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Impacts of Climatic Disturbances on the Agricultural Sector at the Scale of the Department of Hills (Benin, West Africa)

Koudérin A. Lucie[1], Avahounlin Ringo F.[1,2], Ouassa Pierre[1,4], Vissin Expédit W.[4]

[1]Chaire Internationale de Physique Mathématique et Applications (CIPMA CHAIRE-UNESCO, FAST, UAC), Cotonou, Benin

[2]Ecole Normale Supérieure (ENS, UNSTIM), Natitingou, Benin

[3]Département des Sciences e la Terre, Université d'Abomey-Calavi, Benin

[4]Département de Géographie et Aménagement du Territoire (DGAT, FASHS, UAC), Cotonou, Benin

Résumé – Les populations du département sont particulièrement vulnérables aux effets néfastes des variations hydroclimatiques en raison des ressources limitées dont elles disposent. La présente étude analyse les impacts des perturbations hydroclimatiques sur l'agriculture à l'échelle du département des Collines. La démarche méthodologique a consisté en la détermination des aléas liés à la variabilité hydro-climatique à travers les données climatologiques (pluie, ETP) et hydrométrique (débits) de 1971 à 2017, l'étude des indices de précipitations standardisées et l'analyse des séries pluviométriques et hydrométriques appuyés par les observations de terrain et les investigations socio-anthropologiques. Par ailleurs, la matrice de sensibilité a servi de base à l'analyse des impacts risqueshydro climatiques sur les activités agricoles dans le secteur d'étude. L'étude de la variabilité saisonnière du régime hydrologique, des hauteurs pluviométriques et les ETP sur la période 1971-2017 et les données socio-anthropiques recueillies, montre que le département des Collines est sous la menace des catastrophes hydro climatiques. Ainsi, l'analyse de la vulnérabilité de l'agriculture montre que, les cultures maraîchères, la culture de maïs et d'igname sont les plus vulnérables aux risques hydroclimatiques identifiés avec un indice d'exposition de 77 % que les cultures de patate douce (71 %), du riz (68 %), de manioc (68 %), et d'anacardier (66 %) qui semble être la culture la moins exposée aux risques. Le système agricole n'est donc pas à l'abri des effets pervers des risques hydroclimatiques dans le département des Collines. Face à une telle situation la mise en œuvre des stratégies appropriées et efficaces doit être prises pour réduire la vulnérabilité de l'agriculture aux phénomènes hydroclimatiques.

Mots clés – Département des Collines, Perturbations climatiques, Impacts, Risques hydroclimatiques, Agriculture, vulnérabilité

Abstract – The populations of the department are particularly vulnerable to the harmful effects of hydroclimatic variations due to the limited resources at their disposal. This study analyzes the impacts of hydroclimatic disturbances on agriculture across the Collines department. The methodological approach consisted in determining the hazards linked to hydro-climatic variability through climatological (rain, ETP) and hydrometric (flow) from 1971 to 2017, the study of standardized precipitation indices and the analysis of pluviometric and hydrometric series supported by field observations and socio-anthropological investigations. In addition, the sensitivity matrix was used as a basis for the analysis of hydro-climatic risk impacts on agricultural activities in the study sector. The study of the seasonal variability of the hydrological regime, rainfall levels and ETPs over the period 1971-2017 and the socio-anthropic data collected, shows that the Collines department is under the threat of hydro-climatic disasters. Thus, the analysis of the vulnerability of agriculture shows that market gardening, corn and yam crops are the most vulnerable to hydroclimatic risks identified with an exposure index of 77% than sweet potato crops. (71%), rice (68%), cassava (68%), and cashew tree (66%) which seems to be the crop least exposed to risks. The agricultural system is therefore not immune to the perverse effects of hydroclimatic risks in the Collines department. Faced with such a situation, the implementation of appropriate and effective strategies must be taken to reduce the vulnerability of agriculture to hydroclimatic phenomena.

Keywords – Department of Hills, climatic disturbances, Impacts, Hydroclimatic risks, Agriculture, vulnerability

I. Introduction

In the West African climate system, climate variability manifests itself in a drop in rainfall of between 10 and 25% compared to those recorded at the beginning of the 20th century (Sircoulon, 1990), then an increase in temperatures from 0.3 to 0.6 ° C, thus causing a significant increase in the number of dry years (Houndénou, 1999; Afouda and al., 2002 and Ogouwalé, 2006). Climatic disturbances have led to a significant yields decrease and heavy crop losses with enormous economic and social consequences in this part of Africa (GIEC, 2007).

In many developing countries, the agricultural sector is of paramount importance for economic growth. But, agriculture, more than any other sector, is particularly exposed to the risks of disasters, such as climatic episodes and epidemics (Roger and al., 2011). Thus, the spatial and temporal variability, combined with the unpredictability and climate change, which is at the heart of the scarcity of water resources (Sodonougbo, 2012), generate as consequences, vulnerability and considerable impacts on agricultural production.

In rural areas where the majority of people live from agricultural activities; the total or partial loss of products at harvest following extreme weather disasters contributes to life risks at the subsistence or poverty line. In Benin, Beninese agriculture contributes more than 15% of state revenue and remains the main growth driver (NEPAD – PDDAA, 2005). It is heavily rainfed agriculture and is exposed to climatic hazards. At the level of the Collines department, persistent climatic crises, combined with other factors are the causes of the decline in agricultural yields (Chédé, 2012). The objective of this study is to analyze the impact of climatic disturbances on agricultural activities in the hills department of Benin.

II. Materials And Methods

2.1 Study area

The Collines department is located between 7°27 'and 8°46' North latitude and between 1°39 'and 2°44' East longitude (figure 1) with an area of 13,931 km2. The rainfall regime in the hills is straddling that of the bimodal distribution of the South and that of the unimodal distribution of the North. In recent years, the rainfall trend has been unimodal with a broad base and the annual rainfall levels generally oscillate between 900 and 1200 mm (Atchadé, 2014). From mid-October to March, the average monthly rains remain less than half of the potential evapotranspiration (ETP) and testifies to the presence of a dry period not, favorable to agricultural activities; from April to May and during October, the average monthly rains are greater than half of the ETP but less than the ETP; this reflects the slightly humid periods. On the other hand, from mid-April to mid-October, the monthly average rains are well above the other two variables with a slight inflection in August. So this period is very favorable for crops. In addition, the temperature does not affect the development of agriculture. On the scale of this department, there are a total of 297 villages with a population of 716. 558 habitants (RGPH4). The rainfall regime in the Collines Department presents a contrasting situation. It straddles that of the bimodal distribution of the South and that of the unimodal distribution of the North (Bokonon-Ganta, 1987; Boko, 1988;Afouda, 1990; Houssou, 1998; Ogouwalé, 2006).

Essentially rainfed agriculture based on a cropping system of palm, peanuts, yams, cassava, cotton, sugar cane, vegetable crops and rice is strongly influenced by fluctuations in rainfall.

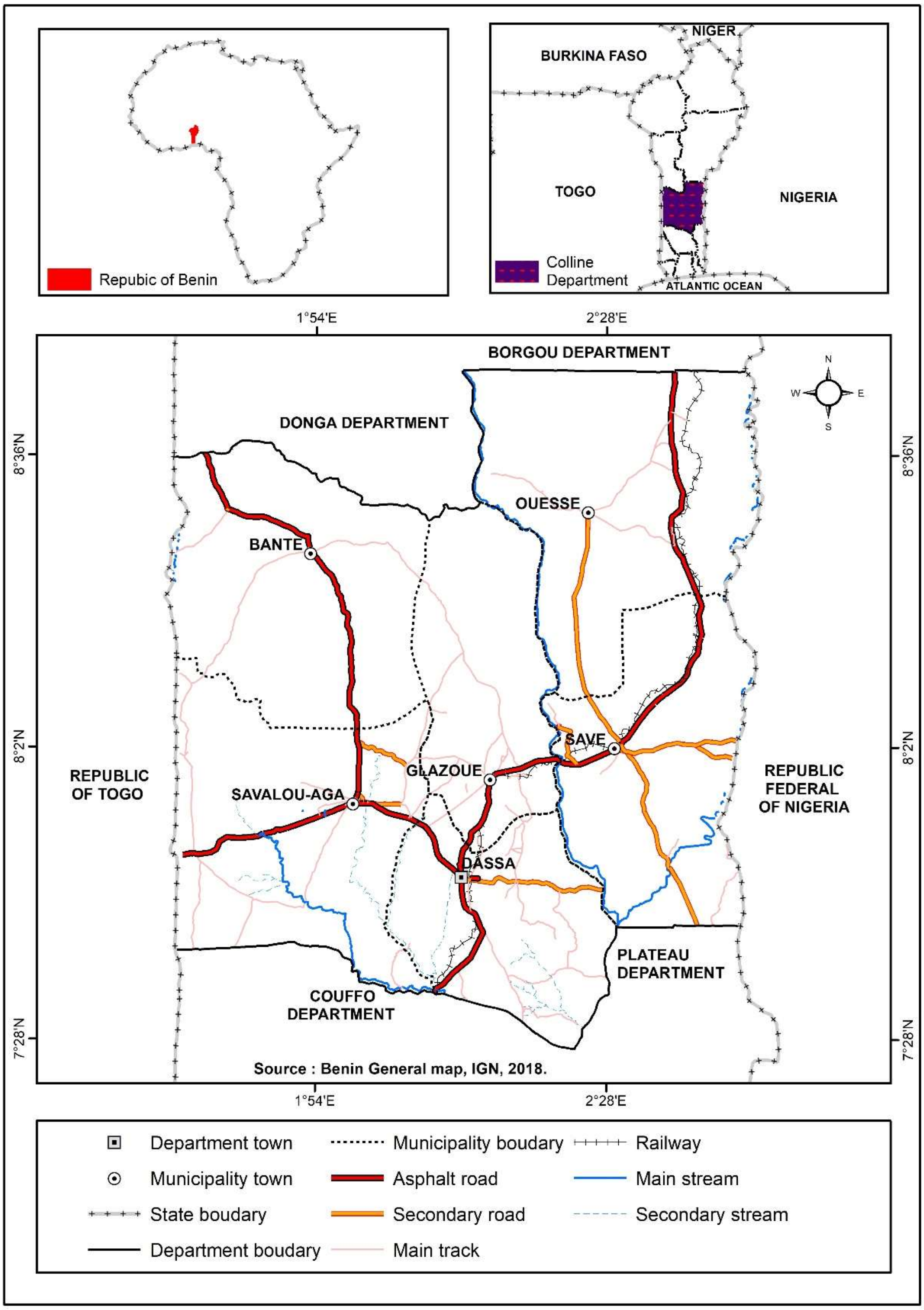


Figure 1: Geographical and administrative location of the Collines department

2.2 Data collection

The data used for this study are climatological, qualitative, planimetric and quantitative in nature.The climatological data are rainfall amounts, minimum and maximum temperatures provided by the National Meteorological Agency over the period 1971-2017 to the synoptic station of Savè: The qualitative data come from field investigations carried out by the method of individual surveys (Diop, 2013) and supplemented in some cases by interviews. The survey consists of open, semi-open and closed questions. The questions were addressed to stakeholders in the agriculture sector, including 917 farmers. The size of the sample was determined by the method of Schartz (2002). Table 1 provides information on the socio-demographic characteristics of the farmers surveyed. The investigations focused on assessing the perception of the populations on climate change; the identification of major climate risks linked to climate change and their influence on agricultural activities.

The planimetric data are the topographic backgrounds (IGN 2016) and the Landsat ETM + images (2005; 2010 and 2016) which allowed us to assess the land cover in different years in the hills. The quantitative data made up of demographic statistics (from RGPH4, Benin) and agricultural statistics obtained from decentralized structures in the departmental hills provide information on the state of the population and agricultural production.

2.3 Method of data analysis

The data collected was analyzed and processed using the appropriate tools. The statistical parameters (average and frequency) were calculated for the construction of tables and figures. The standardized precipitation index "SPI" (Standardized Precipitation Index) made it possible to characterize the precipitation deficits for a given period and to obtain a threshold value for decide on the state of drought or not (Table 1). The climate risk sensitivity matrix (Badolo, 2007) was used to analyze the vulnerability of modes and means of existence. Table 2 shows the five levels of sensitivity considered.

Table 1: Classification of drought in relation to the SPI value

SPI Class	Interpretation
SPI>2	Extreme humidity
1<SPI<2	High humidity
0<SPI<1	Moderate humidity
-1<SPI<0	Moderate drought
-2<SPI<-1	Severe drought
SPI<-2	Extreme drought

Table 2: Climate risk assessment scale (Badolo, 2007)

Magnitude of the degree of vulnerability	Magnitude of the risk
1	Low
2	Rather weak
3	Way
4	Strong enough
5	Strong

Applying the matrix produces three indicators including the exposure index; the exposure rank of exposure units to climate risks and the climate risk impact index. These indices were used to establish a hierarchy of risks in relation to the exposure units considered. Table 3 presents the conceptual framework of the sensitivity matrix.

Table 3: Formal presentation of a sensitivity matrix (Badolo, 2007)

Exposure units	Hydroclimatic risks	Exposure index
Exhibition unit 1		
Exhibition unit 2		
Exhibition unit 3		
Exhibition unit 4		
Impact index		

III. RESULTS

3.1 Climatic variability observed at the scale of the hills department

The calculation of the reduced-centered index on precipitation shows an alternation of dry and wet years (Figure 2).

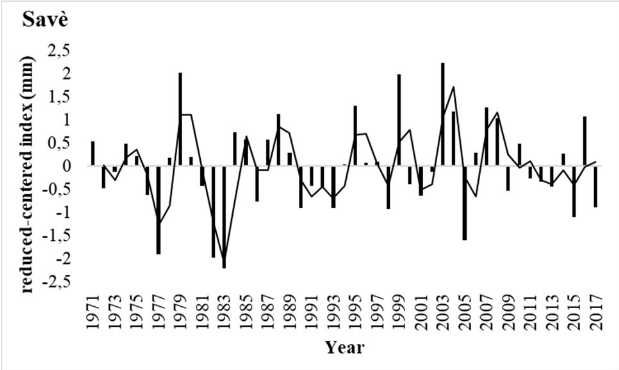


Figure 2: Interannual evolution of rainfall levels (Savè) in the Hills

Table 4: Identification of years of drought and humidity in the hills

SPI Class	Corresponding years	Interpretation
SPI>2	1979, 2003	Extreme humidity
1<SPI<2	1988,1995,1999,2004,2007,2008,2016	High humidity
0<SPI<1	1971,1974,1975,1978,1980,1984,1985,1987, 1989,1994,1996,1997,2006, 2010, 2014	Moderate humidity
-1<SPI<0	1977,1982,2005,2015	Moderate drought
-2<SPI<-1	1977,1982,1983,2005	Severe drought
SPI<-2	1983	Extreme drought

The department of hills has a slightly increasing annual rainfall trend from 1984 (year of rupture) preceded by a period of rainfall deficits. The first phase (1971-1983) is marked by low rainfall with a strong predominance of deficit years. The second phase (1984-2017) is characterized by a strong instability in the evolution of rainfall, however, we note a predominance of wet years over dry years. Following these results, the different classes of standardized index have been interpreted (table 4). The analysis of Table 4 shows that the study period (1971 - 2017) is marked by years of moderate humidity (15 years) and years of moderate drought (04 years) with two years of extreme humidity and one year of extreme drought in the middle of the study period. The frequency of these years with high humidity and high dryness is respectively 15.21% and 8.69%. That of years with moderate humidity (32.6%) should actually promote the development of agriculture if and only if there is a good spatio-temporal distribution of the average amounts of rain that fell during the year. According to Atchadé (2007), the alternation of surplus years and deficit years accentuate rainfall variability and adversely affect annual agricultural yields.

This exposes crops to climatic risks (drought, pocket of drought) given the predominantly rain-fed nature of agriculture in the study area.

Years with high humidity cause serious damage to crops. Similarly, the occurrence of years of strong drought does not protect farmers from the risk of drought according to 51.6% of the populations encountered.

According to Médéou (2015), this situation of decreasing and increasing rainfall levels remains undoubtedly the most remarkable climatic phenomenon of the last three decades and will have repercussions on agriculture, and by ricochet on humans.

Analysis of the interannual temperature variability shows that the Collines department is marked by an overall upward temperature trend between 1971 and 2017. Minimum temperatures are changing faster than maximum ones (Figure 3).

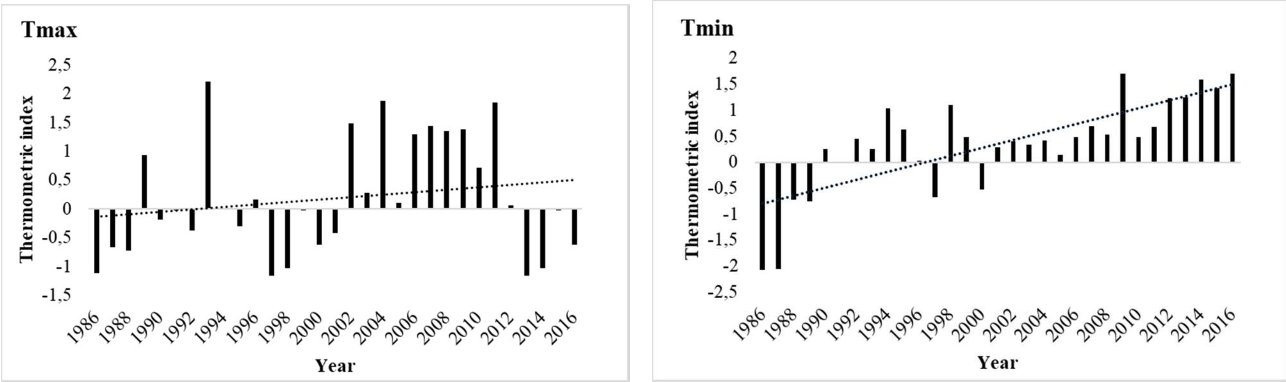
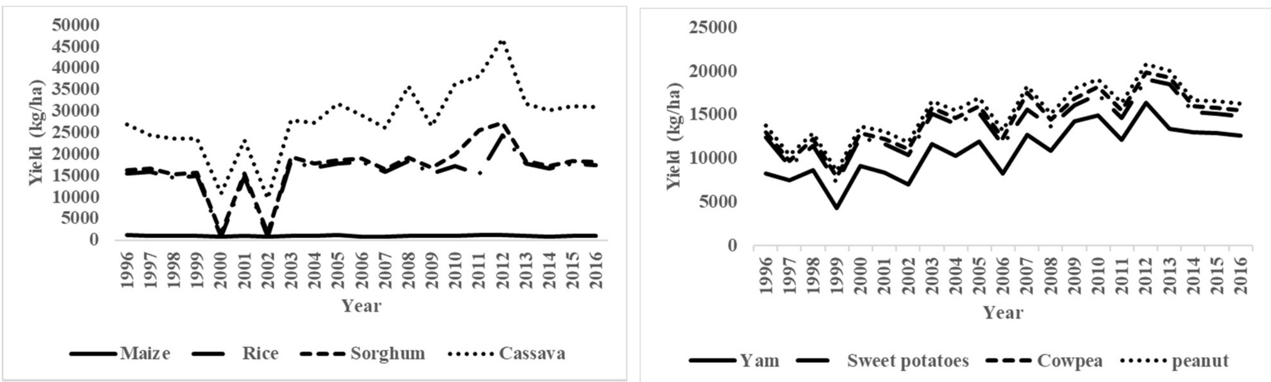


Figure 3: Thermometric anomalies and trends in the Collines department

The average of minimum temperature is 22.12°C (1971-2017). The minimum temperature deviations from the average vary between -2.05°C in 1987 and +1.70°C in 2016. As for the maximum temperatures, the annual average is 33.00°C with variations ranging between -0.6°C in 1980 to +1.2°C in 2006. Overall, the graphs in figure 3 show that the years after 1995 were increasingly hot with the exception of 1997 and 1999. The magnitude of the anomalies of average temperature between -1.9 in 1976 to 2.4 in 2010 with some fluctuations confirm the tendency of the climate warming in the department of Collines, which would dangerously disrupt the good progress of agricultural activities according to the speculations of 51.6 % of the populations interviewed. These different results corroborate with the conclusions made by Afouda (1990), Houndénou (1999), Ogouwalé (2006) and Yabi (2008) which denote a decrease in the annual totals of precipitation and an increase in temperatures, in particular on the normal 1961-1990. Indeed, higher temperatures decrease the yields of useful crops while causing the proliferation of weeds and pests (Nelson and al, 2009). According to the author, changing rainfall patterns increase the probability of short-term crop failures and long-term production decline.

3.2 Annual variability of the yield of different crop speculations in the hills

The interannual variabilities recorded in the climatic parameters during the different sub-periods probably affected agricultural crops whose productions remain essentially water-dependent and on an equally important need for the amount of rainfall. Figure 4 shows the variability of the annual yields of different crop speculations. Analysis of these graphs shows that almost all of the different crops cultivated in the Collines department, experienced a continuous decline in their yields from 1998. This decline was broken in 2006 and began to change in a saw-tooth pattern until 2016. This situation clearly illustrates the evolution of rainfall in the study area. Indeed, the analysis of rainfall levels reveals that the sub-period 1984-2017 experienced a strong instability in the evolution of rainfall. However, this rainfall instability seems to have a weak impact on sweet potato, cowpea and peanut crops, whose yields grew between 1996 and 2016. According to 86% of producers, this situation is due to the fact that the latter are more resistant to rainfall recession.



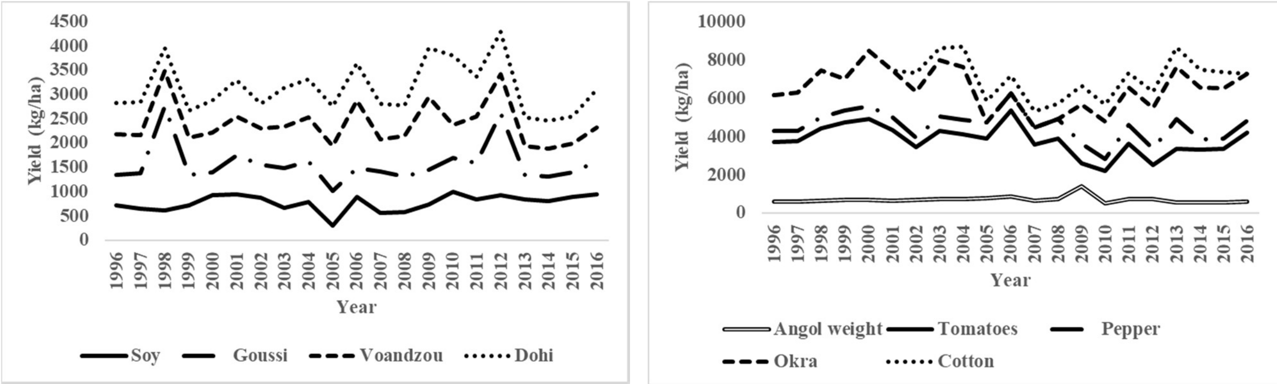


Figure 4: Variability of annual yields of crop speculations in the Hills (Field survey: MAEP, 2017)

3.3 Manifestations of major climate risks in the Hills

The results of interviews with producers in the Collines department indicate that the major climate risks are in order of importance. Analysis of the figure shows that the major hydroclimatic risks faced by producers are late and heavy rains, pockets of drought, poor spatial and temporal distribution of rains, floods, early end of rains, strong winds and excessive heat. These major climate risks were identified through the participatory diagnosis with social groups. They are similar to those indicated in the existing documentation (PANA-Bénin, 2008).

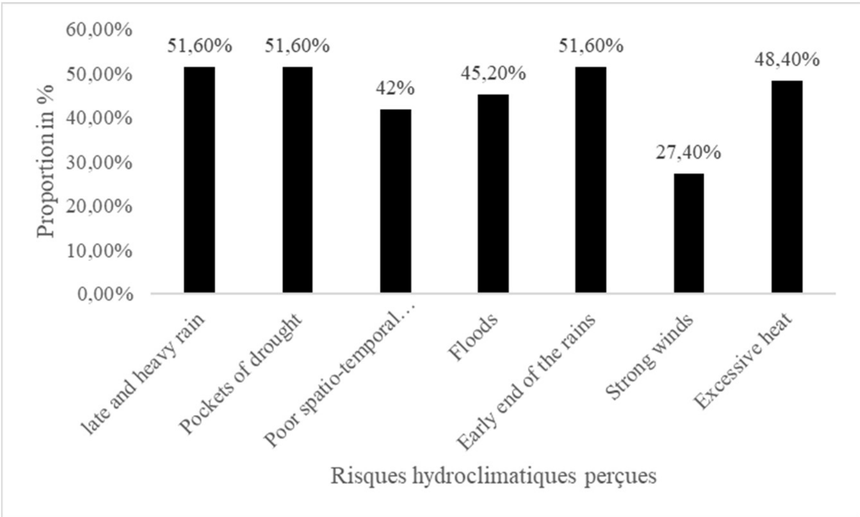


Figure 5: Major climate risks impacting the agriculture sector and perceptions of producers in the hills (Field survey, October 2019)

According to the producers, the risks identified manifest itselves in different ways. So :

- The late and violent rains perceived by 51.6% of producers are characterized by a false alarm of impending rain. This delay lasts about two months and repeats itself almost every year or every three years. This phenomenon would lead to poor crop yields throughout the Collines department;
- Perceived pockets of drought also 51.6% of the peasants are characterized by the breaks of rains in full rainy season. According to these producers, pockets of drought have devastating effects on all crops since the development and completion of the vegetative cycle depend on the availability of water for the plant. This phenomenon is one of the elements that seriously disturbs agricultural forecasts both at the level of agricultural campaigns initiated by institutions in the agricultural sector and at the level of producers. Photo 1 (plate 1) illustrates a lettuce crop which has suffered the effects of a pocket of drought in Dassa 1. Indeed, the pockets of drought have caused excessive heat which will result a significant drop of the soil in hydric condition, consequently that of the plants. The poor distribution of rainfall is a factor aggravating the extreme temperatures observed in the hills.

- 42% of stakeholders interviewed claim that recent years have been marked by poor distribution of rains and a reduction in the number of rainy days. The floods perceived by 45.2% of producers, are characterized by regular and abundant rains over several days across the Collines department. According to the producers met, these floods are generally due to the overflow of the Ouémé river via the Ofè river, the Zou and Agbado rivers, backwaters and the presence of many poorly developed lowlands in the event of heavy rains.
- The intense rains recorded between August and September cause the rivers to rise and the water to accumulate in the lowlands. This phenomenon very often leads to the destruction of crops.
- The early end of the perceived rains by 51.6% of producers, are characterized by a sudden break in the rainy seasons, that is to say a shortening of the rainy seasons. Photo 2 (plate 1) shows a tomato crop victim of the end of the rain early in the rainy seasons.

Plate 1: Lettuce crop affected by a pocket of drought in Dassa 1 (Photo 1) and Tomato crop affected by an early end of rain in Ottola (Photo 2), **Shooting:** Koudérin A. Lucie (October, 2019)

- Strong winds according to 27.4% of producers, sometimes accompanied by storms are observed at the start of the rainy season (April-May) and also around November. These winds are at the origin of the destruction of crops, especially when they are in their stages of maturity and heading. This risk remains significant in view of its frequency, which is almost annual.
- Excessive heat according to 48.4% of producers met in the study area, are risks which are manifested by an excessively high rise in thermal averages, both daily, weekly and monthly, and by an extension of the dry season.

3.4 Vulnerability of the agricultural system and modes of existence to hydroclimatic risks in the Collines department

Figure 6 shows the degree of vulnerability of agriculture and livelihoods to climate risks in the Collines department.

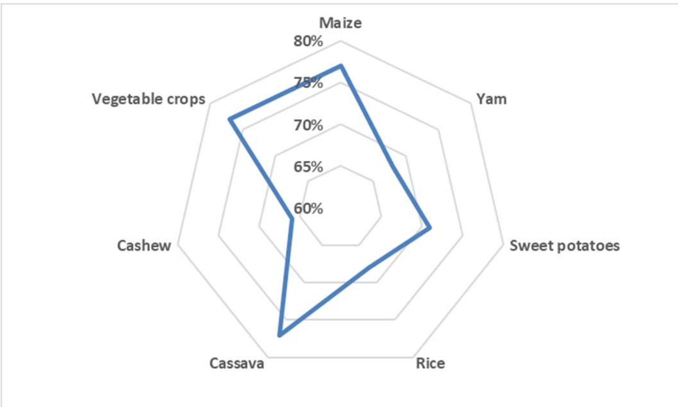


Figure 6: Vulnerability diagram of the agricultural system relating to livelihoods in the Hills

The analysis of Figure 6 reveals that vegetable crops, corn and yams are the most vulnerable to hydroclimatic risks identified with an exposure index of 77% than sweet potato (71%), rice (68%), cassava (68%), and cashew (66%) which seems to be the crop least exposed to risks. The agricultural system is therefore not immune to the perverse effects of hydroclimatic risks in the Collines department. In addition to the analysis of the vulnerability diagrams to climatic hazards, there is the analysis of the Sensitivity Matrix (Table 5).

Table 5: Major risk sensitivity matrix

Exposure units	Hydroclimatic risks							Exposure index
	Late and violent rains	Pockets of droughts	Poor spatial and temporal distribution of rains	Floods	Early end of rains	Strong winds	Excessive heat	
Corn	4	4	4	4	4	3	4	77 %
Rice	2	5	4	2	4	2	5	68 %
Potato	3	4	3	4	4	2	5	71 %
Cassava	2	3	4	5	3	3	4	68 %
Yam	3	5	4	5	4	2	4	77 %
Cashew	2	3	2	2	3	5	3	66 %
Vegetable crops	3	4	3	5	4	3	5	77 %
Impact index	54 %	80 %	68 %	77 %	74 %	57 %	85 %	

Source: Processing of field data, October 2019

It emerges that the major hydroclimatic risks are excessive heat and pockets of drought with respective impacts 85% and 80% affect more market gardening crops, corn and yam crops with an exposure index of around 77%. It should be noted that the agricultural system is vulnerable to hydroclimatic risks, thus constituting a handicap for sustainable development at the scale of the study sector. Also the analysis of the impact matrix (Table 6) shows that flooding , pockets of drought, late and violent rains and poor distribution of the rains are the risks that have the greatest impact on the variables studied, which constitute the very likely climatic risks in the study area. These results agree very well with those reported by Affo-Dogo (2012) on the plateau region in Togo and Chédé (2012) on the Commune of Savè in Benin and Codjo (2017) in the lower valley of Ouémé in Benin.

Table 6: Matrix of the impacts of climate risks on the variables

(the colored backgrounds corresponding to the degrees of the impacts of each risk on each of the variables in which the impacts are superimposed)

Legend

Occurrence Risks		*Impact of risks*	
Extremely likely		*High*	
Very probable		*Average*	
Likely		*Low*	

Climate risks	Variables Crops	Soil	Water availability
Flood	Rotting of crops, loss of crops and crops, Increased water requirements,	leaching of soils, destruction of roads	Excess water
Pockets of drought	Increased water requirements, hydric and thermal stress in crops and lower yields,	Decrease of soil temperature, reduction of soil water available for plants	Reduced water availability, increased evaporation, degradation of water quality
Late and heavy rains	Disturbances in the development of agricultural activities, chronic decline of crop yields,	Lower soil moisture	Reduced water availability, drop in water potential, drop in yield
Poor distribution of rain	High production cost, lower yield, lower producer income,	Lower soil moisture, soil degradation, reduced yield	Lower water potential, lower yield
Early end of the rains	Lack of water for crops and lower yields,	Reduction of soil water available to plants	Reduced water availability
Strong winds	Pouring of crops, disruption of development stages, drop in yield,	Decrease of soil moisture	Reduced water availability
Excessive heat	Severe drop in yields, increased water stress	Significant drop in soil moisture, land degradation	Reduced water availability

Data source: *Results of field surveys, October 2019*

IV. Discussion

The planetary climate system in which West Africa and Benin is part through the Collines department, is undergoing large-scale modifications which remain amplified by natural and anthropogenic factors, both regional and local. The results of this study show that the Collines department has a slightly increasing annual rainfall trend from 1984, unlike the period from 1971 to 1983 which experienced more rainfall deficits. This corroborates with the conclusions made by Afouda (1990), Houndénou (1999), Ogouwalé (2006) and Yabi (2008) which denote a decrease in the annual totals of precipitation, in particular over the 1961-1990 normal. As for the average temperature, it varies between 25 and 30°C. The daily thermal amplitude is overall 8.5°C, but at times reaches 10°C north of the Commune of Savè (Afouda, 1990 and Oloukoi and al., 2006). The results of Médéou (2015), also indicate since 2000, thermal deviations from the average have been positive and increasing in the Collines department. This climatic context observed in recent years has created water constraints which are not without consequences for the agricultural sector. The major hydroclimatic risks that producers face are late and heavy rains, pockets of drought, poor spatial and temporal distribution of rains, floods, early end of rains, strong winds and excessive heat. These climate risks are similar to those indicated in the existing documentation (PANA-Benin, 2008).

The analysis of the vulnerability of the agriculture sector to hydroclimatic risks help us to retain that market gardening, corn and yam crops are the most vulnerable to hydroclimatic risks identified with an exposure index of 77% than crops of sweet potato (71%), rice (68%), cassava (68%), and cashew (66%) which seems to be the crop least exposed to the risks. The agricultural system is therefore not immune to the perverse effects of hydroclimatic risks in the Collines department. This confirms the results obtained by Chabi (2013) and Ikoudamiloro (2018), which state that the floods cause enormous loss of crops and homelessness in the study area. Through these climatic risks, climate change has an impact to varying degrees on the activities of the populations of the Collines department who live in already precarious conditions. Chédé (2012) in Savè and Affo-Dogo (2012), in Togo produced similar results by showing that in terms of agricultural production, the impact of climate change will depend not only on extreme climatic hazards but also on internal dynamics agricultural systems, in other words their adaptive capacity. For a better development of agriculture, the regularity of the rains is much more important than the amount of rainfall.

A good spatio-temporal distribution of rainfall is an essential element for the growth and productivity of cultivated plants. It is therefore necessary to develop more effective strategies like those proposed by Chédé (2012), such as the development of early varieties resistant to drought, the development of irrigation techniques to improve yields and relieve populations of the Collines department.

V. CONCLUSION

The Collines department is increasingly subject to climatic variations that negatively affect agriculture. The present study allowed to analyze the impacts of hydroclimatic disturbances on agriculture at the scale of the Collines department. It emerges from the analyzes that the hydroclimatic variations had repercussions on the good progress of agriculture over the period of study (1971-2017). The major hydroclimatic risks that producers face are late and heavy rains, pockets of drought, and poor spatial and temporal distribution of rains, floods, early end of rains, strong winds and excessive heat.

The perceptions of populations on hydroclimatic phenomena relate to the disruption of agricultural activities, the hydrological regimes of rivers, and the reduction in the number of rainy days, the decrease in soil moisture, soil degradation and reduced yields

REFERENCES

[1] Affo-dogo A. (2012) : Vulnérabilité et stratégies d'adaptation des Agriculteurs dans la région des plateaux au Togo face au changement climatique : cas de la communauté rurale de Kpimé. Mémoire de Master II, Centre Régional AGRYMETH, 81 p.

[2] Afouda F. (1990) : L'eau et les cultures dans le Bénin central et septentrional : Etude de la variabilité des bilans de l'eau dans les relations avec le milieu rural de la savane africaine. Thèse de Doctorat nouveau régime, Paris IV, Sorbonne : 348p.

[3] Atchadé A. A. G. (2014) : Impacts de la dynamique du climat et de l'occupation des terres sur les ressources en eau du bassin versant de la riviere zou dans le Bénin méridional. Thèse de Doctorat Unique, EDP/FLASH, UAC, 235p.

[4] Atchadé A. A. G. (2007) : Péjoration pluviométrique et production céréalière dans le centre Bénin : cas de la Commune de Ouèssè. Mémoire de maîtrise. DGAT, FLASH, UAC, 86p.

[5] Boko M. (1988) : Climats et communautés rurales du Bénin : rythmes climatiques et rythmes de développement, thèse de Doctorat d'Etat ès Lettres et Sciences Humaines. Centre de recherche de climatologie, URA 909 C.N.R., Université de Bourgogne, Dijon, 2 volumes, 608 p.

[6] BADOLO M., (2007): Indications sur les incidences potentielles des changements climatiques sur la sécurité alimentaire au Sahel, Cahier des changements climatiques, IAVS, 9 p.

[7] Boko M. (1988). Climatologie et communautés rurales du Bénin ; Rythmes climatiques et rythmes de développement, Thèse de doctorat d'Etat ès-lettres à l'Université de Bourgogne Dijon, 1988, 608 p.

[8] Bokonon-Ganta E. (1987) : Les climats de la région du Golfe du Bénin (Afrique Occidentale). Thèse de 3è Cycle, Paris IV : 243p + annexes

[9] Chédé F. (2012) : Vulnérabilité et stratégies d'adaptation au changement climatique des paysans du Département des Collines au Bénin : cas de la Commune de Savè. Mémoire de Master II, Centre Régional AGRYMETH, 86 pages.

[10] Diop, A. (2013) : Diagnostic des pratiques d'utilisation et quantification des pesticides dans la zone des Niayes de Dakar (Sénégal). (Thèse de doctorat) Université du Littoral Côte d'Opale, France.

[11] GIEC (2007) : Changements climatiques : Impacts, Adaptation et Vulnérabilité, Résumé à l'intention des décideurs, GIEC Cambridge, 22 p.

[12] Houndénou C. (1999) : variabilité climatique et maïsiculture en milieu tropicale humide : l'exemple du Bénin, diagnostic et modélisation. Thèse de doctorat de géographie. UMR 5080, CNRS « climatologie de l'Espace Tropicale » Université de Bourgogne, Centre de Recherche de Climatologie, 341 p.

[13] Houssou S. C. (1998) : Les bioclimats humains de l'Atacora (Nord-Ouest du Bénin et leurs implications socio-économiques. Thèse de Doctorat, Université de Bourgogne, 331 p.

[14] Ikoudamiloro M. (2018) : Manifestations et stratégies d'adaptation aux risques climatiques dans la commune de Ouesse. Mémoire de Licence de Géographie, UAC/ FASHS/DGAT, 75p.

[15] Médéou K. F. (2015) : Ambiances bioclimatiques et changements climatiques dans le Département des Collines au Bénin : Vulnérabilité socio-sanitaire et performance des agriculteurs. Thèse de doctorat unique, EDP, UAC, FLASH, 229p.

[16] Nelson, Gerald C. Mark W. Rosegrant, Jawoo Koo, Richard Robertson, Timothy Sulser, Tingju Zhu, Claudia Ringler, Siwa Msangi, Amanda Palazzo, Miroslav Batka, Marilia Magalhaes, Rowena Valmonte-Santos, Mandy Ewing et David Lee*,* (2009) : Changement climatique : impact sur l'agriculture et couts de l'adaptation. Politique Alimentaire, Rapport, IFPRI (Institut International de Recherches sur les Politiques Alimentaires, 30p.

[17] NEPAD-PDDA (2005): Revue des efforts de développement dans le secteur agricole. Rapport sur le Bénin, 8p.

[18] Ogouwale E., (2006) : Changement climatique dans le Benin méridional et central : indicateurs, scenarios et prospective de la sécurité alimentaire. Thèse de doctorat unique, UAC/EDP ; 302 page.

[19] Oloukoi J., Mama V.J. et Agbo F. B. (2006) : Modélisation de la dynamique de l'occupation des terres dans le Département des Collines au Bénin. Télédétection 6 (4) : 305-323

[20] PANA-Bénin (2008) : Programme d'Action Nationale d'Adaptions aux changements climatiques. Cotonou, 81pages.

[21] Roger A. C. Jones ; Martin J. Barbetti (2011) : Influence of climate change on plant disease infections and epidemicscaused by viruses and bacteria. CAB Reviews20127, No. 022

[22] Sircoulon J. (1990) : Impact possible des changements climatiques à venir sur les ressources en eau des régions arides et semi-arides. WMO/TD-n°380, 87p.

[23] Yabi I. (2008) : Etude de l'agroforesterie à base de l'anacardier et des contraintes climatiques à son développement dans le Centre du Bénin. Thèse de Doctorat Unique, EDP, FLASH, UAC, 235 p.