Research Article

A comparative study of the influence of climatic elements on cocoa production in two agro-systems of bimodal rainfall: Case of Ngomedzap forest zone and the contact area of forest-savanna of Bokito.

Amougou Joseph Armathé, Tchindjang Mesmin, Haman Unusa, Batha Romain Armand Soleil

Departament of Geography, Faculty of Arts, Letters and Human Sciences (FALSH), University of Yaoundé I. joearmathe@yahoo.fr; mtchind@yahoo.fr; hamanunusa@yahoo.fr;bathsol33@yahoo.fr

ABSTRACT

Cocoa production in Cameroon, cultivated on a surface area estimated at 450,000 hectares stood at 200.000 tons in 2012 and represented 2.1% of GNP. This productivity remains low compared to that of other African countries like Ivory Coast, Ghana and Nigeria. This paper aims at determining and comparing the influence of climate on cocoa production in the forest zone of Ngomedzap and the Bokito savanna zone. Ngomedzap has an equatorial Guinean climate type with bimodal rainfall characterized by the alternation of two dry seasons and two rainy seasons of varying durations. The average annual temperature in Ngomedzap is 25.5°C and the average annual rainfall is between 1500mm and 1700 mm . The climate in Bokito is equatorial transition type with a bimodal rainfall, characterized by two rainy seasons and two dry seasons with variable durations. The average temperature is 26.8°C and the average annual rainfall is between 1200mm and 1450 mm. Generally, despite the precarious climate, the influence of climatic parameters on the production of cocoa is more significant in Bokito than in Ngomedzap. The Bokito zone with less precipitation is more favourable for flowering than in Ngomedzap, with 4% and 2.2% respectively while the formation of pods is equally 32.4% in Bokito compared to barely 2.8 % in Ngomedzap. The notion that cocoa production is exclusive to the forest area is accordingly not the rule anymore. These results are useful in situating suitable areas of cocoa production in Cameroon.

Key words: Climate, cocoa, production, rainfall, Cameroon, agrosystem

RESUME

La production du cacao au Cameroun a atteint 200.000 tonnes en 2012, ce qui équivaut à 2,1% au produit intérieur brut (PIB). Sur une superficie agricole totale de 47 millions d'hectares cultivés, 450.000 hectares sont utilisés à des fins cacaoyères. Ce rendement reste faible par rapport à celui de certains pays d'Afrique tels que la Côte d'Ivoire, le Ghana et le Nigéria. La présente étude a pour but de déterminer l'influence comparée du climat sur la production du cacaoyer dans la zone forestière de Ngomedzap et celle de contact forêt-savane de Bokito. Il règne à Ngomedzap un climat équatorial de type guinéen à pluviométrie bimodale caractérisé par l'alternance de deux saisons sèches et deux saisons de pluies à durée variable. La température moyenne annuelle est de 25,5°C et le total pluviométrique est compris entre 1700 et 1800 mm de pluies par an. Le climat de Bokito est de type équatorial de transition à pluviométrie bimodale caractérisé par deux saisons de pluies et deux saisons sèches théoriques à durées variables. La température moyenne est de 26,8°C et, le total pluviométrique est compris entre 1300 et 1600 mm de pluies par an. Dans l'ensemble, malgré la précarité du climat, le degré d'implication des éléments du climat sur la production du cacaoyer est plus significatif à Bokito qu'à Ngomedzap. Bokito connaît une implication des précipitations plus forte à la formation des fleurs ouvertes qu'à Ngomedzap, soit 4% à Bokito contre 2,2% à Ngomedzap et, même à la formation des cabosses présente 32,4% à Bokito contre 2,8% à Ngomedzap. L'idée selon laquelle la production du cacao est une exclusivité de la zone forestière n'est plus d'actualité aujourd'hui. Ces résultats pourront servir comme critères de base nécessaires à l'amélioration de la productivité du cacaoyer au Cameroun.

Mots cle: climat, cacao, productivite, pluviometrie, Cameroun, agrosysteme

Introduction

The instability of the climate in the early twenty-first century affected all sectors of the socio-economic life. As in most tropical countries, Cameroon's economy is based on agriculture (especially the production of cocoa) which is sensitive to climatic fluctuations. The cacao tree (Theobroma cacao) is a shrub of the Malvales family, cultivated in the tropics, with its own characteristics. Figure 1a presents the map of Cameroon and 1b the localization of the study zones.

These two zones of bimodal rainfalls are characterized by two rainy and two dry seasons, but there are also different climatic characteristics, as shown in the hydrothermal graphics (Figure 2 and 3). The average annual rainfall is between 1200 mm and 1450 mm in Bokito, and between 1500 mm to 1700 mm in Ngomedzap.

Soria (1970), demonstrated that cocoa grows in agro-ecological zones between 10 ° South and 20 ° North. In this zone, the daily temperature falls between 24 ° C and 28 ° C with a minimum of 1500 mm rainfall. However, the objective of this work is to show that cocoa grows both in forest area in the moist savannah zone.

Materials and Methods

Data collection was carried out in three main stages: field data collection, data processing and finally, data analysis.

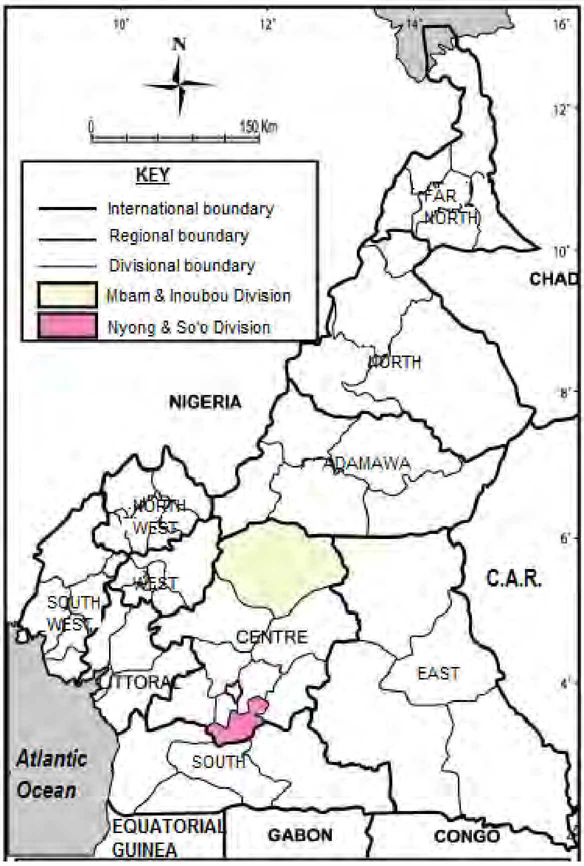

Figure 1a: The Mbam and Inoubou (Bokito) and Nyong and and So'o (Ngomedzap) in Cameroon

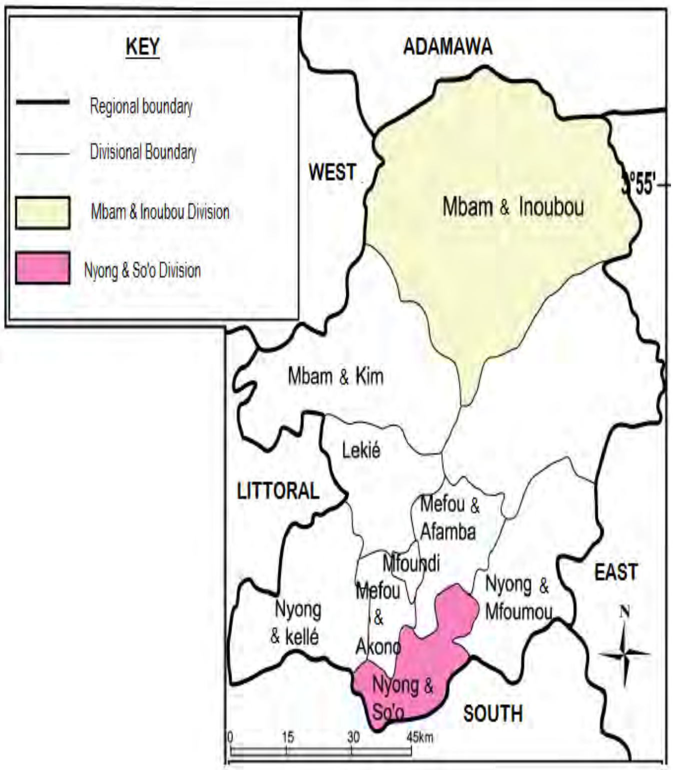

Figure 1b: The Mbam and Inoubou and the NyongSo'o Divisions in the Center region in Cameroon

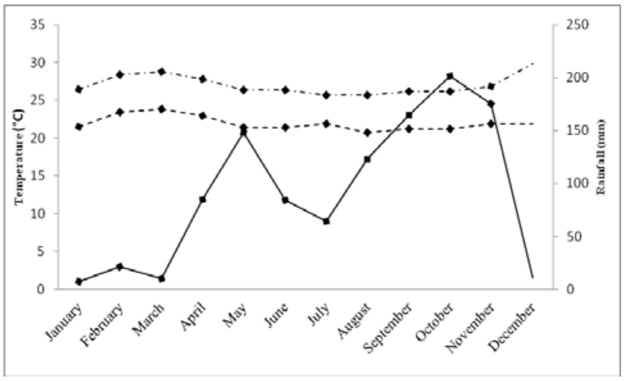

Figure 2: The hydrothermal abacus of Ngomedzap.

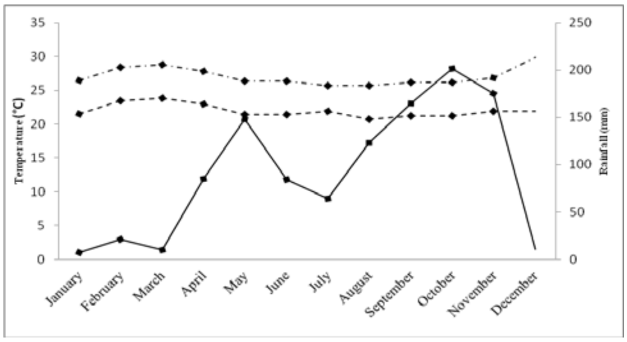

Figure 3: The hydrothermal abacus of Bokito

Criteria for selection of data collection sites

The daily climate data and those on weekly movements concerning the generative cycle of cocoa tree (open flowers, cherelles, pods and wilted fruits) come from a station of IRAD, located at Nkolbisson in Yaoundé. These data were collected and treated between 2003 and 2007 within the framework of the project "Priority Solidarity Fund" (FSP). Climate data were mainly made of rainfalls and temperature

The climatic data collection and those on the generative cycle of cocoa were conducted in cocoa plantations. For that, 16 plantations were selected in four (04) villages of the two study areas. The choice of the plantations was based on the representativeness (of different species of cocoa) within the selected areas, on the availability of the farmers and the accessibility in the plantations. The villages of Kedia and Bakoa were selected in the area of Bokito, while the villages of Abod-Mveng and Nnom Nnam were selected in Ngomedzap zone (Table 1). The choice of the farmers took into account socio-economic factors (that belong to common initiative groups of ordinary farmers, which may facilitate the relationship with the producers of cocoa). In order to conduct a statistical analysis, 30 contiguous cocoa plants were defined in each plot, thus making a sample of 240 cocoa plants per study area.

Three groups of cocoa were observed in Ngomedzap and Bokito: the Cryollo, Forestero, Trinitario. The cocoa farms of Ngomedzap were created since the colonial period around the 1894 to 1900, while the one of Bokito was after the Independence of Cameroun in 1960.

Table 1: Location of the experimental plots.

Location	Localization	Number of de village	Name of the villages	Number of Parcelles	Number of feet of cocoa to study	Type of cocoa	Age of Bokito
			Kédia	4			
					120	-Cryollo	40-50 years
Bokito	**4°34'N 11°07'E and 4.567°N 11.117°E**	2					
			Bakoa	4	120	-Forestero	40-50 years
						-Trinitario	10-30 years
			Abod-Mveng	4	120	-Cryollo	40-80 years
Ngomedzap	**3°15’N11°10'E and 3°20’11°15'E**	2				-Forestero	40-80 years
			Nnom-Nnam	4	120		
						-Trinitario	10-20 years

The climate data and the cycle of the generative cocoa variables in different areas of study

During a period of 24 months, IRAD mobilized an observer to record and read the temperature with a thermometer "min-max" and the daily rainfall in each village with a Fisher pluviometer. The growth of cocoa is affected by two regular alternations during a year.

-The vegetative activity is characterized by some foliar outbreaks of discontinuous rhythm, which seems to follow a climatic cycle.

-The generative activity that begins by the flowering, followed by fruition is characterized by a slowdown of the growth, which according to Ndoumbè Nkeng (2002) is equivalent to maximal growth of the wood.

During 24 months, two other observers were also responsible to collect once a week, between 6 and 8 am, the activity of the generative cycle of cocoa in each plot. The following variables were taken into consideration: open flowers, cherelles, pods, wilted fruits.

Processing and analysis of collected data

<u>*Data treatment in this study*</u>

The resulting variables were analyzed using the Excel program 2000, SPSS version 12.0, GLA version 2.0 and SAS version 8. Decade averages were computed and the variable was established using the data of the observations contained in each plot.

$$Pm = \Sigma(Pa.b)/nNb \quad \text{(Equation 1)}$$

- Pa. b = daily volume rainfall collected in the area (a), in the day bin mm;
- N = total number of villages in an area ;
- N = total number of days in a month;
- Pm, the average monthly rainfall in mm and 1 = b = 31, 1 = a = 4 and 1 = n = 2

2.3.2.2. Calculation of the average monthly temperature (Tm)

The average monthly temperature is defined with the statistical formula:

Tm = Σ (tmni + tmxi) / 2N (Equation 2) with
- N = number of days per month;
- Tmni = minimum temperature of the day in °C;
- Tmxi = maximum temperature in the day in °C;
- Tm is the average monthly temperature in °C.

<u>*Calculation of the potential evapotranspiration*</u>

Monthly potential evapotranspiration (ETP) is derived from the formula of Turkey:

$$\text{with: } Etp = \frac{P}{\left(0{,}9 + P/L^2\right)^{1/2}} \quad \text{(Equation 3)}$$

- P = average monthly rainfall (mm);
- L = 300+25T+0.05 T^3;
- T = average monthly temperature of the air in °C;
- Etp in mm.

The measurement of the levels of light transmission in Bokito and Ngomedzap

The recovery rate in the field is measured by the degree of light transmission in a cocoa plantation. The choice of the sample frame in one area reflects its representativeness (presence of shade trees and ground cover relatively) on one side and on the other hand the range of speeds of light transmission in a cocoa plantation. Also, for the trees of experimentation, the cocoa and the shade trees were assigned in a surface (45X45) sq. ft. Several types of light transmissions were collected in both locations of Bokito and Ngomedzap.

The implementation of the law of Shelford on tolerance helped to determine the tolerance intervals where the light is likely to induce flowering of the cocoa tree. Using a digital camera with a lens "fisheye", was photographed from an angle of 360° of the cop that protrudes from the cacao trees. The shots were fired using a scale positioned above the upper parts of cocoa. Some 30 to 50 photographs were taken for each plot, with a precise positioning in the planes. Then, these photographs hemispheric were analyzed using the program "Light Analyzer Gap" (GLA, version 2.0). This software was deployed to estimate the rate of solar insulation that penetrates below canopy level as proposed by Frazer and al., 1999. The characterization of this influence of shade portrays the level of correlation between optimal insulation and the optimal level of flowering.

<u>*Calculation of the average monthly fuition per tree by the area*</u>

The calculation of the average monthly production per tree by locality was conducted in the variables used: the open flowers (f), cherelles (ch), pods (ca) and the wilted fruits (fw).

By the number of open flowers: (Equation 4)

E(f) = Σn(f)i /NaN for the number of open flowers of registration;
E(ch) =Σn(CH)i/NaN for the number of the cherelles;
E(ca) = Σn(Ca)i /NaN for the number of pods;
E(fw) = Σn(fw)i /NaN for the number of wilted fruits;
With:

- N (f) = total number of open flowers observed by month;
- N (ch) = total number of cherelles observed by month;
- N (ca) = total number of pods observed by month;
- N (wf) = total number of wiltedfruits observed by month;
- Na = total number of trees in the area;
- N = number of weeks in the month and $1 \leq i \leq 5$ (i = number of village per zone)

The correlation between the climate elements and the variables of the generative cycle of the cocoa tree of Ngomedzap and Bokito

The Spierman test was adopted statistically to estimate the influence of the elements of the climate (rainfall, temperature and evapotranspiration) in the different variables of the generative cycle of the cocoa tree (the open flowers, pods, cherelles and the wilted fruits) in Ngomedzap and Bokito.

This test is used to accurately estimate the level of association between two variables. To do this, we calculated the correlation coefficient of Spierman in accordance with the statistical formula below:

$$rs = \frac{1-6\sum D^2}{n(n^2-1)} \quad \text{(Equation 5)}$$

- D = difference in status between the two measures;
- Σ D² = sum of the squares of these differences;
- n = sample size (number of pairs of measurements);
- rs = correlation coefficient of Spierman.

Coefficient of determination of the degree of involvement of climatic elements in the production of cocoa in Ngomedzap and Bokito.

The coefficient of determination was calculated to estimate the degree of influence of the climatic elements in the production of cocoa, in Ngomedzap and Bokito areas in accordance with the statistical formula:

$R = rs^2$ (Equation 6)

Results and interpretation

Analysis and comparison of deviations from the average temperatures, rainfall and potential evapotranspiration in Bokito and Ngomedzap.

During the period considered, deviations from the average temperatures, rainfall and evapotranspiration show notable differences depending on the areas of study.

In Ngomedzap, temperatures, rainfall and evapotranspiration are in phase. Differences in rainfall and evapotranspiration are positive between March and July. They extend between the months of August and November (Fig. 4). Only the months of January, February and July are experiencing negative rainfall deviations. Concerning temperature, only the months of March, April and May experience positive differences.

In Bokito, the rainfall and evapotranspiration occurs simultaneously (Fig 5).Throughout the year, the temperature variation in relationship to the mean is positive between the months of February and April. Rainfall and evapotranspiration are negative relative to the mean in the months of December, February, July and positive between the months of March, June, August and November.

Regarding the temperature, only the months of March, April and May are experiencing positive differences.

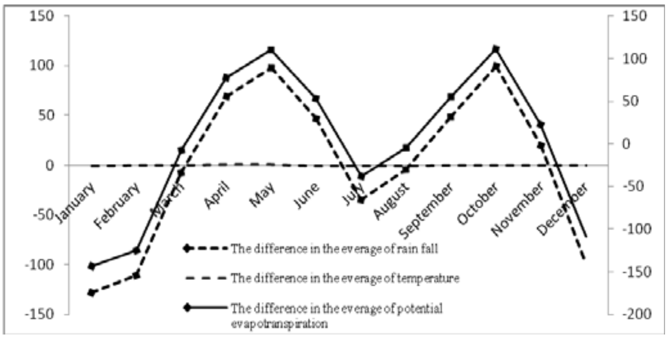

Figure 3: The differences in the average temperature, rainfall and potential evapotranspiration of Ngomedzap.

In Bokito the temperature difference from the mean does not occur in the same rhythm with respect to rainfall and evapotranspiration (Figure 4). Throughout the year, temperatures will be positive between the months of February and April. Rainfall and evapotranspiration will be negative in the months of December, February, July and positive between the months of March, June, August and November.

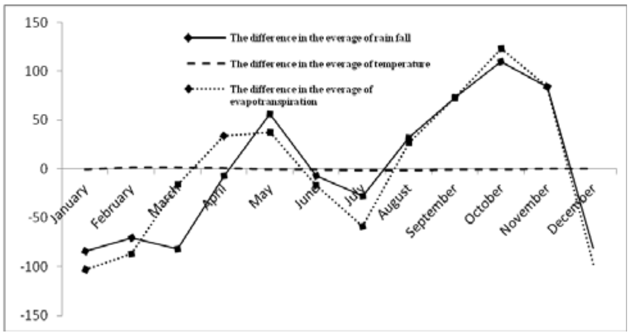

Figure 4: The differences in the average temperature, rain fall and potential evapotranspiration of Bokito.

Influence of climate on the production of cocoa in the two study areas

Influence of temperature on the production of cocoa in Ngomedzap and Bokito

Cocoa production in Ngomedzap had an average of one flower per month at an average temperature of 26°C (Figure 6). Up to three flowers per tree occurred in May at a temperature of 26.8°C. From the month of August, there was a total absence of flowers that extends until January. A monthly average of 4 cherelles per tree was observed with a maximum of 12 cherelles in June at a temperature of 25°C. The pods production occurs from July to October with an average pods per tree per month. A peak of 2 pods was observed in the month of September with a temperature around 27°C. The presence of the wilted fruits is noticeable between April and August, with the average being around a fruit per tree.

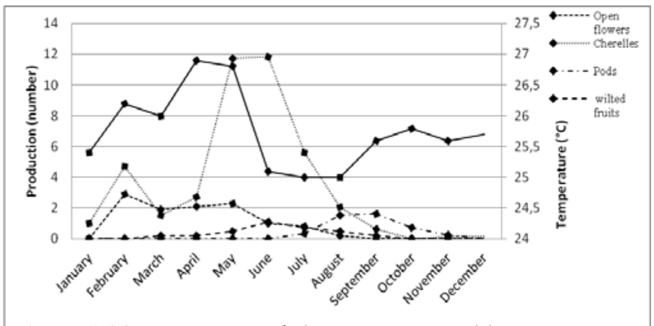

Figure 6: Temperature and the average monthly production of cocoa in Ngomedzap

The production of open flowers, cherelles and wilted fruits are in line with changes in temperature. On the contrary, the pods are out of phase. The pods and ripe fruits are not influenced by temperature.

The average temperature is around 27 °C in Bokito. April is considered the hottest of all (30 °C). A maximum of 11 open flowers was recorded in May at a temperature of 28 °C (Figure 7). A maximum of nine cherelles per tree was observed in July, with temperatures hovering around 26°C. A maximum of the pods was observed in November, four pods per tree for a temperature of 26.5 °C.

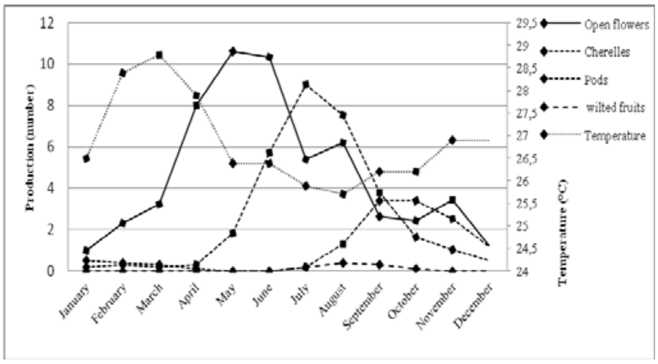

Figure 7: Temperatures and average monthly production of cocoa in Bokito

The production of flowers and cherelles does not match with the changes in temperature. However, the production of pods and wilted fruits is in line with changes in temperature.

Influence of rainfalls on the production of cocoa in Ngomedzap and Bokito

The average rainfall is around140 mm per month in Ngomedzap. May, the wettest of all, is registering 239 mm of rainfall, for producing 3 open flowers and 12 cherelles average per tree (Figure 5).

The effect of rain on the pods is not very significant. The production of pods is more pronounced between June and November two pods per tree on average, with an average rainfall of 171 mm. Wilted fruits are visible between April and August, with an average of 01 fruit per tree.

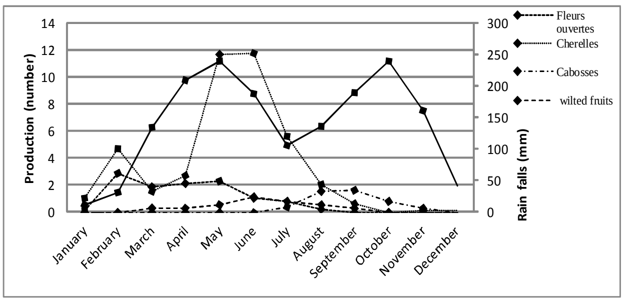

Figure 8: The average monthly rainfall and the production of cocoa in Ngomedzap.

The production of open flowers and wilted fruits depends on rainfall patterns. It is only during the long rainy season that the pods are in phase with the rainfall.

Bokito registers an average of 91mm of rain per month (Figure 9). A record of 11 flowers per tree on average was observed in May with 140mm of rain. The cherelles production extends throughout the entire year, with a maximum of 8 cherelles per tree corresponding to 125 mm of rain in August.

A maximum of four pods per tree at an average of 165 mm of rain was observed in the month of May and September. Therefore, the wilted fruits can not be seen between July and October.

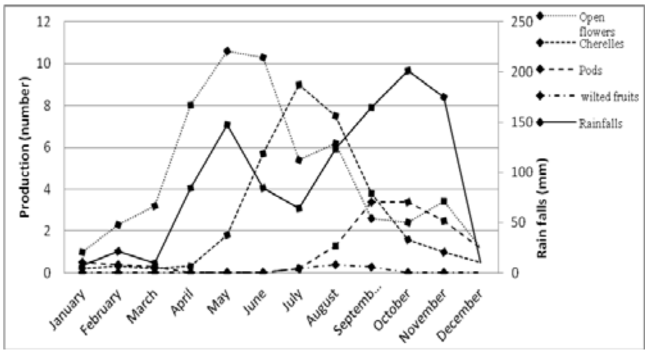

Figure 9: The average monthly rainfall and the production of cocoa in Bokito.

Throughout the year, the production of open flowers and cherelles depends on rainfall patterns. The pods and wilted fruits are in the same phase with the long rainy season. This is equally the period when cocoa fruits ripen.

Influence of the evapotranspiration in cocoa production in Ngomedzap and Bokito

In Ngomedzap (Figure 10), the production of open flowers will be visible between January and July. The average monthly evapotranspiration is around 156 mm. The optimum of open flowers and cherelles, with an average of 3 flowers and 12 cherelles per tree for 260 mm evapotranspiration. The pods will be visible between June and October, with an optimum of two pods in September by 210 mm evapotranspiration. The period between April and August is conducive to the development of the wilted fruits, an average of one wither fruit per tree.

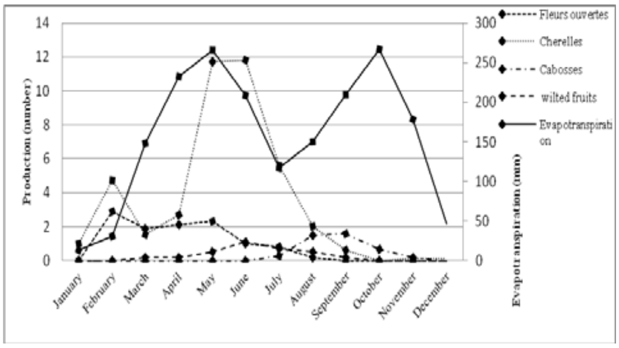

Figure 10: Evapotranspiration and average monthly production of cocoa in the Ngomedzap area

The monthly production of open flowers, pods and the fruits that wilted is not in line with the evolution of evapotranspiration. Only cherelles evolve to keep pace with the rate of evapotranspiration, especially during the short rainy season.

In Bokito, the long dry season from December to January is experiencing a null evapotranspiration (Figure 11). A maximum of 11 open flowers per tree is visible between May and June with 150 mm of average evapotranspiration. Cherelles production extends throughout the entire year with a peak of 9 cherelles average per tree for 52 mm of evapotranspiration. The first phase of production of pods is between January and March, with one pod per tree on average, through 42 mm of evapotranspiration. The second phase runs from July to November. For a peak of 234 mm of evapotranspiration, we notice an average of two pods per tree. However, wilted fruits, spread from July to September, with an average of one fruit per tree.

The production of open flowers is according to the changes in evapotranspiration during the short rainy season. Nevertheless the cherelles, pods and wilted fruit site evolve with the phase shift rate of evapotranspiration.

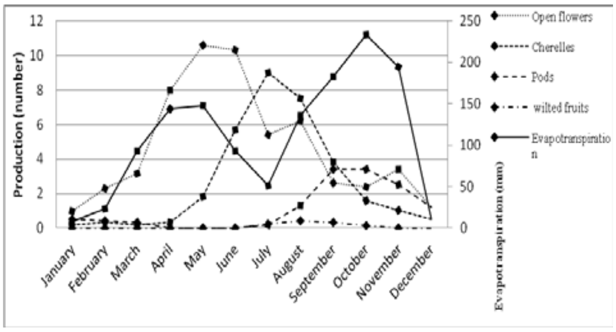

Figure 11: Evapotranspiration and average monthly production of cocoa in Bokito area.

Influence of shading on the production of cocoa in Ngomedzap and Bokito

According to the Law of 'Preferendum' by Shelford, the production of flowers in Ngomedzap increases with the photosynthetic activity of the plant up to a certain threshold called the preferential area (Fig 12).The preferred area corresponds to 57.4% of light, which corresponds to a production of 6.5% of flowers. Beyond this optimum, excess light will cause a reduction or total cessation of flowering.

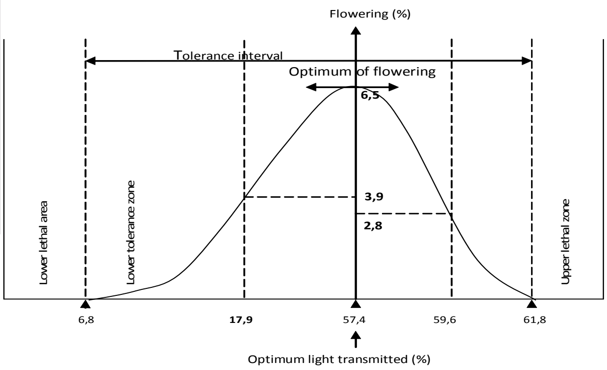

Figure 12 : Flowering depending on the light transmission in Ngomedzap (according to the law of tolerance of Shelford).

The flowering of cocoa plant increases with photosynthetic activity to a preferential area of 54.9 % of the light transmitted in Bokito. This optimum light corresponds to a 21.5 % of the flowering (figure.13). Beyond the optimum, too much light will be detrimental to the flowering, which may cause a reduction or even a total cessation of the flowering of the cocoa tree.

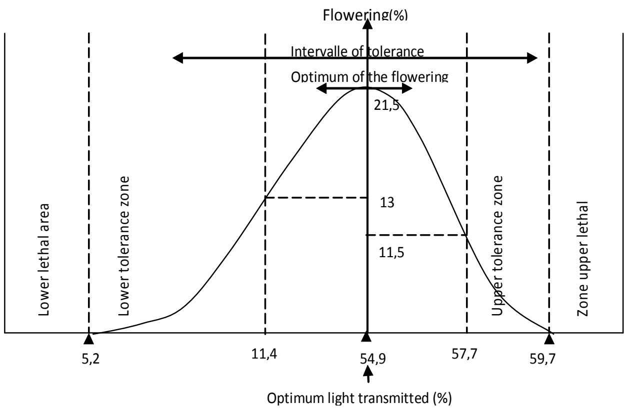

Figure 13 : The flowering in function of the transmission of light in Bokito (according to the law of tolerance of Shelford)

Intense sunlight causes low flowering of cocoa in Ngomedzap. But on the contrary, low sunlight causes high flowering of cocoa in Bokito. Differently, the sunlight is a limiting factor in the flowering of cocoa in Ngomedzap and Bokito.

The Correlation between elements of climate and the different variables of the generative cycle of cocoa in Ngomedzap and Bokito.

The Correlation between temperature, rainfall and evapotranspiration with the different variables of the generative cycle of cocoa production in Ngomedzap and Bokito.

For the two areas of study, was carried out the test of Spearman's correlation that accurately determined the degree of participation of climatic elements on the production of cocoa in Ngomedzap and Bokito.

Of all the results, the Spearman test has a high level of influence of temperature on the production of flowers in Ngomedzap (Table 2), with a correlation coefficient of 0.45.

Table 2: Matrix of correlation between climatic elements and different variables of cocoa production in Ngomedzap (Spearman's test).

Climate \ Cocoa production variables		Open flowers	Cherelles	pods	Wilted fruits
Temperature	correlation coefficient	0,454**	-0,023	-0,39**	-0,343**
	GIS (bilateral)	0.139	- 0,944	0,103	0,274
Rainfall	correlation coefficient	-0,046	-0,014	0,304**	0,275*
	GIS (bilateral)	0,886	0,966	0,337	0,388
Evapotranspiration	correlation coefficient	-0,046	-0,014	0,304**	0,275*
	GIS (bilateral)	0,886	0,966	0,337	0,388

*** difference was highly significant, ** significant difference, * difference is not significant

At Bokito two results are highly significant to know the involvement of temperature on the production of cherelles (-085) and the wilted fruits (- 0.82) (Table 4).

<u>*Comparison of the different degrees of involvement of climatic elements in the production of cocoa in Bokito and Ngomedzap.*</u>

When comparing the degree of influence of climatic elements (temperature, rainfall, and evapotranspiration) in the production of cocoa in Ngomedzap and Bokito, it seems that the climate affects the majority of training of cacao pods process in Bokito than in Ngomedzap. It is 40 % in Bokito, compared to only 33.2 % in Ngomedzap (Table 4).

Table 3: Matrix of correlation between the variables in the production of cocoa and elements of climate in Bokito (Spearman's test).

Climate \ Cocoa production Variables		Open flowers	Cherelles	pods	Wilted fruits
Temperature	correlation coefficient	-0,250*	-0,857***	-0,339**	-0,828***
	GIS (bilateral)	0,434	0	0,440	0,001
Rainfall	correlation coefficient	0,385**	0,498**	0,403**	0,420**
	GIS (bilateral)	0,217	0,099	0,194	0,174
Evapotranspiration	correlation coefficient	0,392**	0,274*	0,364**	0,312**
	GIS (bilateral)	0,208	0,389	0,244	0,323

*** Difference highly significant, ** significant difference, * difference is not significant

Table 4: Comparison of the different degrees of involvement of the elements of climatic variables in the production of cocoa in Bokito and Ngomedzap.

Climate \ Cocoa production Variables	Open flowers		Cherelles		pods		Wilted fruits	
Zones	Bokito	Ngomedzap	Bokito	Ngomedzap	Bokito	Ngomedzap	Bokito	Ngomedzap
Temperature	4%	20%	64%	0,05%	11%	15,2%	67%	11%
Rainfall	14%	0,21%	24%	1%	16%	9%	17%	7%
Evapotranspiration	15%	0,21%	7%	1%	13%	9%	9%	7%

In general, despite the instability of the climate and the degree of influence of its variables in the production of cocoa, such influences are more important in Bokito than in Ngomedzap. This is proof of the fact that cocoa is more suitable in the areas of contact with forests-savannah than in forested areas. This shows that, in addition to weather, other factors come into play in the process of developing the pods of cocoa. Amongst them are soil type, variety of cocoa planted, the attack of insect pests, and the degree of care taking.

The correlation between the rate of transmission of light and the flourishing of cocoa in Ngomedzap and Bokito.

The correlation between the percentage of light transmission and the rate of flowering of the cocoa tree was obtained using the law of Shelford tolerance (Table 5). Of 57.4 % of the transmitted light there was 6.50 % flowering in Ngomedzap. In Bokito against the 21.5 % of the flowers, there was 54.9 % of the transmitted light.

Table 5: Comparison between the rate of flowering and the percentage of light transmitted in the areas of Ngomedzap and Bokito.

Ngomedzap		Bokito	
Transmitted light (%)	Flowering (%)	Transmitted light (%)	Flowering (%)
57,4	6,50	54,9	21,5
17,9	3,90	11,4	13,0
62	0	59,7	0
59,6	2,8	57,7	11,5
6,8	0	5,2	0

It is clear from these results that the degree of transmission of light can induce flowering of cocoa stronger in Bokito than in Ngomedzap. The flowering observed in Bokito confirms the importance of the transmission of light in the process of production of cocoa.

General discussion

In a nutshell, the results obtained in the area of contact of forest-savanna presents a better proportion of cocoa pods than in the forested zone, i.e. 40% in Bokito and 33.2 % in Ngomedzap respectively.

A similar observation was made by Sounigo (2002) in a study of the cambial activity and the rate of relapse of the sheet of cocoa. It has been shown that there is a close parallelism between the seasons of the year, the sheet of outbreaks and the phenomenon of leaf fall. The same results pushed Ndoumbè Nkeng (2002) to conclude that "for all the ecological factors that influence the production of cocoa, temperature seems most likely.

Frazen et al. (2007) adds that the assumption of Ndoumbè Nkeng is both more certain that "for all the climate elements, only temperature is kept constant throughout the year." Since cocoa is a tropical plant, their culture is best suited to temperatures between 15 and 25 ° C from one season to another. It is true that the results obtained in these communities deserve to be tested in other parts of Cameroon and Africa in greater spatial and temporal scales.

In spite of belonging to the equatorial zone, Bokito is a contact area with the forests of savannah that has a monthly average temperature of 27 °C with an annual precipitation of 1450 mm. Despite the relatively better weather conditions, the cocoa of Bokito is still not in best performance because of structural and organizational problems affecting the farmers. . Ngomedzap, which is an area of rainforest, is experiencing a much more high rainfall (1700 mm), with a monthly average temperature of 25 °C. Although cocoa production is a forest activity, rain can affect the productivity of the cocoa plant (flowers, small fruits opening of pods and withering of the fruit) and may lead to lower yields.

According to Torquebiau *et al.* (2007), direct sunlight plays an important role in the variation of relative humidity in cocoa plantation and therefore evapotranspiration. In addition to this important function, the transmission of sunlight is a factor that depends on the photosynthetic activity of plants with flowers. For Frazen (2007), the result of the direct impact of light in the cocoa plantation increases the density of insect pests of cocoa (black pod and miridos) that would be bound "to a greater availability in the exposed blades metabolites del sol to carbon-based". To remedy this, one must consider the agricultural calendar by choosing the exact period for the health of crops that depend on the length of the dry period. We must recognize that these observations do not take into account the rate of relapse of the sheet that the optimum is also the degree of cacao trees for shade. Optimization **of** the flowering will be possible through rationalization of the number and arrangement of the shade of trees in the cocoa plantation. If this is done rightly, we can continue with a healthy harvest that takes into account the wet and dry periods.

This study was conducted during only two years of observation (24 months), and the results we have do not permit a general understanding of the influence of climatic variations in cocoa production in the area of forest and forest-savanna zones of contact. On the contrary, a study for a period of 30 years would have been much more relevant. It is the same for the study sample confined to two areas (area of forest, and the contact with the savannah woodlands). A similar study in other climatic zones of Cameroon will permit the generalization of the results, especially in a country with great climatic diversity.

Conclusion

The characteristics of the climate, their variables and their fluctuations influence the development of the production cycle of cocoa. These results could serve as a first-hand tool for farmers and, especially, the authorities responsible for the development of the agricultural calendar. These services may include the duration of drought, the periods of likely start of the rainy season, will be made available to the producers of the essential information regarding the harmful effects of climate change in the production process of the cocoa tree. It is a body of practical knowledge that integrates climate control and the negative impact on the management of cocoa.

Bibliography

Ardoin Bardin S., (2004), "Variabilité hydroclimatique et impacts sur les ressources en eau de grands bassins hydrographiques en zone soudano-sahélienne". Thèse de doct. Univ. Montpellier II. 440 p.

Babin, R., Dibog, L. et Bisseleua H., 2003. Mise au point d'une méthode d'élevage de SahlbergellasingularisHagl. (Hemiptera : Miridae) au Laboratoire. Résultats préliminaires des travaux menés au Cameroun .14 th International Cocoa Research Conference, vol. II, 1333-1340.

Franzen, M. & Borgerhoff Mulder, M., 2007. Ecological, economic and social perspectives on cocoa production worldwide. Biodiversity Conservation, 3835-3849.

Ndoumbè Nkeng M. (2002). Incidence des Facteurs Agro-Ecologiques sur l'épidémiologie de la pourriture brune des Fruits du cacaoyer au Cameroun : contribution à la mise en place d'un modèle d'avertissement agricole. Thèse de doctorat de l'Institut Nationale Agronomique Paris-Grignon, PP 151-165.

Segalen P. Letouzey R., 1959. Les sols plantés en cacaoyers de la région Centrale du Cameroun. Yaoundé, FOM-ORSTOM, 44 P.

Sonwa, D. J., Nkongmeneck, B. A., Weise, S.F., Tchatat, M., Adesina, A. A. & Jansens, M.J.J. (2007). Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon. Biodiversity Conservation, 16, PP 2385-2400.

Sounigo O., Coulibaly, N., Brun, L., N'goran, J., Cilas, C. &Eskes, A.B. (2003). Evaluation of resistance of Theobroma cacao L. to mirids in Côte d'Ivoire: results of comparative progeny trials. Crop Protection, PP 375-379.

Sighomnou, D., 2004. Analyse et redéfinition des régimes climatiques et hydrologiques du Cameroun : perspectives d'évolution des ressources en eau. Thèse de doctorat en sciences naturelles. Département des sciences de la terre, Université de Yaoundé I. 291P.

Torquebiau, E. (2007). L'agroforesterie des arbres et des champs. L'Harmattan, Paris.
230P.

Sounigo O., Coulibaly, N., Brun, L., N'Goran, J., Cilas, C. &Eskes, A.B. (2003). Evaluation of resistance of Theobroma cacao L. to mirids in Côte d'Ivoire: results of comparative progeny trials. Crop Protection, PP 375-379.

Soria, V, J. (1970). Principal varieties of cocoa cultivated on tropical America Cocoa Growers Bulletin, 15:12-21.

Received: 26/06/13
Accepted: 15/07/13