to rainfall and maize were considered within the period from planting to harvesting as scheduled in the Rwandan agricultural season B. The analysis was performed with use of Origin Pro Software for statistical analysis.

3. Results

The results of this study are illustrated in both Figures 2 and 3, (monthly maximum rainfall of 2015 and 2016) and Table 3, the maize seasonal cropland and production. The results as illustrated in Figure 2 below revealed high rainfall mainly in March (about 270 mm) at Kibungo-Kazo station, 220 mm at Kawangire station in April and about 180 mm at Kabarondo station in November. However, the rainfall records of March comparatively exceeded the registered rainfall in April and May, when the maize requires much water for its growth (see Table 2).

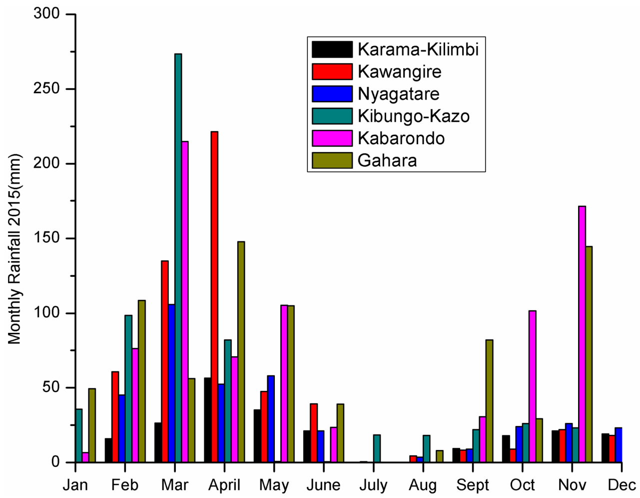

Figure 2. Maximum rainfall of 2015.

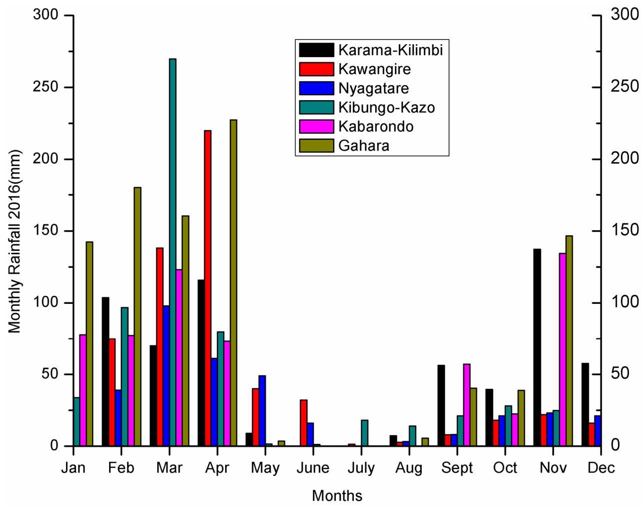

Figure 3. Maximum rainfall of 2016.

As shown in Figure 3 above, the abnormal rainfall was mainly recorded at the Kibungo-Kazo meteorological station; the rainfall fell from 269.7 mm in March to 79.8 mm in April of 2016. Similar rainfall anomalies were registered at Kabarondo, Kalama-Kilimbi and Nyagatare meteorological stations. In addition, it is worth note that the rainfall of 2016 was low compared to the record of 2015, specifically between May and September. These changes in rainfall affected the normal calendar of rainfall, and then reduced the rainfall in April, the month when high rainfall intensity and frequency is recorded, and consequently, led to the early beginning of dry season in May 2016 instead of June [13, 15]. These changes on rainfall intensity have impacted on the maize production as illustrated in Table 3, since they occurred during the maize growth period, when much water is required for the growth [28-30].

Table 3. Seasonal Maize production per cultivated area.

Crop Season	Target (Ha)		Planted areas (ha)		Production in MT	
District	2015	2016	2015	2016	2015	2016
Bugesera	6,323	6,323	6,191	6,191	18,573	1,147
Gatsibo	2,366	2,366	2,121	2,121	5,303	2,548
Kayonza	4.1	4.1	3,001	3,001	5,702	1,206
Kirehe	1.4	1.4	663	663	1,459	671
Ngoma	300	300	61	79	153	167
Nyagatare	10	10	9,473	9.7	26,524	12,312
Rwamagana	1.4	1.4	1,027	1,234	3,081	2,916
Total	25,889	25,889	22,537	25,889	57,695	20,967

Ha: Hectare, MT: Million Tons and MT/Ha: Million Tons per hectare

As shown in the above Table 3, the target cropland of 25,889 ha did not change in both years, while the production considerably declined by about 36,728 million tons in defiance of increased planted area, from 22,537 to 25,889 ha in 2015 and 2016, respectively. This crop failure was associated to the limited rainfall recorded during this crop season as well as the maize growth schedule as illustrated in Table 2. This expresses that limited rainfall affected the maize production in the study area.

4. Discussion

This study evaluated the impact of rainfall variability on seasonal maize production of the season B of the years 2015 and 2016. The results indicated that, as illustrated in both Figures 2 and 3, the period when there was limited rainfall, the maize was in need of water (Table 2) and this, led to reducing its production as shown in Table 3. In Rwanda, as previously reported [31-33] agriculture employs about 70-80 percent of the total population and contributes about 33% of the national Growth Domestic Product (GDP). The sector is subdivided into three seasons. The season A starts from September to February of the following year, where Maize, Rice, Wheat, Beans, Soya, Groundnuts, Irish and Sweet potatoes and other seasonal crops are grown. Season B starts from March to June of the same year and the same crops of the season A are grown, and high rainfall intensity is recorded during season B. While the season C starts in July and ends in September of the same year, during this season, due to water scarcity, wetlands are largely used than hilly lands, and maize and vegetables are the main crops grown within the season.

In Rwanda, it is reported [13, 34, 14] that there is sufficient rainfall despite its low intensity in the study area. However, in defiance of this low rainfall distribution, the area has abundant ground and surface water sources (Figure 4), but not fully accessed and used due to limited human skills and financial capacities.

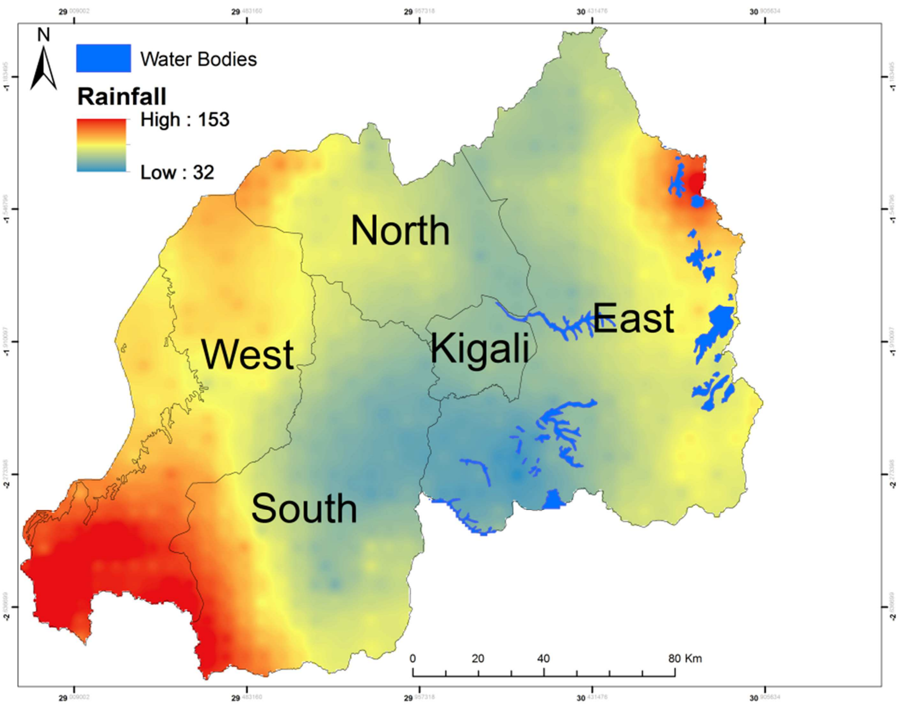

Figure 4. Rainfall distribution and water sources in eastern Rwanda.

Moreover, the Eastern province is the largely inhabited province countrywide, it was inhabited by 20.9% of the total Rwandan population in 2002, and this rate grew up to 22.3% and 24.6% in 2008 and 2012, respectively [35, 22]. These figures make the Eastern province highly populated and express immense food demand. Nevertheless, previous reports [13, 36, 15] highlighted that the rainfall is unequally distributed in Rwanda, and the eastern province is among the parts of the country receiving low rainfall (Figure 4). This rainfall variability, largely affect the community's livelihoods and the agriculture sector is greatly affected among others, due to the fact that the sector is still rain-fed.

The above can be associated to the findings of this study, where the rainfall was only high in March then abruptly reduced in April (Figures 2 and 3) in both 2015 and 2016, the month in which Rwanda expects much rainfall and the dry season started early from May instead of June compared to the normal calendar. However, this has impact on crops due to water scarcity, especially during maize growth, when much water is required prior to and during the reproductive growth stages [37-39], and as illustrated in Figure 2 and 3 and Table 2, low rainfall was recorded during such periods, and consequently, led to the maize production failure (Table 3). The maize total target cropland was 25, 889 ha in both 2015 and 2016, however, 3,352 ha in 2015 were not planted against 25,889 ha planted in 2016. Although the total area was maximized in 2016, a crop failure of 36,728 million tons, (from 57,695 to 20,967 Million tons in 2015 and 2016, respectively), was recorded.

Although, this maize failure (Table 3) can be associated to several reasons, such as farming practices, fertilizers applied, etc., the eastern Rwanda (study area) as previously reported [40, 19, 22, 26] has a fertile land and fertilizers are provided to farmers along with technical approach to boost its specific grown crops (maize and soya). Therefore, the lack of sufficient water noticed, as a result of decrease in rainfall (Figures 2 and 3) can be the likely cause of the maize failure registered (Table 3), due to the reason that rainfall reduced (Figures 2 and 3) during the period when maize was in need of water (Table 2) which expresses a strong correlation between water shortage and maize production. Thus, the more the rain reduced the higher crop failure was recorded. Therefore, the above express how much water scarcity impact on maize production and the whole community's livelihoods. Accordingly, as far as Rwandan agriculture is still a rain-fed practice, maize should not be prioritized in the Eastern province of Rwanda, as a water requiring plant being grown in a water scarce area.

5. Conclusion

This study assessed the impact of rainfall variability on maize production in the crop growing season B of 2015 and 2016 in the Eastern province of Rwanda. The results indicated that rainfall registered high records in March and decreased in April, while normally it starts from end of March and keeps on increasing in April up to the mid-May, and this led to early beginning of the dry season, when water is not enough. These phenomena affected the maize production, which is grown in such period of time and reduced the maize production than the predicted. Therefore, the results suggest to (1) plan on when, where and which crop(s) to grow depending on the available water, (2) the Rwanda Meteorology Agency should work closely with farmers and launches climatic data in advance for alert, (3) the water richness should be an advantage to explore by both private and public sectors, and (4) drought tolerant and /or resistant crops can generate higher yield in this area.

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