Original Research Article

Effects of Rainfall Variability on the Occurrence of Crop Pests at Foumbot Subdivision, West Region of Cameroon

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ABSTRACT

Rainfall is an essential climate variable for plant development. Its variability has an impact on the plant phenology. The present study aimed to analyze the variation in rainfall in order to determine the rainfall hazard responsible to the occurrence of pest and diseases in tomato and maize. The study was carried out at Foumbot located in the Western Region of Cameroon, more specifically in the Noun Division. Part of this district occupies the left bank of the river Noun, more precisely the Noun plain. The rainfall data was collected from the period of 1997 to 2019 and analyzed. Monthly data was collected from 1997 to 2019 and daily data from 2010 to 2019.The surveys were made with three groups of actors: the agricultural services (the Agricultural Delegation of Foumbot), the agricultural research services (IRAD of Foumbot), and the farmers' organizations (the Common Initiative Group (CIG) and cooperatives). Stratified random sampling was used for the surveys. The results revealed that the first cropping season from March to July is characterized by an increase in consecutive dry days of 5 to more than 7 days. This situation has been confirmed by 30% of the investigated actors, who mentioned that consecutive days without rain were favorable to the appearances of pest and diseases. The SPI (Standard Precipitation Index) analysis of rainfall data showed that this can be link to the prolongation of the dryness season in the cropping season which started in March. Therefore, the monthly SPI consider March as a dry month. So, March and May are not suitable for the beginning of cropping season due to the multiplication of drought episode. The tomato leaf miner (*Tuta absoluta)* and the armyworm had been identified as the pest and disease which appear during the consecutive dry days. They are characterized by an increase in temperature. The study is useful for agricultural drought management and crop productivity in an unpredictable environment.

Keywords: West Cameroon, crop pest; maize, tomato; rainfall variability

1. INTRODUCTION

More than 40% of crop losses are due to pests worldwide [1-3]. Two factors increase the risk of potential pest pressure in agriculture. Climate change provides suitable conditions for pests to adapt across areas which were previously detrimental for their survival [4-5].

Dramatic situation has been observed in specific regions due to the change in rainfall distribution within the cropping season [6]. Despite the relative evolution of maize production, producers face some diseases threats from climatic constraints [7]. Climate change will also have a complex interaction with the timing and severity of the disease, pests and weeds interactions [8]. The African rainy agriculture will be continuously affected [9]. Crops such as maize and tomatoes will be highly sensitive to rainfall variability [10]. Indeed, crops simulation models indicate that by 2050 in Sub-Saharan Africa, average rice, wheat, and maize yields will decline up to 10%, due to climate change and climate variability [11].

Diseases and pests (plant pathogens, vertebrates, insects, nematodes and weeds) are among the important causes of low agricultural productivity in Cameroon in general and in the study area, in particular. Cereals (maize, rice ,sorghum and vegetables) are part of the basic diet in Cameroon [12-17]. Pests and diseases affect maize and tomato production, either directly through crop losses or indirectly through lost profits. Today, changes and increased volatility of rainfall hazards increase the frequency and intensity of pests and diseases and thus losses, threatening food security and the livelihoods of rural households. The biological and environmental risks especially rainfall variability has an impact over all stages of maize and tomato production. Due to rainfall uncertainty a total loss in crop production is estimated at 35-45% in Cameroon [18].

The development of harmful pests and diseases that affect crops, particularly maize and tomatoes, over the production stages, their frequency and intensity of damage are increased as a result of the variation in rainfall. The changes in precipitations patterns alone will significantly increase the likelihood of crop failures, such as maize and production declines [19]. As a result of changes in rainfall patterns, maize post-harvest is easily contaminated with fungi that produce potentially lethal mycotoxins [20]. In Cameroon, few studies were done on the identification of pest appearance based on climate indices.

Therefore, the study investigates the effects of rainfall variation on the appearance of some maize and tomato diseases, and pathogens. The objective of the study was to analyze the variation in rainfall in order to determine the climate indices responsible to the occurrence of pest and diseases.

2. EXPERIMENTAL DETAILS

2.1 Study site

Study was done at Foumbot (Fig. 1). It is located in the West Region of Cameroon, more precisely in the Noun Division. Part of this district occupies the left bank of the river Noun, more precisely the Noun plain. It is one of the agricultural basins of the Grass field. It is an old volcanic land and the fertility of the soil is the reason of the attractively of farmers around the neighboring cities.

Foumbot is located in the tropical Sudano-Guinean climate, characteristic of the entire West Region. The average rainfall varies between 2500 and 5000mm of rain per year, with minima and maxima in october and July respectively (IRAD, 2013). The average annual temperature fluctuates around 21°C.We note the presence of violent winds which change direction and strength according to seasons. These winds are the cause of some damage to homes, fragile plants such as banana trees without stakes and corn plants. They are also the cause of wind erosion, especially on bare plots and on those that have just been turned over and sown. The average relative humidity is above 80% with maximums in August and September.

2.2 Rainfall data collection

The rainfall data were collected at Institute of Agricultural Research for Development (IRAD) of Foumbot. These monthly and daily data cover the period from 1997 to 2019. The data was used to determine and characterize the monthly rainfall variation within the cropping season.

2.3 Survey in the study area

The active participatory research method and its main tools were used to collect information in the study area (Foumbot). These included interviews, questionnaires and direct observation. The survey was carried out in six villages (table 1).

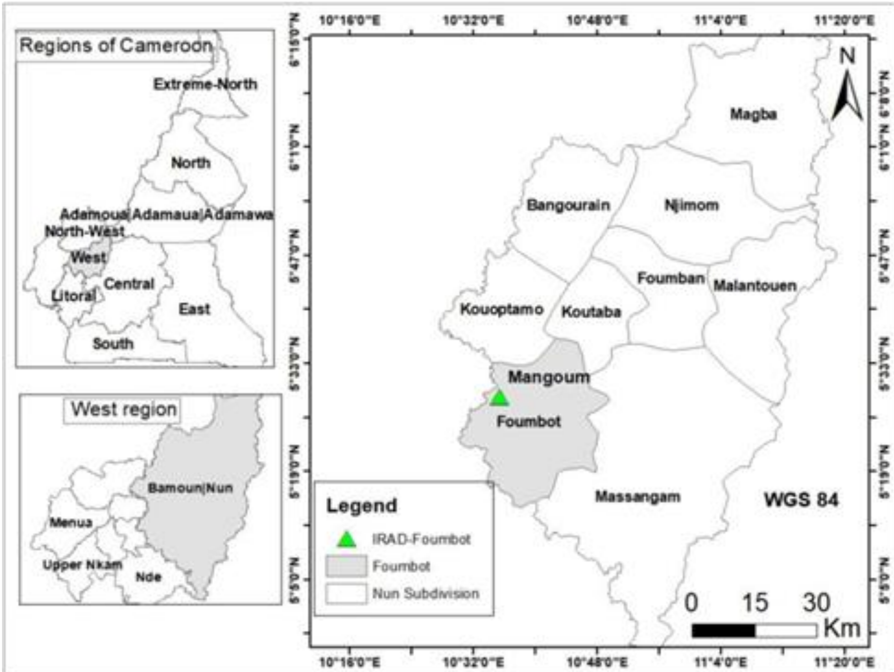

Fig. 1. Study area in Foumbot located in the Western Region of Cameroon.

The villages are areas of the intense crops production (tomato and maize) following the guidelines defined by the heads of the agricultural services that ensures the coordination of farmers' organizations. Questions were focused on the agricultural activity, the production of maize and tomato, the difficulties faced in the production of maize and tomato, the behavior of seasonal rainfall, and the cropping periods, types of pests that affected crops with a particular rainfall hazard. Questions were also focused on the perception of rainfall variability, and the investigation of the climate variables which are among the first problem affecting the production of maize and tomato.

Three groups of people were interviewed. These were the agricultural services (the Agricultural Delegation of Foumbot), the agricultural research services (IRAD of Foumbot), and the farmers' organizations (the Common Initiative Group (CIG) and cooperatives). The farmers must meet the following criteria: they must be members of the agricultural organization’s board, residing in the Foumbot Sub-Division, be able to provide information on agricultural disasters induced by rainfall variability, agriculture must be their main economic activity, and they will produce maize and tomato in Foumbot. Ten agricultural organizations were investigated and each organization sent three members to participate to the survey. The total of sixty (60) people from the ten organizations participated in the survey (Table 1).

Interviews were conducted with the agricultural services especially the managers of the structures, particularly the chief and five staff members. The interviews were focused on their perception of climate change, the types of rainfall hazard responsible for the spread of pest and pathogens. Moreover, the interview was based on the diagnostic of climate variables increasing the severity of pest and pathogens in Foumbot.

Table 1. The rural and urban area of the study area, Farmers organization and number of members interviewed in July 2019.

Villages of the study area	Farmers organization	Nº of members interviewed
Baïgom	COOP-CA-RIFO	10
	COOPROMA	06
Mongoun	PROLEG-SA	08
Mangoun	GEBAM	05
Mangoun	GIC NAOUSSI	08
	GEBAC	07
	TERRA NOSTRA	05
	GEBAMENE	03
Foumbot	Coop GIJAF	3
Fossang	GIC POTONA	05
Total	10	60

2.4 Data analysis

2.4.1 SPI) analysis for monthly meteorological drought

In 2009, the World Meteorological Organization (WMO) recommended that the Standard Precipitation Index (SPI) would be used primarily to monitor changes in meteorological drought conditions [21-22]. By advocating wide use of the SPI, it pointed the way for countries seeking to establish some level of early warning for drought. SPI satisfactorily explained that the contrast, hotter and drier conditions which many already semi-arid areas of the world will limit the possibilities for agriculture [23]. The calculation of the Lamb's rainfall anomaly index, or SPI, is expressed by the equation.

$$li = \frac{xi - \bar{x}}{s} \qquad SPI = \frac{1}{N_i}\sum_{j=1}^{N_i} \frac{P_j^i - \overline{P_j}}{\sigma_j}$$ (Equation 1)

With xi: the value of the annual rainfall; $\bar{x}$ the interannual mean value over the period from; S: standard deviation; Where Pj: the rainfall of year i at station j, Pj: la the interannual mean rainfall of station j, σj: the standard deviation of the series of seasonal cumulations at station j and Ni: the number of stations of the year i. It is a very important index, to determine the level of dryness and wetness of the cropping season (March to November). The classification adopted by the WMO, where seven classes of drought, ranging from extremely dry to extremely wet, can be distinguished (Table 2).

Table 2. Drought class according to Standardized Precipitation Index (SPI) [23]

SPI values	Drought category
2.0 and more	Extremely wet
1.50 to 1.99	Very wet
1.0 to 1.49	Wet
-0.99 to 0.99	Normal
-1.0 to -1.49	Moderately dry
-1.50 to – 1.99	Severely dry
-2.0 and less	Extremely dry

2.4.2 Analysis of some climate indices link to the pest and diseases

2.4.2.1 Consecutive Dry Days (CDD)

The daily precipitation amount on a day in a period. Count the largest number of consecutive days where:

$RRij < 1\,mm$ (Equation 2)

2.4.2.2 Consecutive Wet Days (CWD)

The daily precipitation amount on a day in a period. Count the largest number of consecutive days where:

$RRij \geq 1\,mm$ (Equation 3)

2.4.3 Tools and Survey data analysis

The data collected from the respondents were analyzed using SPSS software (version 25.0 for Windows). This software was used to analyze the quantitative and qualitative data from the survey conducted in the study area. Microsoft Excel Software was used to plot rainfall and some survey data. R Climdex software was applied to the rainfall data only to analyze extreme rainfall indices. It determines climate indices (consecutive dry days and wet days) which plot graph base on the daily and monthly data.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Characteristics of monthly variation in rainfall of the cropping period at Foumbot

The distribution of monthly rainfall amounts during the growing season is an important variable and should be considered in planning and managing agricultural activity. The monthly evolution of rainfall at Foumbot is characterized by a monomodal rainfall regime (one raining season and one dry season). Therefore, even though the rainfall regime shows one rainy season, agricultural activity is planned twice within the rainy season. At Foumbot, the agricultural calendar shows that the growing season starts with the first rain from 15 March and finishes on 15 November. The rest of the months of the years are considered as dry season. Figure 2 below illustrates the monthly and seasonal distribution of rainfall. However, the annual distribution of rainfall during the dry season and the raining season shows that January and December are the driest months. The rain season can be divided into two periods, March to July and July to mid-November. The difference in rainfall amount between June and July (50 mm) is visible in figure 2. March and November have a deficit in rainfall amount because they are considered as the beginning and the end of the cropping period respectfully.

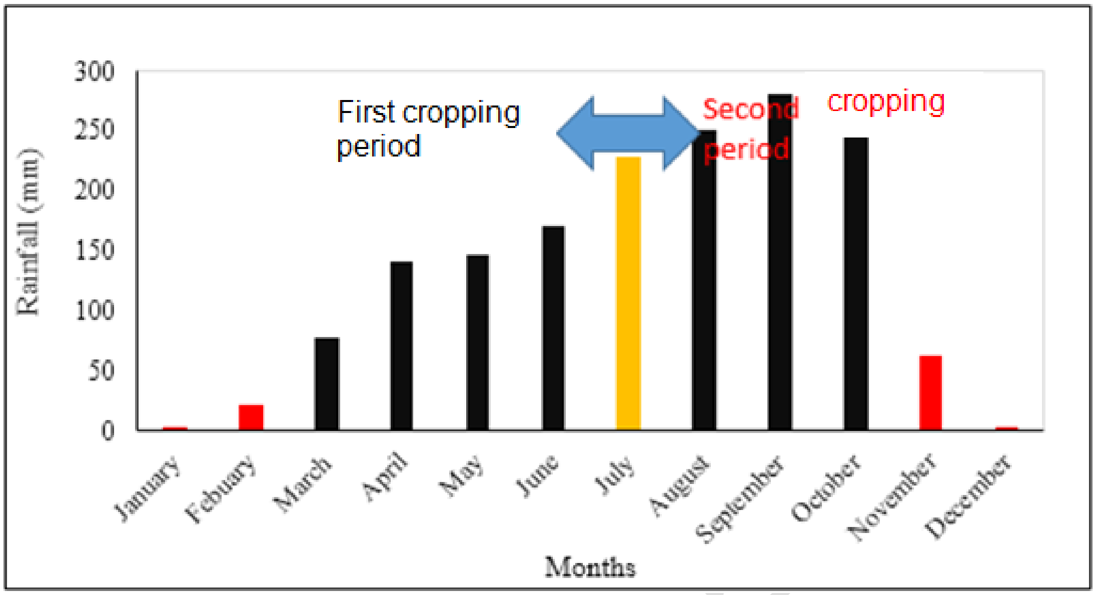

Fig. 2. Monthly rainfall in Foumbot, Cameroon.

The red color indicate de dry season (15 november to the 15 march) the black color indicate the raining period and the yellow color shows the transition phase from the first raining period to the second raining period. The raining period is consider as the cropping period.

The monthly dryness and wetness condition is determined with the Standard Precipitation Index (SPI). It brings out the state (dry and wet) of each month within the cropping period. The month of March which was considered as the period to start the seed sowing is a dry month. So, 52% of farmers sowed in March while 48% in April. March was affected by the prolongation of dry season that spanned across 15th November to 15th March. Therefore, it had a high sensitivity to the occurrences of consecutive dry days which was the source of lowest moisture of April and May (Fig. 3). May corresponded to the vegetative stage of the maize as well as the seedling period of tomato. Those stages of crop growth were affected by pest and diseases. For example, famers mentioned that in 2015 more than 50 hectares of maize was destroyed by pest and diseases in the area (Foumbot) during May.

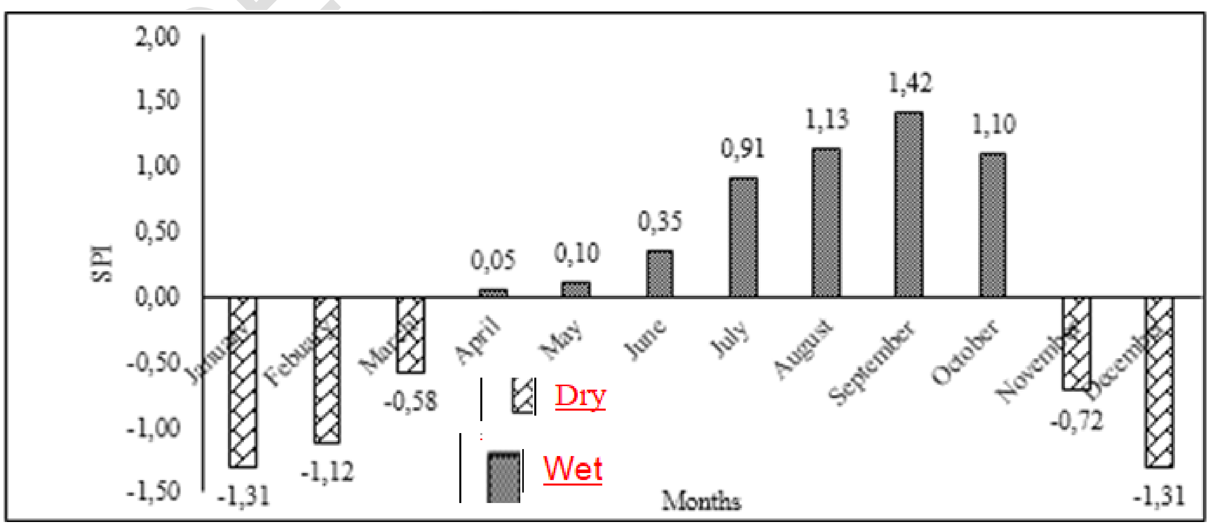

Fig. 3. Monthly SPI of Foumbot, Cameroon.

According to the classification of SPI, March had a moderate dryness while April and May a normal moisture.

The analysis of daily rainfall from 2010 to 2018 allowed to highlight a series of consecutive 5-day without rain and a consecutive of 7-day without rain. As a rule, these consecutive rainless days are favorable to the evolution of pest and diseases in Foumbot. Figure 4 presents an increase in consecutive dry days during the cropping period from 2010 to 2019. While the dry days are increasing, the wet days are decreasing. The study area was affected by an increase in consecutive dry days and this climatic condition was favorable to the development of insects such as Tuta absoluta and borer.

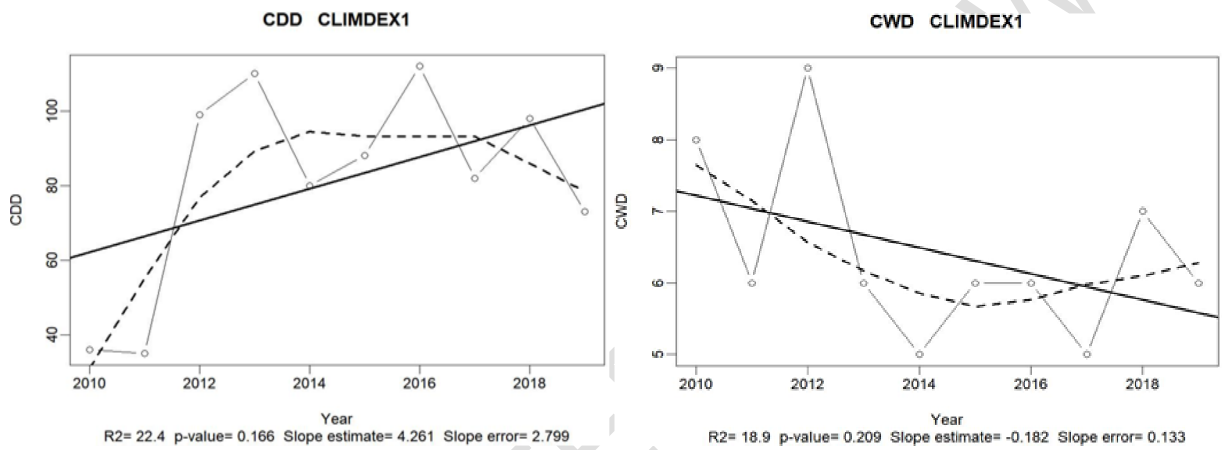

Fig. 4. Evolution of consecutive dry day and Diminution of consecutive wet day's at Foumbot.
CDD: Consecutive Dry Days; CWD: Consecutive Wet Days

From mid-March to mid-November, an estimation of the consecutive dry days showed an increase of days with less than 5 mm of rainfall (Fig. 5). The month of May has a mean of 9.22 days, with less than 5 mm. For 52% of the farmers who sowed in March at Foumbot, the situation of crops during the month of May especially maize and tomato have always been difficult because with less than 5 mm of rain, conditions are favorable for the multiplication of pests and diseases.

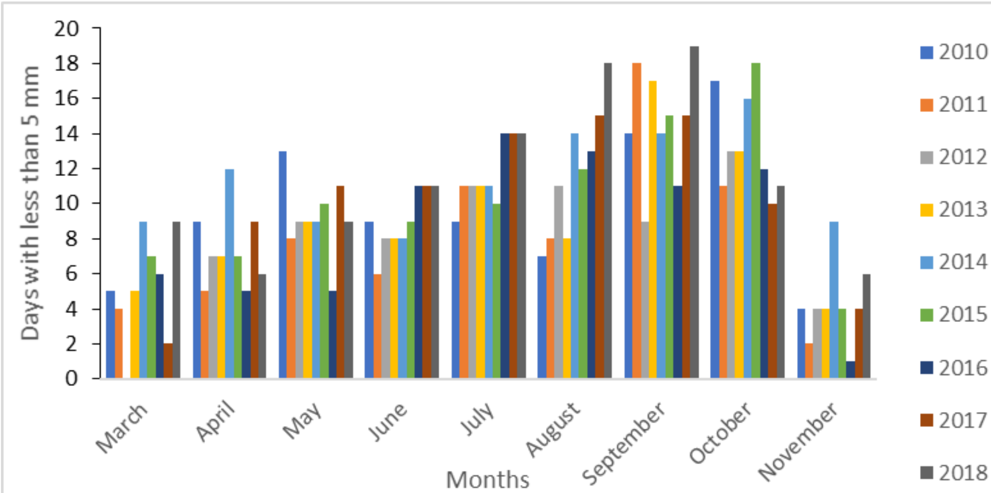

Fig. 5. Number of daily rainfalls with at least 5 mm at Foumbot

The reduction in the consecutive wet days during the last decade justifies the dryness of the study area, especially from 2012 to 2019. This condition led to the multiplication of diseases, insects, and pathogens. Figure 6 explains meteorological drought and agricultural drought are the cause of water stress which predisposed plants or crops to the plant attacks. The analysis carried out in this part was based on the analysis of seasonal drought manifested by the monthly drought and the consecutive dry days.

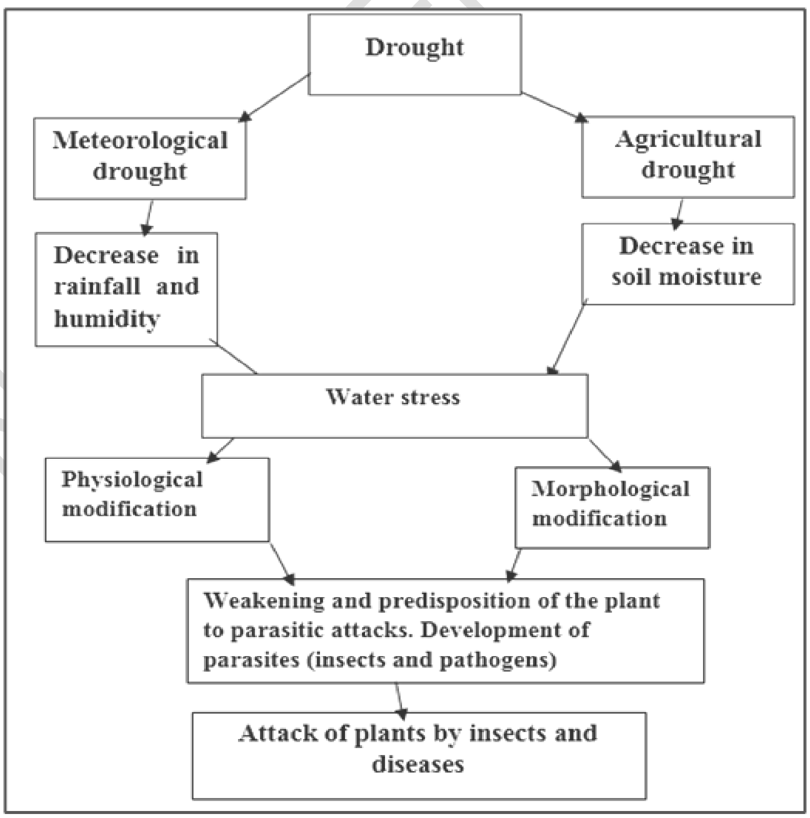

Fig. 6. Effects of drought on plants (adapted from [24])

After analyzing the rainfall data, it is established that Foumbot was affected by the multiplication of dry spell within the cropping period. It is a favorable predisposition to the multiplication of diseases, insects and pathogens.

3.1.2 Identification of pest, diseases and climatic indices responsible of their occurrences

During the participative survey, rain was mentioned by different groups of farmers as the most damaging climate variable in the study area. They agreed on the fact that there is an increase in rainfall perturbation. Based on different answers, it was possible to realize that rainfall indices are pointed out as the most dangerous problem affecting crop growth and production (Fig. 7).

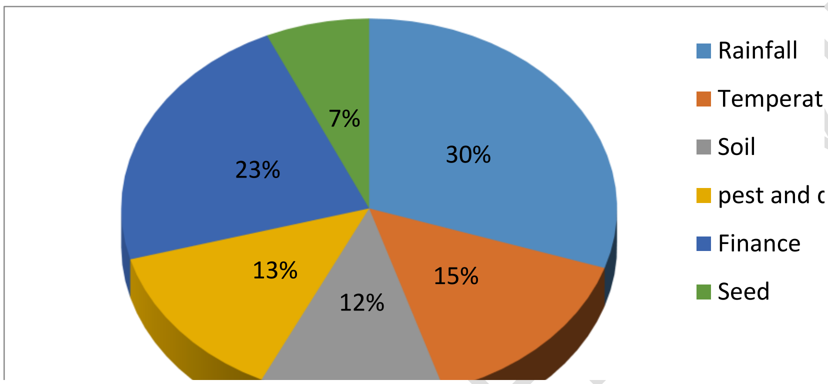

Fig. 7. Types of constraints faced by farmers during the sowing period

Farmer's (30%) consider the consecutive days without rain within the cropping season, as the origin of appearance and occurrences of pest. The expression they used is as follow: "when it is raining, suddenly it stops and days which follow are without rain". Therefore, young plants which are at the vegetative stage are exposed to deep stress which should compromise their development, increasing their exposure to the severity of diseases and the decrease of yield. Farmer's (13%) consider pest and diseases as one of the challenging difficulties affecting their activity and identify Tuta absoluta and borer as the most devastating pest and pathogens in the entire area.

They were complaining of damage from pests and diseases. The field survey was used to evaluate and identified which of the rainfall hazards increase the multiplication and the propagation of diseases, pathogens, and pests.

Table 3. Climatic condition favorable to plant attack at a different stage of growth

Rainfall Hazard	diseases, pathogens and pests	Plant stage
high humidity	Mycotoxin	Maturity (harvest)
Water stress	Nematode	Vegetative
Dry and warm conditions	viral epidemics	Vegetative

Consecutive days without rain	*Tuta absoluta* (Boko Haram) and corn armyworm (Borer)	Vegetative and maturity
Floods	Crazy top and common smut	Vegetative
Drought	*Tuta absoluta* (Boko Haram) and corn armyworm (borer)	Seedling

From the above table (Table 3), it can be concluded that the vegetative stage is the most affected by pest. Apart from the information shown in the table, there was also maize streak virus (MSV) with continuous whitish stripes on the leaf at the vegetative stage 30 to 50 days. Stem rot caused by fungi damaged grain filling and stem integrity. Inflorescence smut, fusiform helminthosporiasis (*Ustilago maydis*) on the ear and bare smut (*Sphacelotheca reiliana*) due to the pathogen (*Helminthosporium turcicum*) were caused by a fungus that attacks the ears and stems, causing malformations and black dust. All of this happens under seasonal drought appearances. The maize aphid (*Rhopalosiphum maydis*) is a sucking borer that feeds on juices (nutrients). Cornstalk borer (*Fusarium* sp) caused by fungi (*Fusarium graminearum*, *Gibberella zeae*) causing dark external lesions or spots at the lower nodes. Inside the stem, the rotten marrow tissue turns a salmon-pink color.
The Borer attacks the stem and cobs of the maize. On the stem, from the second larval stage onwards, the caterpillars drill an entry hole in the epidermis and then drill the stem lengthwise in an upward direction. The medullary parenchyma is then consumed. The caterpillars complete their larval development inside the stem. As the insect approaches the entrance hole, the pupation occurs in a nearby cubicle inside the stem, among excrement and remains. Several caterpillars of the same species can be found at regular intervals along the same stem, whether they belong to the same species.

Fig. 8. Some damage to plants at Foumbot Source: field survey Tchuenga, 2019
A: Destruction of maize plots; B: Drying up of tomato plants following attacks by Tuta absoluta,

The most common disease is Tuta absoluta (Boko haram), according to 90% of the tomato growers surveyed in the study area. T. absoluta has a particularly high reproduction rate. Its life cycle includes four stages of development: egg, caterpillar, pupa and adult. Adults lay between 40 and 250 eggs, most often located on the underside of leaves or the young tender stems and sepals of immature fruits. The females lay their egg s individually at night on the upper third of the plant. There is no information on the ability of this species to enter diapause under unfavorable conditions, such as drought and high temperatures present in the Sahelian region. The danger of this pest lies in the fact that it enters the stem or the epidermis of the leaves where it digs galleries. It causes the plant to dry out as it is observed on the picture above (Fig. 8). The increase in dryness accelerated the destruction of the plant.

On leaves (Fig. 9), the larvae only devour the parenchyma, leaving the epidermis of the leaf; the attack is characterized by the presence of irregular and discolored patches. Subsequently, the attacked leaflets dry out completely. The mines in the leaves take an irregular form of, whitish patches with the presence of excrement, gradually turning brown and necrotic. Heavily attacked leaves may dry out completely. In case of severe damage, the caterpillars can consume the entire leaf tissue, leaving large amounts of black excrement.

Fig. 9. *Tuta absoluta* (Boko haram) in the leaf of Tomato Source: field survey Tchuenga, 2019

Females prefer to lay their eggs on leaves (73%), then on stems (21%), sepals (5%), or green fruit (1%). On stems, flowers or peduncles, the nutrition and activity of the larvae disrupt the development of the organs and can cause the fall of flowers or young fruits. Galleries may appear on young stems, disrupting plant development. Affected fruits show necrosis on the calyx and exit holes on the surface of the integument. They are perforated by galleries that are rapidly colonized by secondary pathogens causing widespread rot and loss of fruit. Fruits are vulnerable from formation to maturity, but egg-laying has not been achieved on ripe tomatoes. One larva can cause damage to several fruits in the same bunch.
Sometimes caterpillars use silk produced by their salivary glands to weave silk shelters or enclose shoots, peduncles or young leaves. The damage caused by Agromyzidae flies (serpentine leaf mines) should not be confused with that produced by *T. absoluta*, whose wider galleries then cause the necrosis and drying out of large leaf patches. In sub-Saharan

Africa, it is possible that *T. absoluta* not only attacks cultivated solanaceous plants, but also local species of the genus *Solanum*, such as African eggplant (*S. aethiopicum*, Kumba and Gilo group, *S. anguivi*, *S. americanum*, *S. macrocarpon*, *S. scabrum*, *S. villosum*).

3.2 Discussion

The climate variability of Foumbot was not known since 1986 [25]. The study describes the seasonal and intra-seasonal variation in climate parameters at Foumbot. The result indicated that during the rainy season, there is an increase of the consecutive days without rain and a decrease on consecutive wet days. The monthly SPI consider March as a dry month even though 52% of farmers consider it as the beginning of the sowing period. Earlier March to mid-April, enough long dry periods are regularly observed, and when rainfalls are registered, their amount is usually very low. The period is very risky, regardless of the abundant rainfall usually recorded at the beginning of the rainy season. Moreover, at the start of the rainy season, the soil is still parched and need a lot of water to adjust the soil water reserve lost by the evapotranspiration [26]. Indeed, the SPI analysis shows that the contrast, hotter and drier conditions which many already semi-arid areas of the world, will limit the possibilities for agriculture [24]. However, wet and moisture condition are also vital for the occurrence of fungal and bacterial species [27]. The same situation has been reported by the sixth assessment report of IPPC (regional fact sheet – Africa) showing that there is a decrease in standardized precipitation index (deficit of precipitation) and increase in agricultural and ecological droughts in Central Africa. In the study, the agricultural drought was analyzed base on the consecutive dry and wet days. The results are similar with the IPCC report. There is an increase in days without rain in Foumbot and a decrease in wet days.

Although some plant species are tolerant of rainfall variability or drought [28-30], these conditions of Foumbot presented above increase the vulnerability of maize and tomato to diseases and pests such as Tuta Absoluta and maize Borer. In Cameroon, three regions (Northeast, West and South) were reportedly affected by T. absoluta with severe yield losses reaching 100% [26]. The earlier May (5 weeks after sowing), the appearance of drought is favorable to the multiplication of pests which destroyed crops during their growth stages. Climate variability could have many effects evident in the occurrence of fluctuations in climate, prolonged variations and crop diseases [31-32]. The survey conducted on the field showed that the dryness and day's with-out rain permit the occurrences of pests and pathogens. So, the rainfall data analysis and interviews identified dryness in the area as the most dangerous rainfall hazard impacting the occurrences of Tuta and maize borer. The same situation is observed in Niger by Agrhymet [33].

Republic of Niger [34] consider drought as a climate hazard that has adverse effects on agricultural production. Indeed, the distribution of monthly rainfall amounts during months of the growing season are essential variable and should be considered in planning and managing agricultural activity [35-36]. These glaring adversities of climate variability are real in the country in general and, with particular cases, in the Savanna zone, associated with the Cameroon type climate in the Western Highlands [37]. Extreme rainfall events will probably be the most challenging for farmers and society in general under future climate change [38].

Over the last 10 years, the insect Tuta absoluta has become one of the most important threats to agriculture worldwide. Since its introduction in Spain in 2006, this pest has infested 60% of the tomato crops in many regions of the world [27]. Additionally, the studies carried out in tropical areas [39, 40, 41, 42] establish to contribute to present and future research, as well as to support specialists studying the potential impacts of the variability and climate change in the production of crops such as maize [43]; tomatoes [44] and other tropical crops [45, 46, 47]. Despite certain efforts by various organizations aimed at initiatives by peasant communities and small producers to face climate change, the farmers of our study area seem not prepared to face the challenges of a possible effect of climate change and climate variability on agriculture, our results being similar to those reported in vulnerable agricultural areas [48, 49, 50], for this reason this study was carried out on the effects of rainfall variability on the occurrence of crop pests at Foumbot Subdivision and avoid a reduction in agricultural production due to the attack of pests and diseases under climate change scenarios.

4. CONCLUSION

The findings showed an increase in the consecutive dry days in Foumbot and the reduction of wet days. This climatic situation exposes the study area to the appearance of some diseases and pests, which has a huge impact on plant growth and yield. This result was supported by the field investigation carried out with some farmer's organization (GIC) who confirms that the development of some pest such as *Tuta absoluta* and borer is the result of the consecutive days without the rain. Even without climate change, pest management will face some serious challenges in the coming decades. Coordinated research, including climate change, climate variability, agronomy, entomology, and food security programs, will be needed to improve the range of options available in the agricultural research in the country.

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