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Research Paper

Impacts of Climate Variability over Rain-Fed Cultures in the Townships of Kandi, Malanville and Banikoara.

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Abstract
Climate change is putting significant pressure on agricultural activities. In Benin, the agricultural sector is vulnerable to the types of impacts linked to climate change. These are the rise in temperatures and the decrease in rainfall which have a negative impact on agricultural yields. This study aims to identify the impacts of climate variability onrain fed crop systems in the communes of Malanville Kandi and Banikoara. To achieve this objective, meteorological data (temperature, precipitation and relative humidity) from the period 1970 to 2018, socio-demographic data and agricultural data were used. Direct or semi-direct interviews, participatory diagnostics (focus group) and direct observation are the main techniques used. Data processing is done by counting with the mobile data collection application (KoBoToolBox).
At the end of the data processing it emerges that soil degradation, lower yields, modification of the agricultural calendar of producers, abandonment of certain varieties of crops, and the resurgence of crop enemies are the main impacts to be observed major consequence of climate variability for rain-fed crops. The correlation coefficients between yields and rainfall in the communes of Malanville, Kandi and Banikoara show that only cotton yields show a weak correlation with the seasonal accumulations of rainfall.
Keywords: *Impacts, climate variability, rain-fed crops, Malanville Kandi and Banikoara*

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I. INTRODUCTION

Climate change has put important pressure on agricultural activities. The damages caused by climate change in Tunisia include the high dispersal of days and the frequency of dry episodes that can occur over twenty days (A. Abderrahmen *and al.,* 2013, p. 36). This delay provokes the relative weakness of the cultures yields Codjo and *al.,* 2013 pp. 168-169).

In Benin,the agricultural sector is vulnerable to three types of impacts in relation to the climate change. (M. Boko *and al.,* 2012 pp. 36-38). These include the increase of temperature and the fall of precipitation which have a negative impact on the agricultural yields; extreme events that have an impact on the precarious rural housing, and on the cultures; the rise for one degree of the temperature, whose consequence is 10 % additional evaporation that could cause the agricultural sector to be strangled between the rise of temperature and the reduction of the rain season duration. The extent of climate change in the North – West of Benin has had significant impacts on the agricultural production (M. Ouassa Kouaro*and al.,* 2013, p. 438). The impacts of climate vulnerability over agricultural production in the Collines Department in Benin are expressed by a bad space and time distribution, which remains the first cause of the fall of the cotton yields, a precocious or late start, a rise of temperature and the vulnerability of cotton plants which is observed through the fall of the cotton yields (G. Ahouantoumé, 2015, pp. 73-74). This is the case of sorghum which, despite its high resilience, is very sensitive to climate in relation to its productivity(J. Boyard-Micheau *andal.,* 2013 p. 127). This situation is caused by anthropic actions that worsen the degradation of soils, and a then are a menace over food security.

Presentation of the field of study

Set between 2°00'16'' and 3°36'21'' Est longitude, and between 10°55'00'' and 12°00'6'' North latitude,the field of study includes the townships of Malanville, Kandi and Banikoara. These townships cover two agro-archaeologicalzones of Benin, that is the agro-archaeological zone No1 (Malanville), and the agro-archaeological zone No2 (Kandi and Banikoara). The zone stretches over an area of 11227.95 km² and is limited to the North by the township of Karimama and the Niger Republic, to the West by the department of Atacora and the Burkina Faso Republic, tothe East by the township of Segbana and the Nigeria Republic, and to the South by the township of Gogounou. Figure 1 below presents the geographic situation of the field of study.

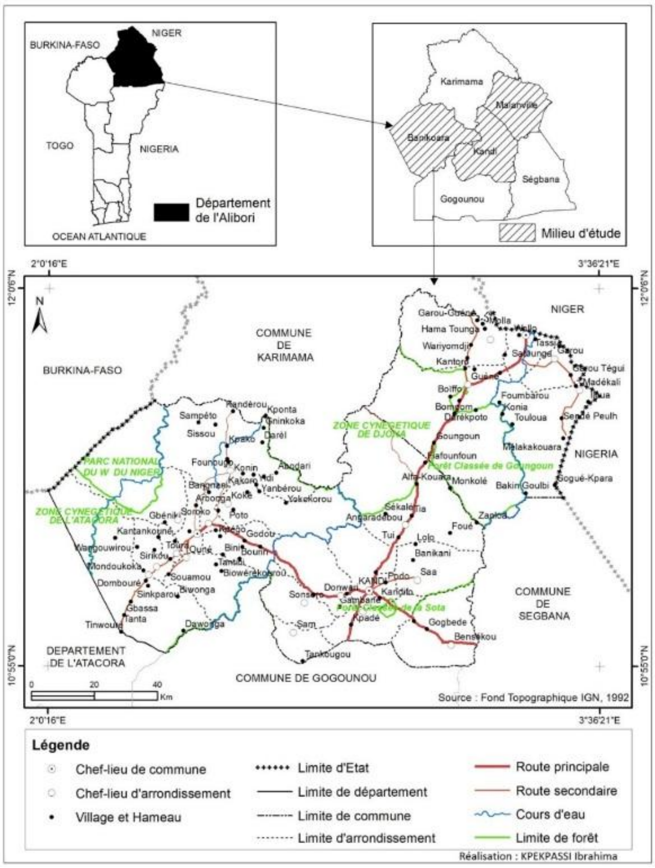


Figure 1:Geographic Situation of the field of study

II. MÉTHODOLOGY

In the frame of the present study, meteorologic some data (rain fall and ETP) in the period from 1970 to 2018 were collected from theNational Agencyof Météorology (Meteo-Bénin) in Cotonou, and other sociodemographic data were obtained from the results of the 2002 and 2013 population census in the townships of Malanville, Kandi and Banikoara, available in the archives of the National Institut of Statistics and Economic Analysis (INSAE), and agricultural data were also obtained from the MAEP filing cabinet and from the Alibori Regional Officeof Agriculture, and these are essentially based on agricultural statistics (area, production,yields and food balance) over the period of time 1995 – 2018.

The tools and materials for data collection are the following: the interview guide, the observation grill, the questionnaires, etc… Many techniques of data collection have been used. Direct and semi-direct interviews, participative diagnosis (focus group) and direct observation are the main techniques used. Individual interview with the technicians of ATDA, DDAEP and the associations of producers have helped in apprehending the influence of climate variability and climate change over rain-fed cultures.

Data processing has been done with analysis through a mobile appliance for data collection (KoBoToolBox). The use of that appliance helps analyse automatically the results of the inquiry, the computing and text processing through Microsoft Word and Excelsoft wares.

The Excel table designer has been used to aggregate the daily data into monthly, then yearly data, in order to turn them into tables, then graphs. The Excel table designer has also been used to calculate the average height of rain, the temperature and agricultural statistics, basing on the following formula:

$$X = \sum_{i=1}^{n} Xi / N \quad (P_1)$$

X = the arithmetic average; N = the total number of modalities, Xi = the modality of thestudied trait.

The Bravais-Pearson correlation coefficient

The correlations between the seasonal rainfall accumulation and the yield of the rain-fed cultures are calculated through the following formula:

$$r = \frac{\mathrm{COV}(x, y)}{\boldsymbol{\sigma x.\sigma y}}$$

With: r= correlation coefficient; COV (x, y) = covariance of x and y; **x =**rainfall variable;**y = yield** variable;**σx**= standard deviation of x ; **σy**= standard deviation of y

The correlation or the coefficient of correlation (r) allow establishing a link between two variables while not strictly defining the causality of the dependence between the two parameters, but it shows the more or less high variance of the non-consistent second element in terms of the first one, creation then the linear function. This coefficient is still set between - 1 and +1.

- If r < 0, the two traits progress in opposite directions;
- If r > 0, the two traits progress in the same directions.
- If 0,6 <|r|< 1, then, the two traits progress the same way, and the evolution of one influences the other's. In this case, the two traits are highly correlated.;
- If 0,3 <|r|< 0,6, the two traits progress approximately the same way. In this case, they are moderately correlated.
- If 0,1<|r|<0,3 the two traits are weakly correlated.
- If 0 <|r|< 0,1, the two traits are independent. As a matter of fact, there exists no correlation between the two traits.

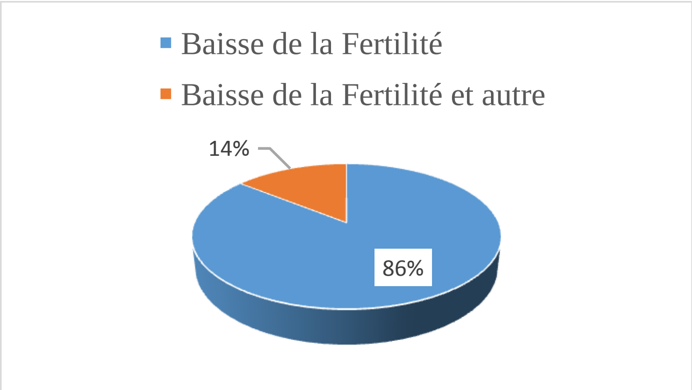
III. RESULTS

The study of the climate variability impacts over the systems of rain-fed cultures has been carried out by comparing the perception of producers, and the correlations between the agricultural yields of the cultures and the rainfall, in the townships of Malanville, Kandi and Banikoara.

2-1- Impacts of t variabilityand the climate change over the systems of rain-fed cultures

✓ ***Impacts of climate variabilityover the decrease of fertility of*** **systems of rain-fed cultures**

Figure 2 presents the statistics about the viewpoint of rain-fed culturesproducersconcerning the decrease of fertility



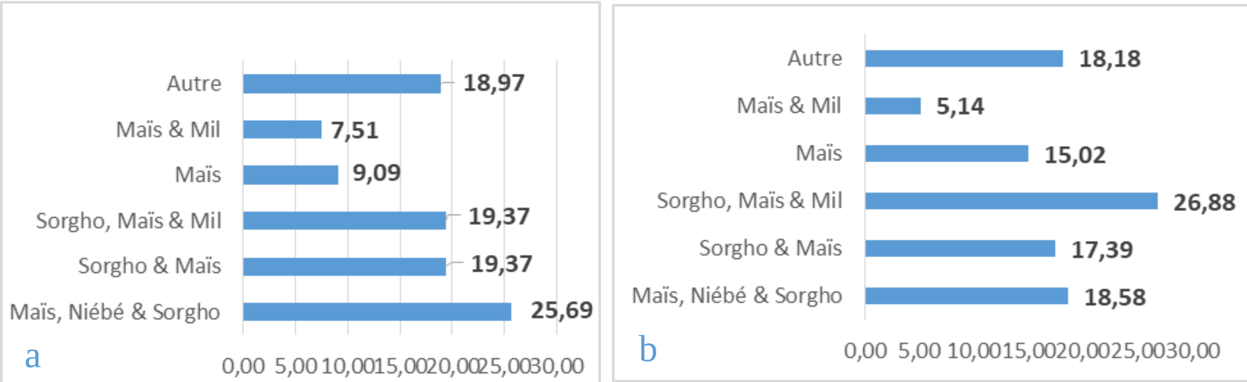
Source :*data from inquiry 2020*

Figure 2: Rain-fed producers'Opinion on the decreased fertility.

With reference to figure 2,the majority of rain-fedproducers (86 %)think that there is a decrease of soil fertility. The remaining 14 % think that, not only there is a decrease of soil fertility, but also there are other consequences linked to the climate variability over the soils, which are erosion, land up silting and land degradation.

✓ ***Main cultures*** **by the rain-fed farmers twenty to thirty years ago**

Figures 3 (a and b)present the main rain-fed cultures in the study area



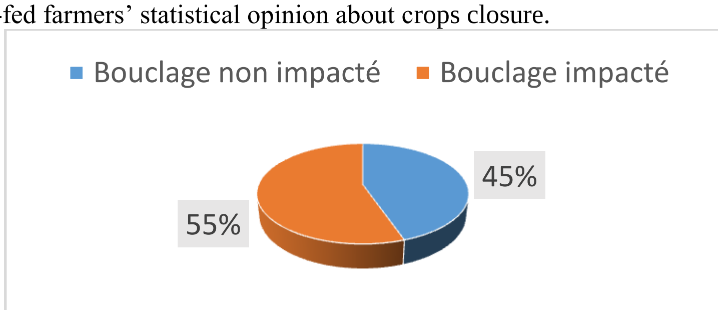
Source :*data from inquiry, 2020*

Figure 3 : Main rain-fed cultures in the past (a) and in the present (b)

Analysis of figure 3 reveals that over ¼ of the interviewed rain-fed farmers were concerned specifically with maize, niebe, and sorghum twenty to thirty years ago. Only 9.09 % grew maize then. On the opposite, the cultivation of sorghum, maize and mil represents more than ¼ of the investigated people in the present. As for maize, its cultivation has grown from 9.9% twenty to thirty years ago, to 15% nowadays. According to the interviewed farmers, niebe resists little to the effects of climate variability. As a consequence, this culture has been substituted with that of mil which, according to those farmers, is more resistant to climate variability.

✓ ***Impacts of climate variability over cycle loop of the rain-fed crops***

Figure 4 presents rain-fed farmers' statistical opinion about crops closure.



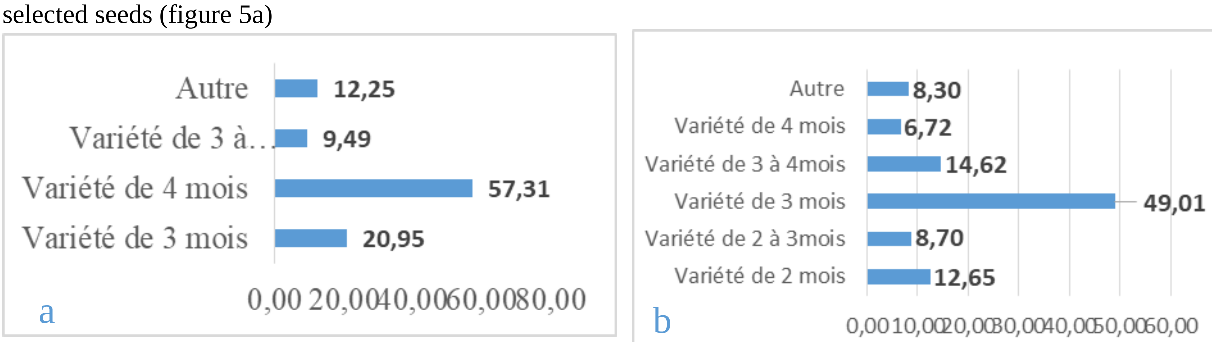
Source :*data from inquiry, 2020*

Figure 4:Opinion of rain-fed farmers about impacts of climate change on crops' looping

From analysis of figure 4, over half of the investigated rain-fed farmers (55.34 %) think that the climate variability has an impact on the crops closure, due to the changes occurring through the sowing dates, against 44.66 % of them who think the opposite.

✓ ***Cycle of rain-fed crops***

Basing on data collected from field investigation, in the past, rain-fed farmer mostly (57.31 %) used four-mouth selected seeds (figure 5a)



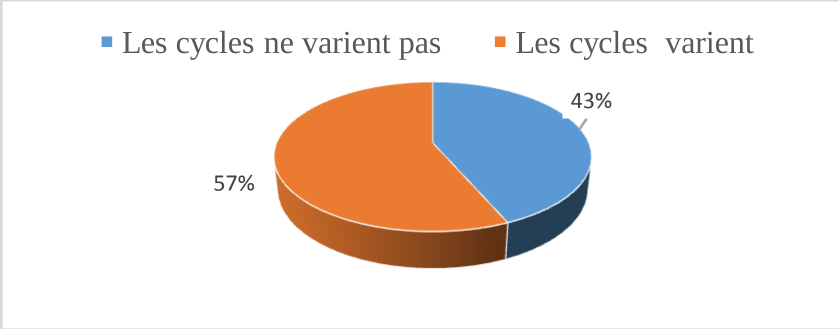
Source :*data from inquiry, 2020*

Figure 5:Varieties ofcrops produced by the rain-fed farmers

On the opposite, today, (figure 5b), around half of those farmers are using three-month selected seeds. This means that rain-fed farmers are in search of short-cycle selected seeds in order to get adapted to the effects of climate variability.

✓ ***Variation ofcrops cycles and sowing dates***

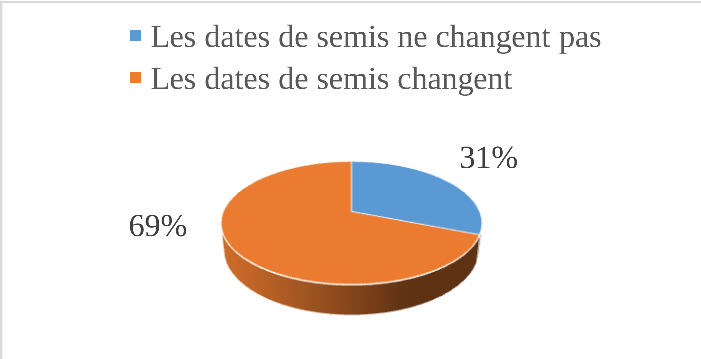
Figure 6shows the rai-fed farmers' opinion about crops' cycle change.



Source :*data from inquiry, 2020*

Figure 6: Farmers' opinion about crops cycles variation due to climate change

From the analysis of the above figure, the majority of rain-fed farmers (57 %) have affirmed that there is a variation of crops cycles due to the climate variability All the same, most of the latter are favourable to modifying the dates for sowing crops. As such, about 69 % of those farmers think having modified the dates for sowing their different crops (figure 7). Such modification of sowing dates is due to the lateness of the rains.

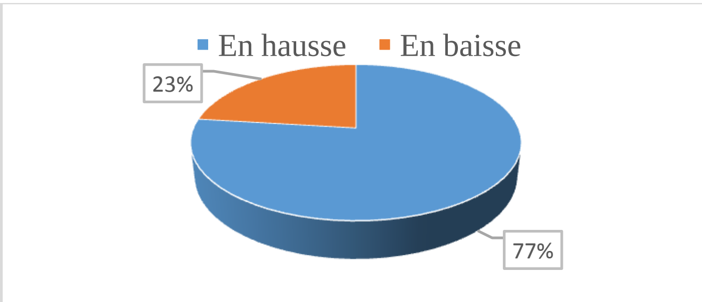


Source :*data from enquiry, 2020*

Figure 7: Distribution of farmers according to their opinion about modifying the sowing dates

✓ **Infestations**

Analysis of data has revealed that the investigated rain-fed farmers think that variation in the number of infestations is on the rise. (figure 8)



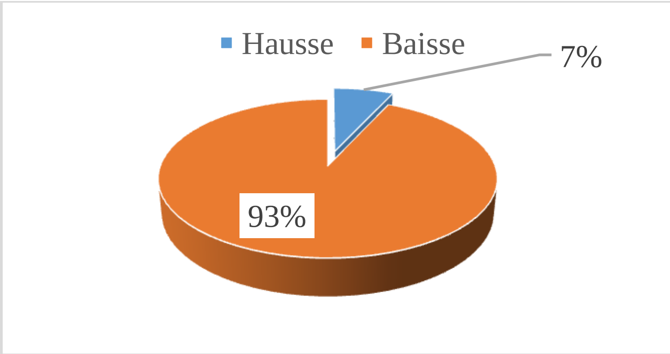
Source :*data from inquiry, 2020*

Figure 8:**Farmers' o**pinion about change in the number of infestations

Almost 77 % of the farmers think that the number of infestations is on the rise because of the ambient humidity in the study area. Yet, 23 % affirm the contrary (figure 8)

✓ **Variation of agricultural yields**

Figure 9illustrates the rain-fed farmers' viewpoint in connection to the yields variation.



Source : *Data from inquiry, 2020*

Figure 9:**Distribution of farmers basing on their opinion about variation of the yields**

As for variation of the agricultural yields, there is a falling tendency due to the climate change. That is why about 93 % of the farmers have affirmed that the yields are on decrease as years pass, while only about 7 % of the farmers say the contrary.

2-2- Impacts climate variability over large rain-fed cultures (cotton, maize, sorghum, mil).

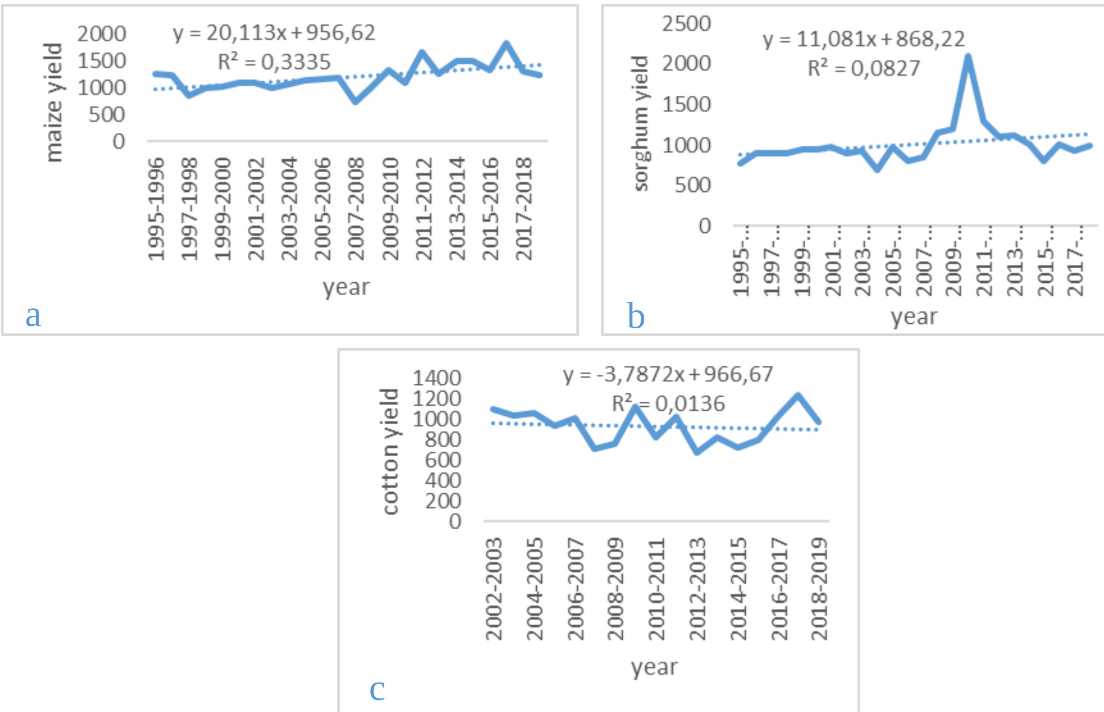
To evaluate the impact of climate variability over large rain-fed cultures, a correlation was identified between pluviometry, and the yield of cotton, maize, sorghum and mil in the areas of Malanville, Kandi and Banikoara over the years 1995 to 2018.

✓ ***Impact of climate variabilityon the yield***

❖ ***Evolution of rain-fed crops yields***

- ***Evolution of the yields of rain-fed cultures in Malanville***

Figure 10 presents the progress of rain-fed crops yields in Malanville



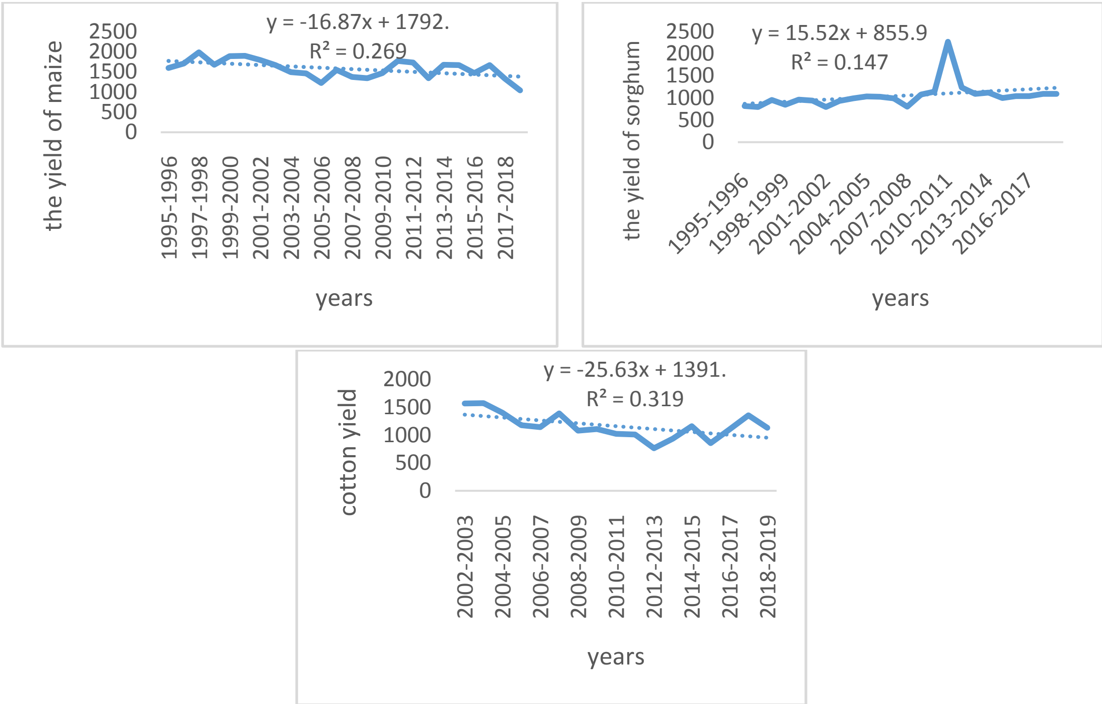
Source :*Meteo-Benin Agency, DDAEP Alibori, 2020*

Figure 10 :Evolution of the yields of rain-fed crops in Malanville

Analysis of graphs of figure 10 shows a rising tendency of maize and sorghum (figure 10a et b)over the period of time 1995-2018. But the graph about cotton (figure 10c) presents a falling tendency. One could conclude about a correlation between those cultures and the climate variability in Malanville.

❖ ***Evolutionof theyield of rain-fed crops in Kandi***

Figure 11 presents the evolution of the yields of the rain-fed crops in Kandi



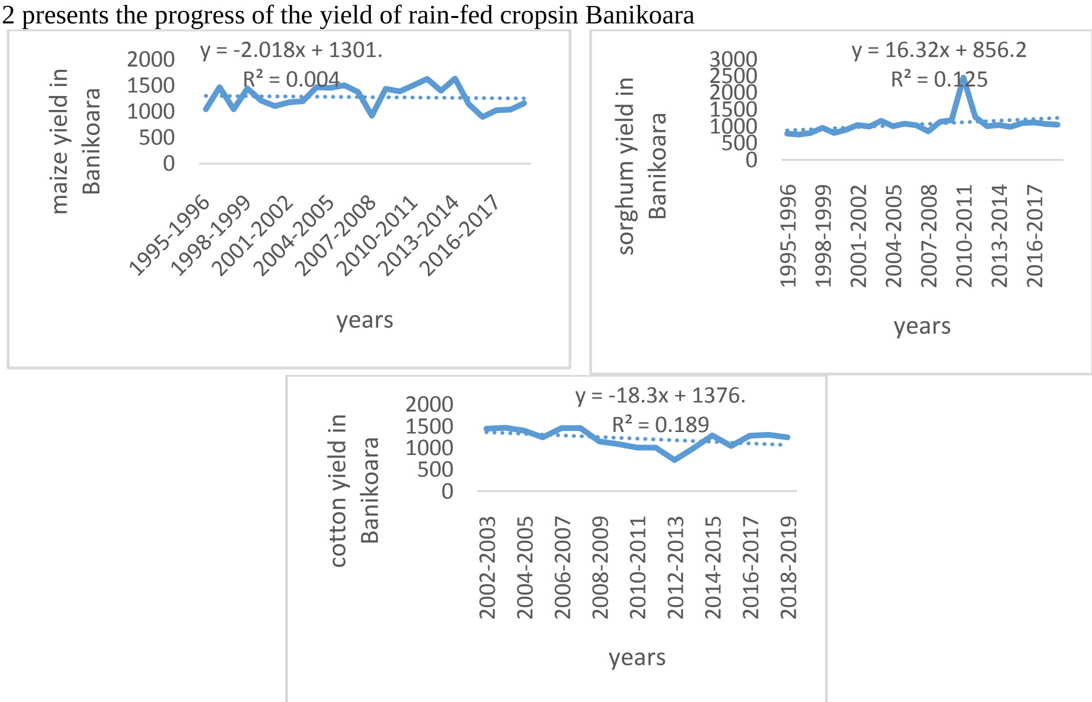
***Source :**Meteo-Bénin Agency, DDAEP Alibori, 2020*

Figure 11 : Evolution of the yields of rain-fed crops in Kandi

Graphs of figure 11show a falling tendency of maize and cotton yields, while for the yield of sorghum, the tendency is on the rise. It is important to make sure that there is a correlation between the yields of those cultures and the precipitations in Kandi.

❖ ***Evolution of the yield of rain-fed crops in***

Figure 12 presents the progress of the yield of rain-fed cropsin Banikoara



***Source :**Meteo-Benin Agency, DDAEP Alibori, 2020*

Figure 12:Evolution of the yield of rain-fed cultures in Banikoara

Analysis of the graphs from figure 12 indicates a falling tendency for the yields of maize and cotton. On the opposite, the yields of sorghum and mil are on the rise in Banikoara. Here again, one could wonder if there exists a correlation between the rain-fed crops yields and the precipitations.

❖ ***Bravais-Pearson's Correlation between the pluviometric variability and agricultural yields in Malanville***

The correlation coefficients between the yields and precipitations in the townships of Malanville, Kandi and Banikoara displayed through table1 shows that only the yields of cotton have a weak correlation with seasonal accumulation of precipitations.

TableI: Correlation between seasonal precipitations and the yields from rain-fed cultures.

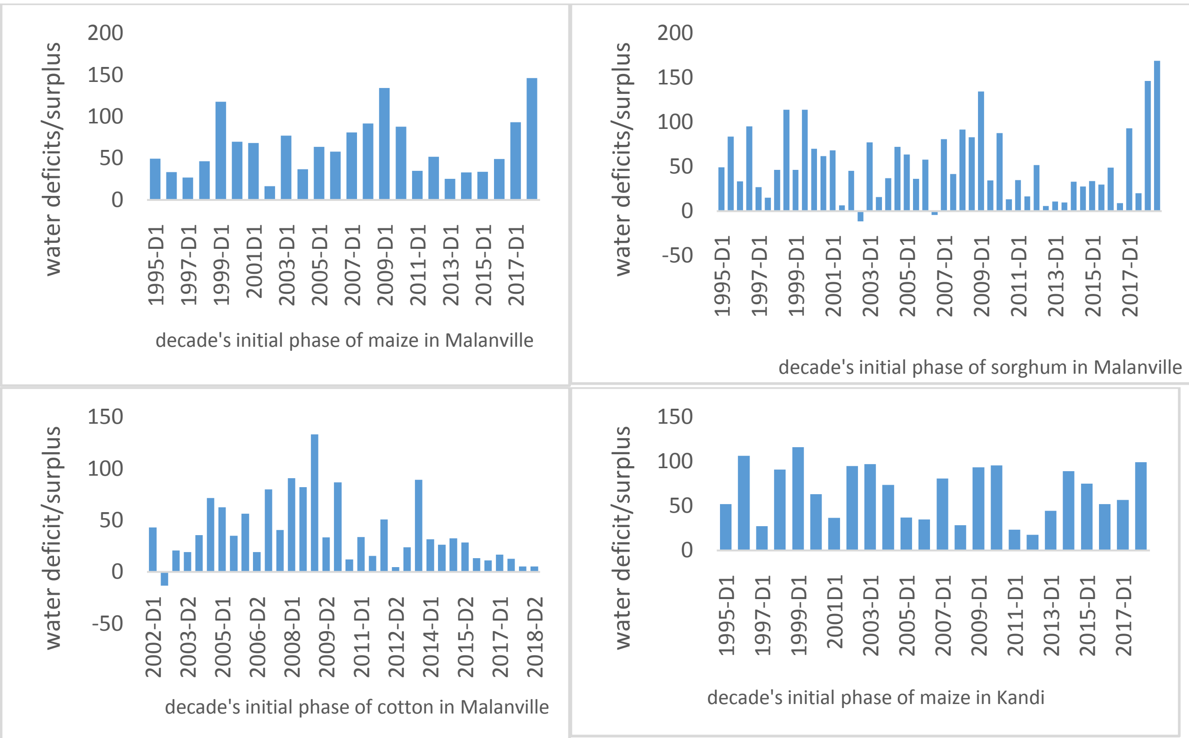
Townships	Cultures	Pearson's correlation Coefficient	Correlation
Malanville	Maize	-0.28391765	Weak
	Sorghum	-0.02932391	None
	Cotton	-0.356279028	Intermediate
Kandi	Maize	0.035938556	None
	Sorghum	0.035938556	None
	Coton	-0,338098126	Intermediate
Banikoara	Maize	0,04940308	None
	Sorghum	-0,031359217	None
	Cotton	0.176861182	

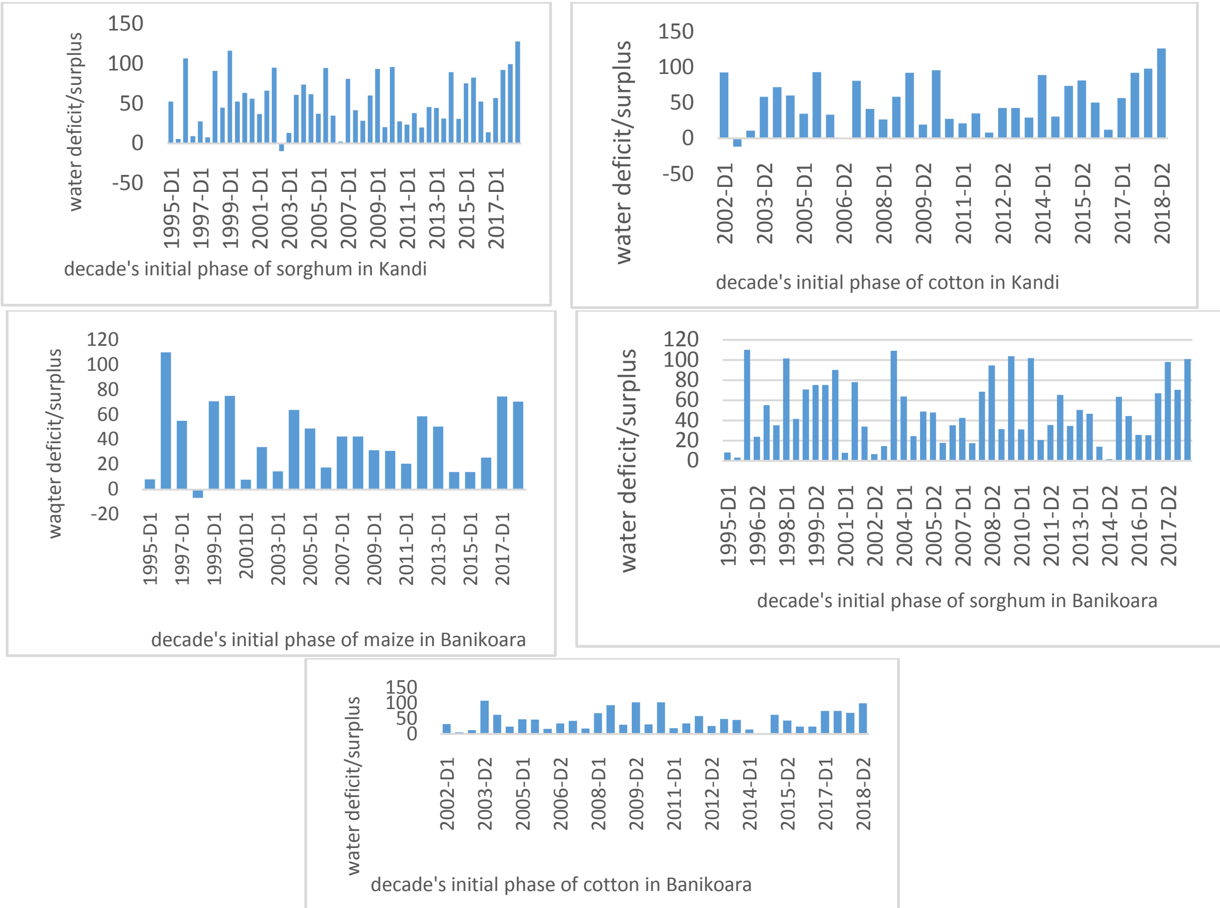
Source : *Meteo-Benin Agency, DDAEP, 2020*

❖ **Ten-day water surplusand deficits**

Water Deficits andsurplus in the study area

The need of water has been evaluated in the study area on maize, sorghum and cotton, in order to deduce the deficits and surplus at each stage of the crops evolution. The graphs of figure 13 presentsthe water deficits and surplus per ten years, and per stage of evolution of maize and sorghum plants, from 1995 to 2018, and of cotton from 2002 to 2018, in the study area.





Source :*NationalAgency of meteorology, Bénin, 2019*

Figure 13:Water deficits and surplus at the initial stage of maize and cotton in the study area.

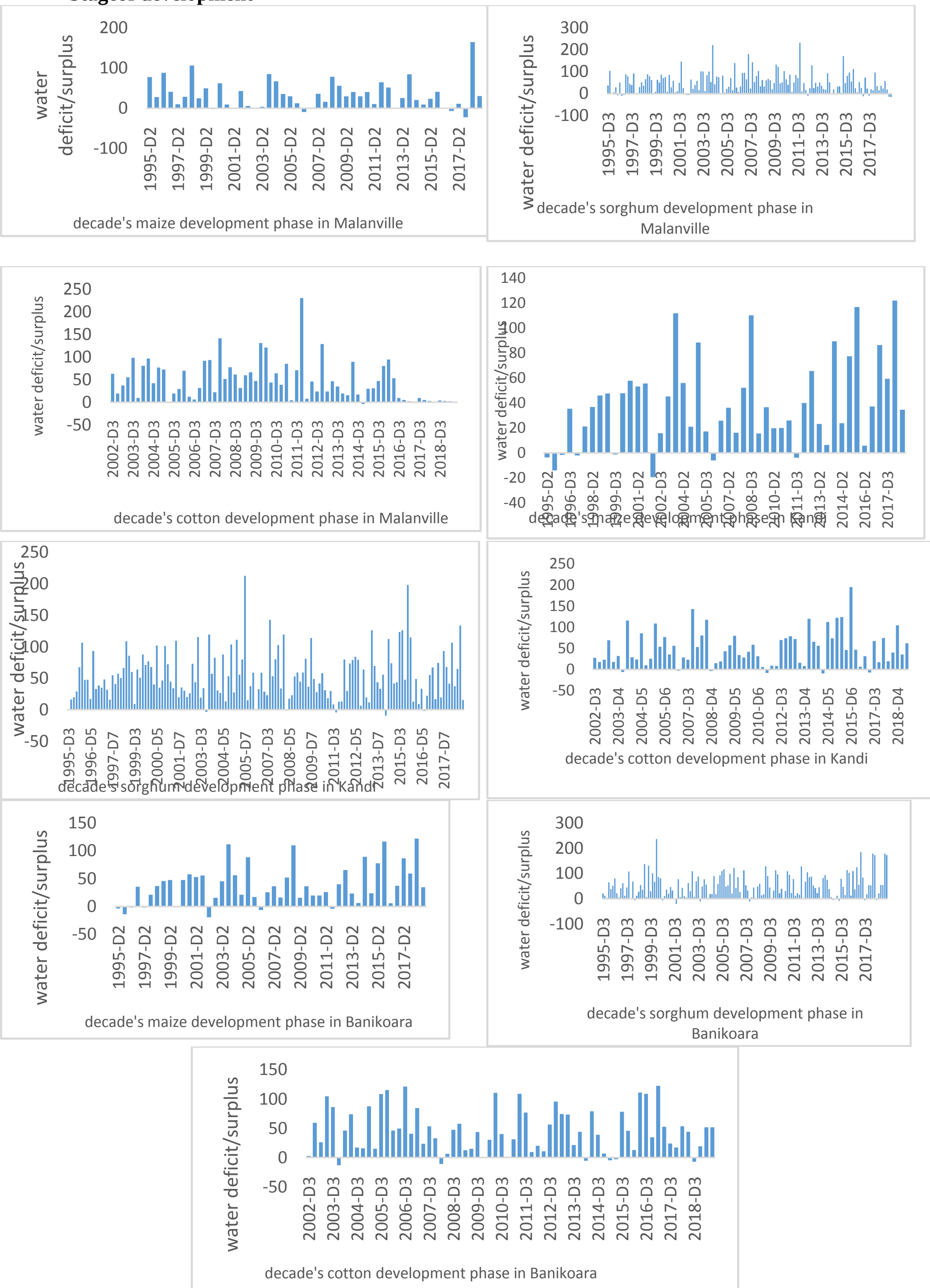
Analysis of graphs in figure 13shows that the initial stage of the cultures in the study area has been submitted to exceeding rainfall of more than 127 mm for sorghum in Kandi. But these excesses have had little impacts on the yields of maize and cotton in Malanville, and on sorghum and cotton in Banikoara (tableII).

TableII : Correlation between the heights of seasonal precipitations and the yields at the initial stage.

Townshipse	Cultures	(r) Correlation coefficient	Correlation
Malanville	Maize	-0.173959693	Weak
	Sorghum	-0.008779355	None
	Cotton	-0.210139332	Weak
Kandi	Maize	0.039147201	None
	Sorghum	0.048946387	None
	Cotton	0.059275322	None
Banikoara	Maize	0.036000521	None
	Sorghum	0.115777075	Weak
	Cotton	-0.169806489	Weak

***Source** : National Agencyof Meteorology, Benin, 2019*

- **Stageof development**



***Source :** Agence Nationale de météorologie du Bénin, 2019*

Figure 14: water deficit/surplus at the stage of development, with maize, sorghum and cotton, in the study area.

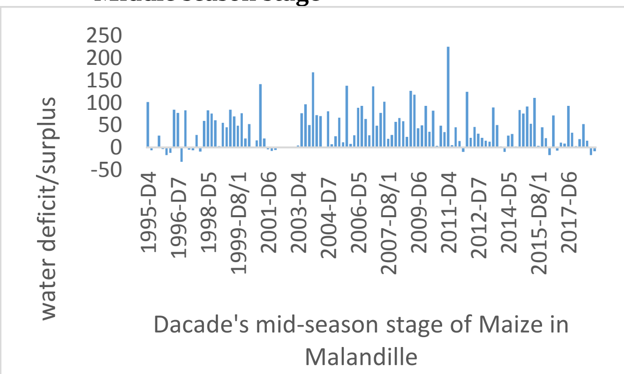
Analysis of graphs from figure 14reveals that generally, the stage of development of crops has been marked with water surplus (photo 2) that have had little impacts on the yields of sorghum and cotton in Kandi, on maize and cotton in Banikoara, and a medium impact (r= -0.421805624) on the yields of maize in Kandi (tableIII).

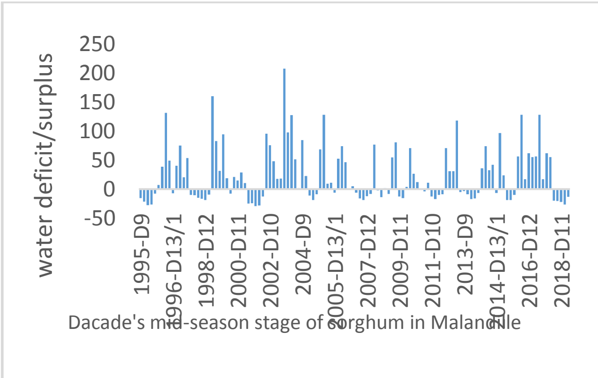
TableIII: Correlation between the heigh of seasonal precipitations and the yields, at the stage of development.

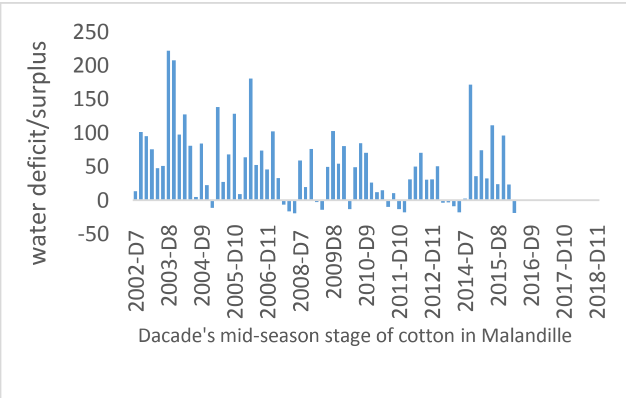
Townships	Cultures	(r) Corrélation coefficient	Correlation
Malanville	Maize	-0.091445212	None
	Sorghum	0.032723862	None
	Cotton	-0.091825034	None
Kandi	Maize	-0.421805624	Intermediate
	Sorghum	-0.114971589	Weak
	Cotton	-0.188366372	Weak
Banikoara	Maize	-0.119532886	Weak
	Sorghum	0.031716026	None
	Cotton	-0.10065657	Weak

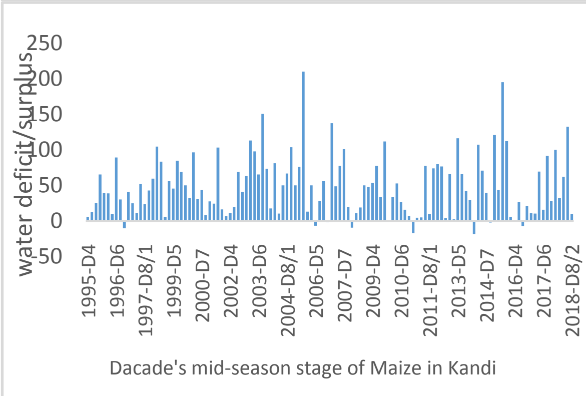
***Source** : National Agencyof Meteorology, Benin, 2019*

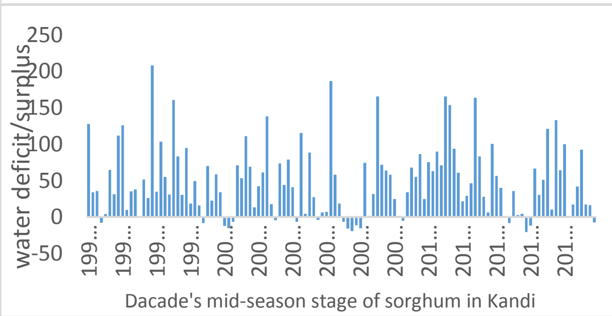
- **Middle season stage**

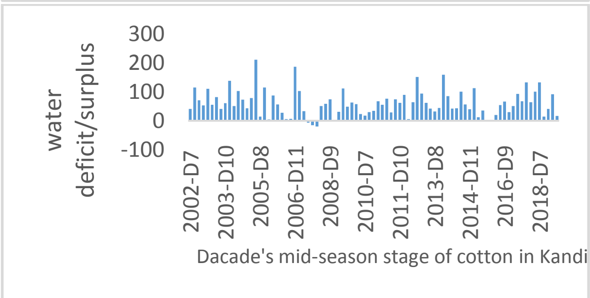


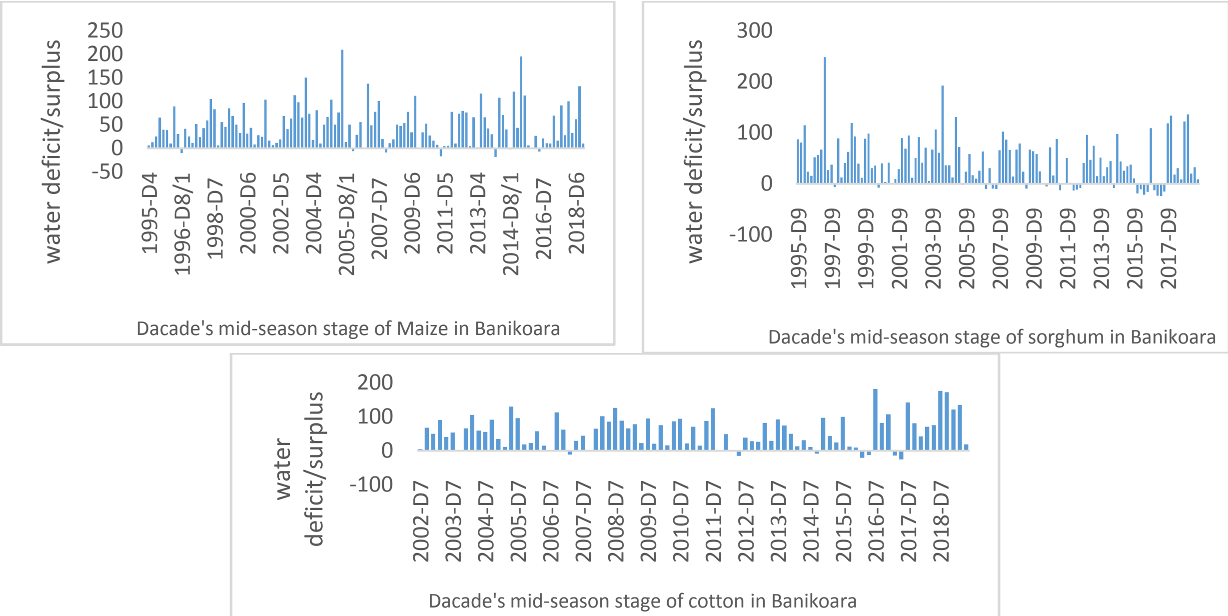












Source *: National Agencyof Meteorology, Benin, 2019*

Figure 15 : Water deficit and surplus, at the mi-season phase in the area of study

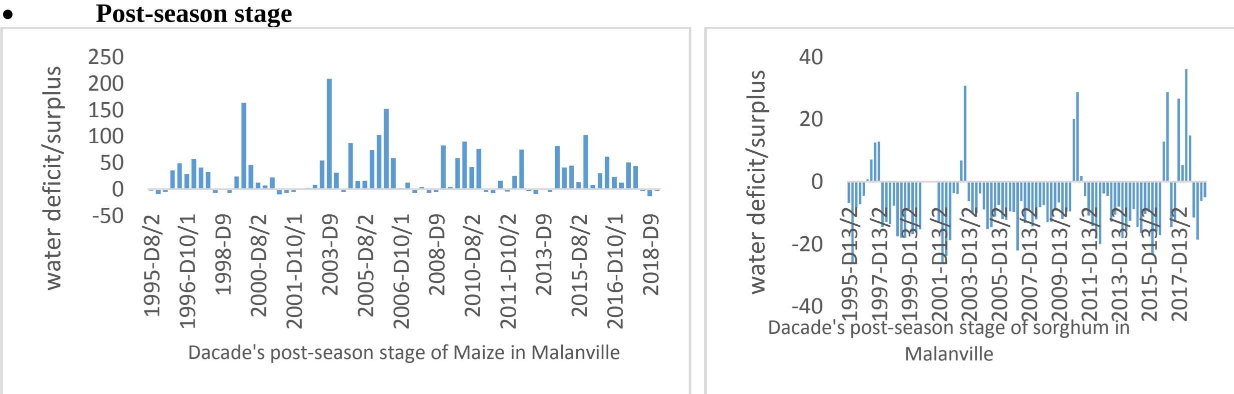
Analysis of the graphs from figure 15 illustratesdecades of high surplus(up to 210 mm) and water deficits that have had little impacts on the yields of sorghum in Kandi, and of cotton in Kandi and Banikoara (tableIV).

TableIV : Correlation between the height of seasonal precipitations and the yields at the stage of mid-season.

Townships	Cultures	(r) Correlation coefficient	Correlation
Malanville	Maize	-0.061000149	None
	Sorghum	-0.02613702	None
	Cotton	0.013500253	None
Kandi	Maize	-0.258089038	Weak
	Sorghum	0.087774519	None
	Cotton	0.098899959	None
Banikoara	Maize	-0.043316921	None
	Sorghum	-0.137837506	Weak
	Cotton	0.107997912	Weak

Source *: National Agencyof Meteorology, Benin, 2019*

- **Post-season stage**



***Source** : National Agencyof Meteorology, Benin, 2019*

Figure 16 : Water deficit and surplus at the stage of post-season, in the area of study

Analysis of the graphs from figure 16shows a variability of the decade's water deficits and surplus, which have had a high impact (r= 0.942773968) over cotton yield in Malanville, an intermediate impact (r= 0.419993339) on the yield of cotton in Banikoara, and a weak impact on the yield of sorghum in Malanville, on that of maize and sorghum in Kandi, and on that of maize in Banikoara (tableV)

Tableau V : Correlation between the decade's high seasonal precipitations and the yields at the stage of post-season.

Townships	Cultures	(r) Correlation coefficient	Correlation
Malanville	Maize	-0.007975713	None
	Sorghum	0.247288806	Weak
	Cotton	0.942773968	Very high
Kandi	Maize	0.132768581	Weak
	Sorghum	0.115995013	Weak
	Cotton	-0.034781669	None
	Maize	-0.119602277	Weak

Banikoara	Sorghum	-0.078560683	None
	Cotton	0.419993339	Intermediate

***Source** : National Agencyof Meteorology, Benin, 2019*

IV. DISCUSSION

Globally, rain-fed crops farmers think that climate variability has had a huge impact on the soils. They evoke as impacts of climate variability:the decrease of soil fertility, erosion, the land silting and leaching. These phenomena have contributed to degrading the soils. Those collected results meet those produced by Mr. Nouhou Koutcha (2012 p. 46) through his study, which concludes that climate variability and climate change have also impacted rain-fed crops, since the decrease on the yields has been confirmed by 100 % of the investigated farmers in Damana, 95 % in Farié Haoussa and 80 % in N'Dounga.

Over half of the rain-fed farmers (55%) affirm that climate variability and climate change have an impact on the cycle loop. Moreover, the majority of the farmers (86 %) affirm that there has been a decrease of soil fertility. These results are similar to those found by Mr. Ouassa Kouaro *and al.*, (2013, p. 438) which state that the extent of climate change in the North-West of Benin has had significant consequences on the agricultural production. To all these, modification of sowing dates and the rise of the number of infestations are to be added. According to A. Abdou Bagnan, (2016, pp. 10-11), farm planning is more and more difficult in that context of variability observed in the rainfall regime.

Furthermore, climate variability has an impact high rain-fed crops, namely cotton, maize, sorghum and mil, in Malanville, Kandi and Banikoara. In the township of Malanville, the yield of maize and sorghum has a rising tendency, while the yield of cotton in the same area is in decline. This situation is different in Kandi where the yields of maize and cotton are on decrease, when the one of sorghum is on the rise. In Banikoara, the yields of sorghum and mil are growing while the one of maize and cotton is falling. The correlation coefficients between the yields and precipitations in the townships of Malanville, Kandi and Banikoara show that only the yields of cotton have a weak correlation with the seasonal precipitation accumulations. These results meet those of I. J. Etéka *andal.*, (2016, pp. 125-127) which have concluded that rainfall variability in its spacio-temporal aspect, has high impacts on agricultural yields, and as a matter of fact, on farmers' socio-economic conditions.

V. CONCLUSION

The present study has allowed identifying the impacts of climate change and climate variability over rain-fed farmers in the townships of Malanville, Kandi and Banikoara. These impacts are concerned with soil degradation, the decrease of yields, modification of farmers' plans, resignation on producing varieties of crops, and recrudescence of crops' parasites.

The highly produced crops in that study area are maize, cotton, sorghum and mil. The yields from those cultures progress with no consideration for climate parameters, mainly the rainfall. The relationship between the yields and precipitations in the townships of Malanville, Kandi and Banikoara show that only the yields of cotton have a weak correlation with the precipitations' seasonal accumulations.

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