

**THE IMPACT OF CLIMATE VARIABILITY ON MAIZE
PRODUCTION IN THE RURAL COMMUNE
OF BÉRÉGADOUGOU (BURKINA FASO)**

**IMPACTUL VARIABILITĂȚII CLIMATICE ASUPRA
PRODUCȚIEI DE PORUMB ÎN DEPARTAMENTUL RURAL
BÉRÉGADOUGOU (BURKINA FASO)**

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Abstract: Maize is the main cereal crop in the rural commune of Bérégadougou, located within the Cascades region, in western Burkina Faso. It is traded commercially and is the staple food of the local population. Given the climatic variability affecting maize farming systems, this study aims to analyse its effects on maize production in Bérégadougou. The research methodology is based on a global geographical approach that integrates meteorological data (1991-2020), climatic parameters and field work. The results show a variation in rainfall patterns, with a rainy season (May to October) and a dry season (November to April). The interannual rainfall trend shows that several years (e.g., 1992, 1996, 1999–2017) are considered dry because the average rainfall is below 900 mm, which is the average for the series. The temperature analysis shows that 1998, 2002, 2003, 2004, 2005, 2010, and 2016 recorded average annual temperatures of over 28°C, while the other years in the study series had average temperatures between 27°C and 28°C. Evapotranspiration is also fairly high in the rural commune of Bérégadougou, at over 2,000 mm for all years in the analysed series. As a result, maize growers have to adjust and implement adaptation strategies: crop association (98% of maize growers), crop rotation (78% of the growers), chemical fertilizers (48% of the growers), and organic manure (97% of the growers). Public and private authorities must therefore encourage farmers to adopt new short-cycle varieties that are resistant to climatic variability.

Key-words: *temperature, precipitation, evapotranspiration, maize, Bérégadougou, Burkina Faso*
Cuvinte cheie: *temperatură, precipitații, evapotranspirație, porumb, Bérégadougou, Burkina Faso*

1. INTRODUCTION

Agriculture is the main economic sector in West Africa and plays a crucial role in ensuring household food security. Given the importance of self-consumption and the role of local markets, around 80% of the region's food needs

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are met by domestic production. Around 80% of the region's food needs are met by regional production. Thus, the challenge the agricultural sector is presently facing is to move from guaranteeing food security to guaranteeing food sovereignty at regional level (Blein, 2008). This type of agriculture tends to become increasingly vulnerable to climate variability, which spares no country. Climate disturbances (climatic variability and extremes) are likely to compromise several decades of development efforts, especially in poor countries, given their impact on the production activities of rural populations in particular. The ability of communities to respond to the consequences of climate variability is limited, given their degree of vulnerability (Yanogo, 2012). Subsequently, the food crises experienced by African countries are mainly linked to climate variability, which makes agropastoral production highly unpredictable. Food security has become a headache for governments, as they seek to preserve social peace and ensure economic development (Ouédraogo, 2012). To achieve this, growing maize is essential. In other words, it is a crop that plays a key role in the production systems of many countries around the world. According to the FAO (2023), maize (*Zea mays L.*) is the most important cereal crop in terms of production.

Worldwide, maize production has risen steadily over the last 20 years, three times faster than wheat or rice, mainly because of its wide range of uses - food and feed, ethanol production, cattle fodder, etc. (Erenstein et al., 2022).

Located in West Africa, Burkina Faso is a country where agriculture is the main activity of the rural population. It is vulnerable to the effects of climate variability. Located in the west of Burkina Faso, in the Cascades region, the rural commune of Bérégaougou is not spared from climate variability. Maize, the locality's main cereal crop, is the subject of numerous commercial transactions and forms the basis of the population's diet. Given these conditions of climatic variability in maize production systems, the question that needs to be asked is: what are the effects of climatic variability on maize production in the rural commune of Bérégaougou? The hypothesis to be examined is as follows: climate variability is at the root of the decline in maize production in the rural commune of Bérégaougou. The aim of this article is to analyse the effects of climate variability on maize production in the rural commune of Bérégaougou. In order to achieve the objective assigned to this research and to examine the hypothesis, the scope of this investigation is broken down into three parts: the framework of the study, the results and the discussion.

1.1. Theoretical framework

From a theoretical point of view, this research is part of the vast field of geography and management of tropical areas. It uses concepts from the fields of physical geography and natural resource management. Many researchers and development practitioners have examined the effects of climate variability on maize (*Zea mays L.*) production. Without being exhaustive, the work of Adjovi et al. (2019) on the effects of climate variation on food production in southern Benin shows that the drought observed in Bohicon led to a drop in the productivity of the

main food crops, namely maize, soya, and sorghum. Maize seems to be the crop most affected by this climatic variability. Since 2011, when maize production peaked, yields of this crop seem to be in perpetual decline despite the various strategies developed by producers in the commune to adapt to the climate. From another point of view, Doukpolo (2014) shows that, despite their uncertainties, future rainfall trends indicate a drop of 20 to 42%, particularly in the Sudanian and Sudano-Sahelian sectors of the study region. The severity of the ensuing drought could lead to a reduction in available water reserves on arable land and changes in the length of the vegetative growth period. Subsequently, the research findings of Djohy et al. (2015) show that the reduction in agricultural production is linked to the increase in temperature and the irregularity and decrease in rainfall.

The possibility of sowing on the right date is becoming a recurring problem. These climatic conditions are forcing peri-urban farmers in the Parakou commune to gradually abandon certain crops, particularly long-cycle crops, in favour of short-cycle crops. Developing crop associations and growing crops in the lowlands have become strategies for coping better with climatic variations. In the same vein, the work of Vlăduț et al (2023) attests to the fact that climate change is perceived as the greatest threat to agriculture, as it can lead to a significant reduction in yields, mainly induced by one-off extreme weather events, as well as major changes in crop phenology if the change becomes persistent.

Similarly, the findings of the research achieved by Dabissi et al. (2011) on climatic variability and rainfed maize production in eastern Côte d'Ivoire show that rainfall underwent a significant drop between 1970 and 2000, with an average deficit estimated at around 20%, leading to major regional disparities. This has led to a deterioration in the maize-growing conditions and the productive potential of maize in the first cycle in the extreme south-east part of Côte d'Ivoire. The pressure is even greater in regions where crops are entirely dependent on climatic conditions (with a particular emphasis on rainfall amounts), known as rain-fed farming. In addition, the investigations of Sarr et al. (2011) in Burkina Faso focused on identifying the climatic risks of maize cultivation in Burkina Faso.

In other words, the state-of-the-art reveals studies carried out on a global scale, while investigations on a local scale remain insufficient. The aim of this study is to analyse the effects of climate variability on maize production in the rural commune of Bérégaougou in western Burkina Faso. To achieve this, it is useful to use a global geography approach to analyse the interactions between climatic parameters, farmers' perceptions, and the resilience strategies adopted by producers in the rural commune of Bérégaougou.

2. DATA AND METHODS

2.1. Geographical context

The rural commune of Bérégaougou is located in the province of Comoé, in the Cascades region of western Burkina Faso. Its geographical coordinates are 10°46'0" N and 4°45'0" W. The commune covers an area of 265 sqkm or 1.72% of the provincial territory. It is bordered to the west and north-west by the rural

commune of Moussodougou, to the east by the rural commune of Tiéfoua, to the north by the rural commune of Toussiana, and to the south by the urban commune of Banfora (Fig.1).

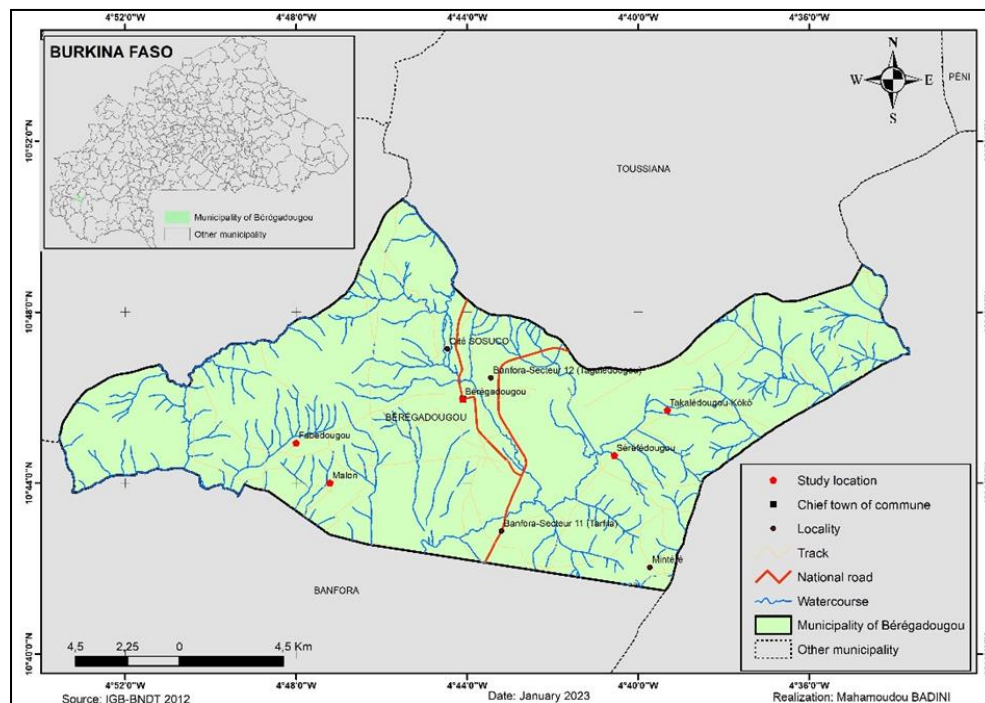


Fig. 1 Location of Bérégadougou rural district

It has a population of 15,162 inhabitants, 51.80% of whom are women according to the National Institute of Statistics and Demography (INSD, 2020). The commune is characterised by two main activities: agriculture and livestock farming. Maize (*Zea mays L.*) is the main cereal crop grown in Bérégadougou.

2.2. Methodological framework

The methodological approach adopted is based on quantitative and qualitative data derived from documentary analysis, interviews, and questionnaire surveys. The documentary analysis consisted of analysing information on climate variability and maize production in articles, dissertations, theses, books, and reports consulted in ministries and development agencies, in university libraries, in research structures, and on the Internet. The field surveys took place in 2023. They were based on the territorial organisation of the commune. Five localities were surveyed: Bérégadougou, Fabédougou, Malon, Takalédougou Kôkô, and Sérifédougou (Fig.1). These localities were selected on a reasoned basis. Farmers were selected for the surveys on the basis of two criteria: they had to be the head of a maize-farming household living in the area and they had to be at least 30 years old. It was necessary to select standard samples, with 25 heads of household

surveyed per locality, regardless of the size of the target population in each locality (Table 1).

Table 1. Breakdown of households by location surveyed

Localities	Number of population in 2016	Number of households	Sample retained	Corresponding rate (%)
Bérégadougou	12,212	2,549	25	1
Fabédougou	875	183	25	14
Malon	192	40	25	62
Séréfedougou	977	204	25	11
Takalédougou Kôkô	908	187	25	12
Total/Average	15,164	3,163	125	4

Sources: INSD, 2022

A total of 125 maize-farming heads of household were surveyed out of a total number of 3,163 households, at an overall sampling rate of 4%. The qualitative surveys were conducted with the heads of the decentralised government departments: the head of the agricultural technical support zone (ZATA) and the head of the livestock technical support zone (ZATE). Data on maize production, areas, and yields in the rural commune of Bérégadougou from 1991 to 2020 were collected from the Ministry of Agriculture of Burkina Faso. In addition, rainfall, temperature, humidity, and evaporation data from 1991 to 2020 from the Bérégadougou station were collected from the National Meteorological Agency of Burkina Faso (ANAM). This station was chosen because it covers the study area. Similarly, the analysis of interannual rainfall variability was carried out using reduced standardised anomalies. These anomalies were calculated using the formula for analysing the interannual variability of the following indices:

$$x'_i = \frac{x_i - \bar{x}}{\sigma(x)} \quad (1),$$

where: x'_i = reduced centered anomaly for year I;

x_i = the value of the variable;

\bar{x} = the mean of the series;

$\sigma(x)$ = the standard deviation of the series.

Furthermore, in order to characterize the level of severity of drought in the rural commune of Bérégadougou, the calculation of the standardized precipitation index (SPI) for the study period (1991-2020) is of capital importance. Indeed, in the Sahel in general and in Burkina Faso in particular, to determine whether a year is rainy or dry, the standardized rainfall index (IPS) or SPI is used. This index is recommended by many organizations such as the World Meteorological Organization (WMO) and the National Oceanic and Atmospheric Administration

(NOAA). In 2009, WMO adopted the SPI as an instrument to measure meteorological droughts, under the “Lincoln Declaration on Drought Indices”.

3. RESULTS AND DISCUSSIONS

3.1. Climate variability

The rural commune of Bérégadougou has a unimodal rainfall pattern, with alternating dry and wet seasons, as shown in Figure 2. The dry season extends from November to April, while the wet season is characteristic to the interval May–October, when monthly rainfall amounts exceed 50 mm. The wettest month is August with 260mm.

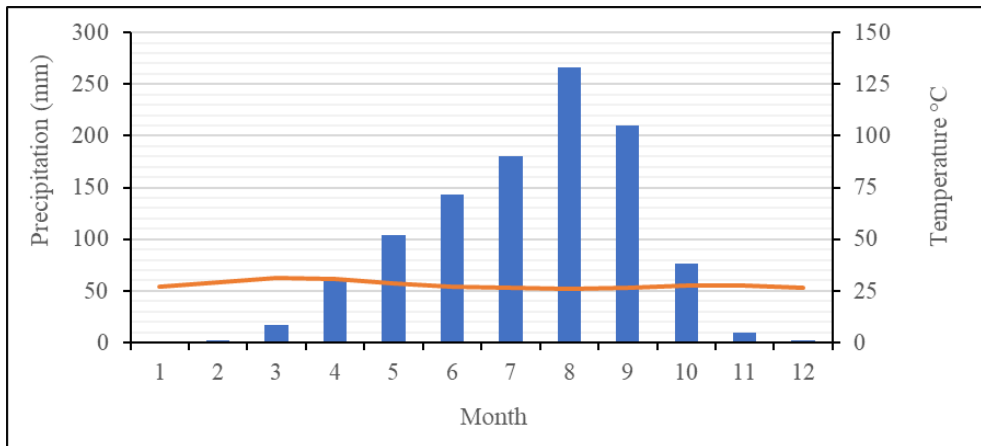


Fig. 2. Umbrothermal diagram for the municipality of Bérégadougou

One of the undeniable characteristics of climatic variability in the rural commune of Bérégadougou is the great variability of rainfall. Figure 3 shows that rainfall evolved in a sawtooth pattern with a slight upward trend, confirmed by the linear regression line and its directing coefficient ($a = 3,9287$). The fairly low coefficient of determination ($R^2 = 0.0426$) shows that the probability of this trend continuing over time is low. This variability in rainfall is characterised by alternating years of deficit and surplus. The study area recorded 50% deficit years, 43% surplus years and 7% average years. This rainfall disruption, marked by alternating wet and dry years, shortens the vegetative cycle and disrupts the maize farming calendar, affecting production through lower yields. The water requirements of maize in the tropical and inter-tropical zone in general, and in the rural commune of Bérégadougou in particular, vary between 500 and 800 mm. Most farmers (93.12%) agree that maize production is subject to rainfall variability. The average rainfall amount for the analysed period is 1992 was the driest maize growing season, with 683 mm, while 2020 with 1490.3 mm, was the wettest of all wet years. Thus, water is an essential element in the growth of the maize plant. Insufficient water would retard its growth during the various stages of its development.

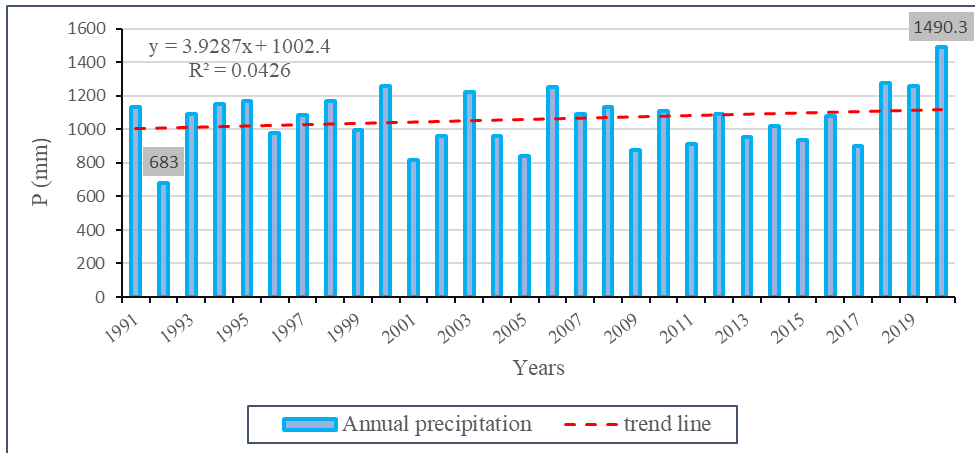


Fig. 3. Annual rainfall amounts and their linear trend

The SPI can be used to detect drought situations quickly and assess the severity of the impact on maize production. It is less complex than many other indices (the Palmer drought index, for example). According to SPI values (Fig. 4), the study period shows alternating wet, dry and normal years, as follows:

- (i) 1996, 1999, 2002, 2004, 2013, 2014, and 2015 are normal years according to SPI values, which range between -0.99 and 0.99;
- (ii) 2001, 2005, 2009, and 2017 are moderately dry (SPI values between -1.0 and -1.49), while the years 2000, 2006, 2018, and 2019 are moderately wet (SPI values between 1.0 and 1.49);
- (iii) 1992 is extremely dry (SPI \leq -2), while 2020 is extremely wet (SPI \geq 2).

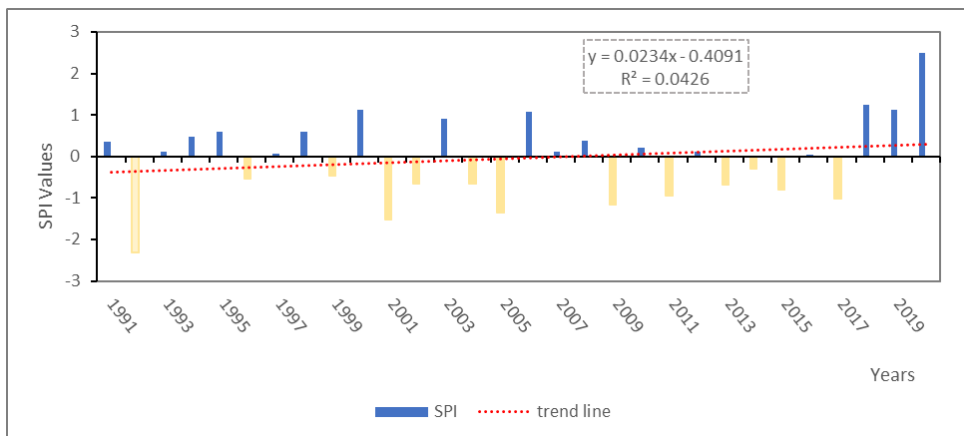


Fig. 4. Standardised precipitation index

The analysis of the evolution of the SPI for the period 1991 to 2020 allowed a reliable comparison between past and present droughts in the rural commune of Bérégaougou, which registers a Southern Sudanese climate of the dry tropical

zone (according to the Guinko climatic division, 1984). However, the year 2020, considered extremely wet, caused flooding in maize plots and in family farm concessions. Thus, 27%, 45%, and 57% of large producers, medium producers, and small producers respectively certified the flooding of their maize plots during this year 2020.

The flooding of the maize fields had a severe impact on small producers because they did not have significant financial resources. Their agricultural equipment is limited to the cattle plough, *dabas*⁵ (for manual tillage), machetes. Moreover, the area of their fields is reduced, between 1 and 4 ha while medium and large producers have maize plots with areas between 4 and 8 ha and 8 and 16 ha, respectively.

Another parameter of climate variability in the rural municipality of Bérégaougou is the high interannual variability of the average annual temperatures. Figure 5 shows that for the analysed data series, seven years (1998, 2002, 2003, 2004, 2005, 2010 and 2016), representing 22.58% of the total number of years recorded annual average temperatures above 28°C while the other years, namely 77.41%, have average temperatures between 27°C and 28°C. The hottest year was 2016 with 28.6°C, while 1992 and 1999 were the warmest at 27.4°C. The analysis shows a 1.2°C (0.025°C/year) increase in temperature and a slight upward trend with a correlation coefficient $R^2 = 0.5086$.

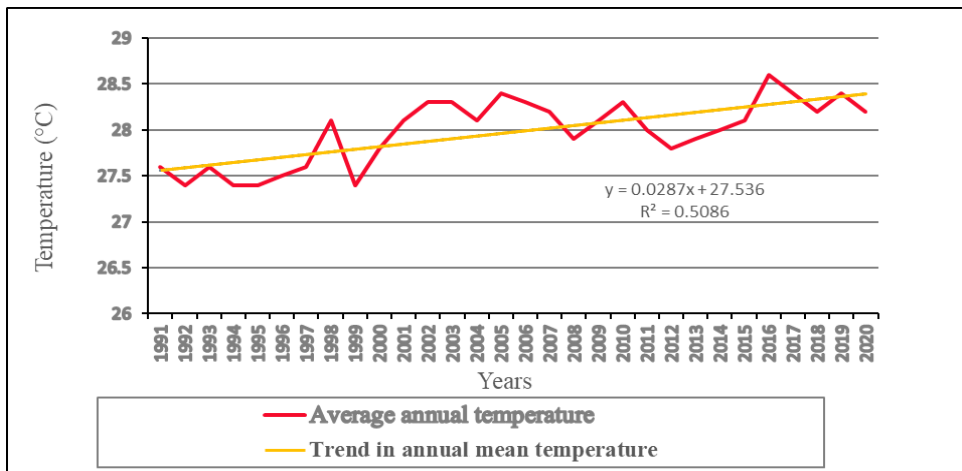


Fig. 5. Mean annual temperatures of the study area

This increase in temperature contributes to the increase in the evapotranspiration rate (Figure 6) in the rural municipality of Bérégaougou. Evapotranspiration exceeded 2000 mm regardless of the year of the studied data series. Evapotranspiration regulates the growing cycle of the maize plant and varies from year to year.

⁵ The *daba* is a short-handled hoe used in Africa in general and in the rural commune of Bérégaougou in particular, for preparing the soil and weeding crops.

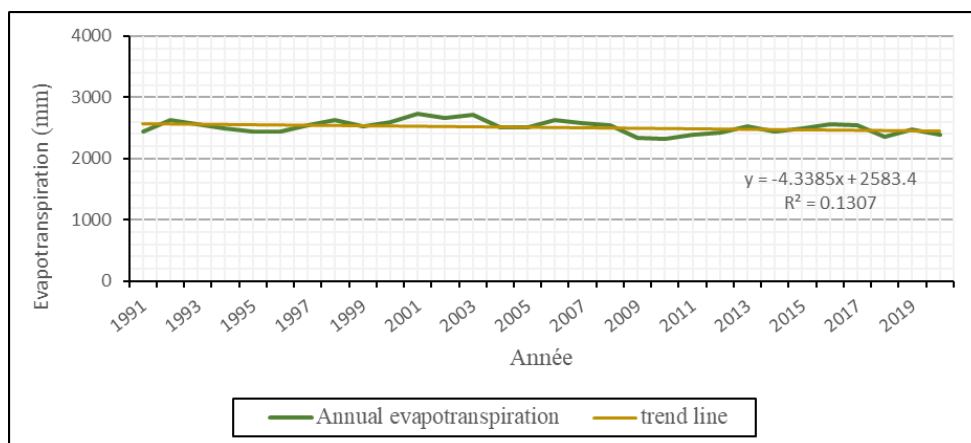


Fig. 6. Annual trend of the potential evapotranspiration

Climate variability in the study area is also influenced by the relative humidity (Fig. 7), which plays an important role in maize growth. When the humidity is too low (less than 35%), the growth of the maize plant is often compromised since it takes much longer to reach the desired size. Also, the bottom leaves fall, growth is difficult, and the overall quality of the plant is damaged.

The analysis emphasizes that the highest relative humidity (65.30%) corresponds to 1996, while the lowest value (58%) to 2008.

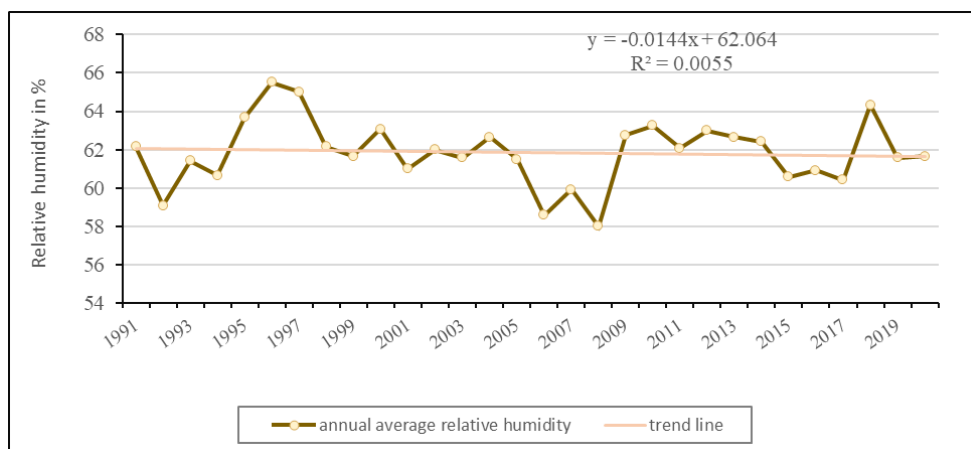


Fig. 7. Average annual relative humidity and its linear trend

3.2. Changes in area, yields and maize production

Maize production in the rural commune of Bérégaougou is closely linked to the increase in planted areas (Fig. 8). The analysis shows that it is not the large areas that give the best yields. In 1998-1999, 1999-2000, 2006-2007, 2007-2008, 2008-2009, 2017-2018, and 2018-2019, the area under maize in Bérégaougou was the highest, about 750 ha, but these were not the years with the highest production

or yield. The highest production was recorded in the 2003-2004 season. This was followed by the 2007-2008, 2017-2018 and 2016-2017 seasons. The highest yields were obtained during the 2001-2002 and 2007-2008 seasons.

These results show that maize production and yield in Bérégadougou depend on other factors and not on the area sown. A large area can produce low yields. Other factors, such as climate and soil type, affect agricultural production and have an impact on yield. Low rainfall, high temperatures and, above all, drought registered during the growing season affect crop yields and lead to a drop in production. 2001-2002, the year in which the area was the largest in the zone, was also the year with the lowest production because, according to the SPI, it was a moderately dry year. Similarly, the 2004-2005 and 2005-2006 seasons, which had low yields and production, were moderately dry years. The same applies to the 1991-1992 and 1992-1993 seasons. In fact, 1992 was extremely dry in the area. This could have an impact on production until 1993, as this year was close to normal.

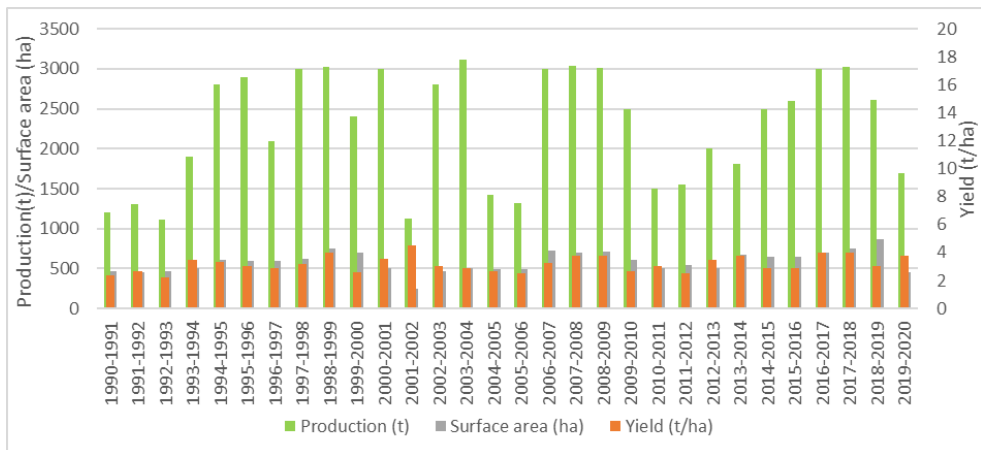


Fig. 8. Area, yield and maize production trends from 1991 to 2020

3.3. Perceptions of climate variability on maize production by family farmers

Farmers' perceptions of climate variability confirm the scientific results, including temperature increases, frequency of dry sequences during the rainy season, and decreasing rainfall. For most (98.5%) of the producers, the persistence of climatic extremes is caused by human activities through practices of vegetation fires, deforestation. Also, 91% of the family maize farmers report that farms are exposed to strong winds at the beginning and end of the season.

This situation currently gets even worse, with maize stalks⁶ being overturned, leading to a de facto proliferation of bacterial and fungal diseases. For 88% of maize producers, the late installation of the beginning of rainy seasons, the uneven distribution of rainfall in time and space, extreme heat and pockets of

⁶ The stalk of maize is a biological structure that must balance its biotic and structural support functions.

drought at the beginning and end of the rainy season justify lower yields. This local climate variability results in a disruption of the agricultural calendar. Thus, the planting periods are dependent on rainfall. 92% of farmers sow in early June instead of mid-May. Over 97% of farmers have adopted short-cycle maize varieties. In the face of this situation, the once neglected low-lying areas⁷ are now the coveted home of all family maize farmers.

To cope with this climate variability, producers are using new production techniques. Thus, the majority (98%) are more likely to apply crop association as a resilience strategy that can mitigate the effects of climate variability on maize production. The most common crop associations are maize-sorghum (67%), millet-maize (23%), okra-maize (9%). The advantage of this strategy is that it facilitates water supply to associated crops by reducing water stress during the cycle through the possibility of offsetting between associated species on the same family farm.

Crop rotation is a crop-growing technique consisting of the succession and distribution of crops on the same family farm. It allows four crops to be grown at the same time without association on the same agricultural plot. 78% of family farmers report that crop rotation techniques are effective in maintaining soil fertility and coping with the effects of climate variability. The use of organic and chemical fertilizers is also a strategy adopted by family maize farmers in the rural municipality of Bérégadougou. This strategy allows producers to increase the yields by using chemical fertilizers such as NPK (nitrogen, phosphorus, potassium). 48% of the producers use chemical fertilizers. Organic fertilizers are used by 97% of maize producers on their farms.

Rainfall disturbances in the rural commune of Bérégadougou, marked by alternating wet and dry years, shorten the vegetative cycle and disrupt the maize farming calendar, affecting production through lower yields. These results are shared by the conclusions of the work of Djohy et al. (2015) on maize cultivation in the commune of Parakou (Benin). These authors attest that the rainfall index for the period 1965-2012 emphasized that the municipality of Parakou is characterized by a high variability in rainfall in the form of an alternation of deficit and surplus years. The municipality recorded 47% of deficit years, 51% of surplus years, and only 2% of normal years. The alternation of wet and dry years in the period 1965-2012, led to the disruption of crop schedules and lower yields.

Furthermore, the investigations of Adjovi et al. (2019) show that mainly rain-fed food production has experienced a gradual decline in yields and production volume in recent years. Indeed, the temporal analysis of climate indicators and food production in this region is a very good example of the effect of climate change on agriculture. Similarly, Akindele et al. (2013) show that rainfall deficits or excesses and rising temperatures led to maize yield declines of 10-30%. The work of Dao et al. (2015) also point out that climate variability is one of the constraints on maize production in Burkina Faso. Indeed, they attest that climatic instability led to intra-annual rainfall variations and drought became a recurring problem. This was acknowledged by famers in the two agro-ecological

⁷ These lowland areas are wet all year round, which means that farmers can harvest crops in dry years.

zones. Drought is characterized by an unequal distribution of rainfall in both time and space. Results show significant difference in drought ranking between the two zones. In South-Sudan zone (annual rainfall is above 900 mm), drought is perceived to be more important than in the north-Sudan zone (annual rainfall is between 600 and 900 mm) because, during the long season (South Sudan zone), two frequent drought periods are generally observed. One is at seedling stage, during the period that many farmers plant, when the first rains fall, but, unfortunately, the rains may stop after one to two weeks. The second drought period occurs during the grain filling stage. In the short-season areas (North-Sudan zone), plants are more subject to drought just after planting.

The results of our research have shown that the rise in temperature favors an increase in the rate of evapotranspiration in the rural commune of Bérégaougou, resulting in a drop in yields and, by extension, in production. Research by Boko et al. (2012) confirms that temperatures in Pobè increased by 2.3°C (maximum temperature) and 1.9°C (minimum temperature). The temperature in the north also increased by 1°C, confirming that the municipality of Parakou, like the other municipalities in Benin, is experiencing a trend towards higher temperatures. Similarly, Gnangle et al. (2009) show that in central Benin, the average temperature has a growth rate of 0.03°C per year and a difference of 2°C between 1960 and 2008 (26.3°C to 28.3°C).

For Djohy et al. (2015), the increase in temperature is also a challenge as it contributes to the reduction of yield because the inter-monthly variation of mean temperature between 26.9°C and 30.1°C influence seedlings that do not find water to germinate and they rot in the soil. Similarly, Traoré's (2016) investigations on maize in Burkina Faso show that temperature, wind, humidity, and light influence maize development. Of these factors, temperature is the most important. A temperature of 15°C is often considered to be the threshold below which the maize plant is under stress, i.e. in a physiological state that reduces the performance of vital functions.

The extent of the reduction in performance varies according to the stage of development at which the cold occurs, the duration and severity of the cold and the genotype. Cold alters the phenology and general productivity of maize. According to Vlăduț et al. (2023), the temperatures and rainfall during the growing season are climatic factors that strongly influence the yield and quality of maize. As a thermophilic plant, maize tolerates high temperatures well compared to other cereal crops, but its productivity is strongly affected by extreme temperatures.

The results of this research showed that farmers' perceptions of climate variability are in line with the conclusions of climatological work. Indeed, family farmers are unanimous on the persistence of extreme climatic phenomena such as temperature increase, appearance of strong winds and regular decrease in rainfall. To deal with them, they adopt strategies such as crop combinations, rotation, use of chemical and organic fertilizers. These conclusions are shared by the work of Djessonou (2013). The author confirms that to face extreme climatic phenomena, agricultural populations of the municipality of Za-Kpota in Benin have adopted as

resilience strategies the association of crops at 95%, 75% rotation, 40% chemical fertilizer and 60% organic fertilizer.

Our results are similar to those of Adjovi et al. (2019) which attest that the maize farmers in Bohicon (Benin) very often engage either in an intensification of the use of chemical fertilizers, or an extension of cultivated land, or a readjustment of the agricultural calendar. Similarly, Djohy et al. (2015) shows that faced with uncertainty, farmers develop various adaptation strategies resulting in the development of new technical routes, intensification and diversification of crops. The results of research by Sithole et al. (2023) on the role of agricultural projects in building a sustainable and resilient maize value chain in Burkina Faso show that Greening maize production is essential for improving sustainability. Using environmentally friendly, socially acceptable, and economic practices enhances productivity and profitability while accounting for social and environmental justice. In Burkina Faso, maize systems, various greening approaches were implemented in maize production: resilient maize seed varieties, stripping, intercropping, crop rotation, and external inputs such as compost and fertilizers. Furthermore, the results of Wokou et al. (2015) are contrary to our findings. These authors attest that most endogenous strategies for adapting agricultural production systems to climate change are not effective because of the cost of implementing them.

4. CONCLUSIONS

The rural commune of Bérégaougou, in the province of Comoé, is a maize-growing area. This production takes place during the rainy season, precisely between May and October. There are four key stages in production: preparing the fields, sowing the maize seed, tending the crops and harvesting. Essentially rain-fed, maize production is influenced by climatic parameters. An analysis of climatic parameters, coupled with farmers' perceptions of climate variability, confirmed variations in the climate, such as violent winds, a regular drop in rainfall, and an increase in temperature.

The results of the survey show that 91% of the growers confirm that they are exposed to strong winds at the beginning and end of the season and 88% say that the rainy season starts late, with uneven rainfall distribution in time and space, extreme heat and pockets of drought at the beginning and end of the rainy season. This climatic variability is at the root of the drop in maize yields and production. Given its strong dependence on rainfall, maize production is characterized by alternating deficit and surplus years, prompting farmers to implement resilience and adaptation strategies.

Maize growers in the rural commune of Bérégaougou have adopted several strategies to strengthen their resilience to climate variability. Most farmers (98%) practice crop association, a technique whose advantage is that it facilitates the water supply to associated crops by reducing water stress during the cycle, thanks to the possibility of compensation between associated species on the same family farm. Crop rotation, implemented by around 78% of growers, effective in maintaining soil fertility and coping with the effects of climate variability. Nearly

half of the farmers (48%) apply both chemical and organic fertilizers to enhance productivity, while many have also opted for short-cycle maize varieties better adapted to the shortened rainy seasons. To further improve maize yields, coordinated actions from public institutions and private stakeholders must provide technical and financial support for these adaptive practices.

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AUTHOR CONTRIBUTION

All authors contributed to the design and writing of the article. Data collection was carried out by Salifou SANOGO, Bienvenue Lawankilea Chantal Noumpoa KARAMBIRI, and Mahamoudou BADINI, analysis and graphical representations were developed by Salifou SANOGO, Bienvenue Lawankilea Chantal Noumpoa KARAMBIRI, Mahamoudou BADINI, and Pawendkisgou Isidore YANOOGO. The first draft of the manuscript was written by Salifou SANOGO and all authors discussed and provided feedback. All authors reviewed the manuscript and approved its published version.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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