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Research Paper

Impacts of Climate Variability and Climate on the Market Gardening Systems in Thetownships of Kandi, Malanville and Banikoara.

Ibrahima KPEKPASSI [1], Abdoul-Ramane ABDOULAYE [2], Aboudou Ramanou ABOUDOU YACOUBOU M[3]

[1]*Ecole Doctorale "Sciences Agronomiques Et Eau", +229 97 07 07 88/*
[2]*Enseignant-chercheur à l'Université de Parakou, +229 97 98 87 36*
[3]*Enseignant-chercheur à l'Université de Parakou, 94372727*

ABSTRACT
Climate variability and change are a major challenge for agriculture in Benin. This study, conducted in the communes of Malanville, Kandi and Banikoara, aims to identify the impacts of climate variability and change on the mairaicheres cropping systems of these communes. To do this, a survey was carried out on a sample of 132 individuals, made up of 103 market gardeners and 29 local managers. Rainfall and temperature data from Kandi, Banikoara and Malanville stations. Survey data was processed using SPPS software. The impacts of climatic risks as well as the levels of consequences of these impacts have been identified on the elements of market gardening systems.
At the end of the work it emerges that the loss of cultivated areas, soil degradation, loss of production, decrease in water availability, drop in yields, drying out of crops are the main impacts of climate variability for market gardening. Likewise, floods, the drop in rainfall as well as the rise in temperatures constitute the risks identified for market gardening.
KEYWORDS: *Impacts, climate variability, market gardening crops, Malanville Kandi and Banikoara*

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I. INTRODUCTION

On the West of Central Africa, the past six decades were characterized by striking changes, particularly with significant drought episodes, a rising tendency of temperature by +1 °C and a decrease of water fall by -11 % (B. Doukpolo, 2014, pp. 241-242). Climate change has had important pressure over farming activities and its impacts are characterized by a huge dispersion of days and the frequency of drought episodes that can last beyond twenty (20) days (A. Abderrahmen *and al.*, 2013, p. 36). These disturbances, coupled with the non-access of farmers to information about weather forecast, gets formers for some seasons, to sow many times before of the farming season begins effectively(A. Abdou Bagnan, 2016, pp. 10-11).

Benin, like the other West African countries, has faced a notable drop of the rain fall, from 1965 to 2015. It has been ineluctably proved that rainfall variability in its spatio-temporal aspect has had impacts on the agricultural yields and, as a matter of fact, on the socio-economic conditions of farmers (I. J. Etéka *andal.*, 2016, pp. 125-127).The extent of climate change in the North-West of Benin has had significant a incidence on the agricultural production(M. Ouassa Kouaro*and al.*, 2013, p. 438). However, the impacts of climate variability on the agricultural production in the Department of Collines in Benin are shown by a bad spatio-temporal distribution, which now remains the main cause of the decrease of the cotton yield, precocious or delayed launching of the agricultural activities, rise of temperature, and vulnerability of cotton plants which results in decrease of the cotton yield. (G. Ahouantoumé, 2015, pp. 73-74). This situation is favoredby anthropic actions that worsen soil degradation,and represents a threat to food security. Yet, there are positive impacts from climate change over the yield of a number of cultures (S. J. R Gbaguidi *andal.*, 2016, pp. 151-152). Among the impacts of climate change, there are: the decrease of the yield, destruction of cultures, disorganization in the classical farm planning, difficulties for farmers in paying back the loans they were allotted(S.S.P. Houssou-Goé, 2008, pp. 85-87). Also, the fall of rainfall accumulation, coupled with the rise of temperature causes precocious

drying up of water ponds and shallows, which also provokes drying up of market-gardening cultures, due to lack of water and appearance of weeds that compete with those cultures (M. Nouhou Koutcha (2012 p. 48).

Presentation of the field of study

Situated between 2°00'16'' and 3°36'21'' East longitude and between 10°55'00'' and 12°00'6'' North latitude the field of study covers the townships of Malanville, Kandi and Banikoara. These townships are stretched over two agro-ecologic zones in Benin: 1-the agro-ecologic zone of Malanville, and 2-agro-ecologic zone of Kandi and Banikoara. The field of study covers a total area of 11,227.95 km², and is limited to the North by the township of Karimama and the Niger Republic, to the West by the Atacora department and the Republicof Burkina-Faso, to the East by the township of Ségbanaand the Republic of Nigeria, and to the South by the township of Gogounou. The below (figure 1) presentsthe geographic situation of the field of study.

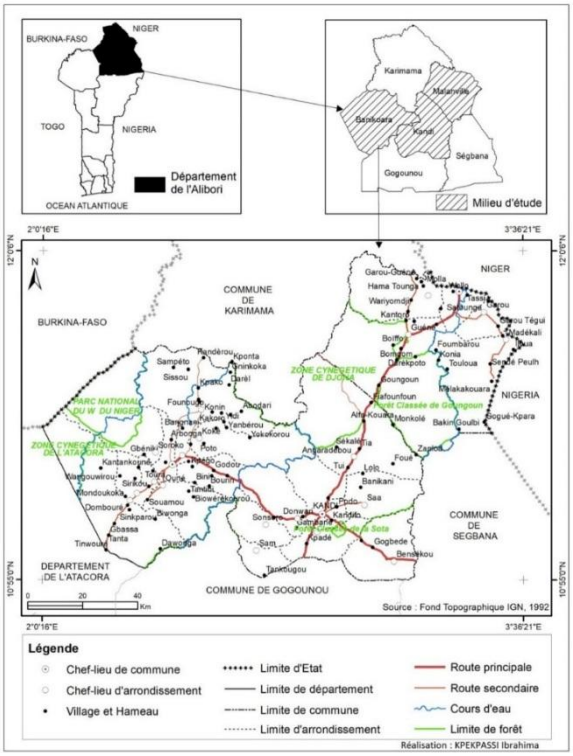


Figure 1:Geographic situation of the field of study

II. METHODOLOGY

In the framework of the present study, socio-demographic data from 2002 and 2013 census results in the townships of Malanville, Kandi and Banikoara, available in the archives of the National Institute of Statistics and Economic Analysis (INSAE), and agricultural data from the files of MAEP and the Alibori Regional Office of Agriculture, essentially made up with agricultural statistics (land area, production, yieldand food balance) over the period of time 1995 – 2018,have been used.

The data collection tools and materials are the following: interview guide, observation grill, questionnaires, etc. Many data collection techniques have been used. Direct or semi-direct interview, participative diagnosis (focus group) and direct observation are the main techniques used. Individual interview with ATDA, DDAEP technicians, and farmers associations have helped apprehend the influence of the climate variability and climate change vegetable crops.

Data analysis has been done by using the data collection mobile app (KoBoToolBox). The use of that app helps process automatically the enquiry results, computerizing and word processing through Microsoft Word and Excel soft wares.

Excel spreadsheet has been used to move the daily data into monthly data, so as to turn the tables into graphs.

- ***Analysisof data***

The enquiry about the field of study local population's perception on climate variability and climate change, and analysis of the meteorological data, have allowed determining the main climatic and agro-climatic risks of the market-gardening cultures that are :

Risk1: fall of the cumulated rainfall;
Risk2:flood
Risk3:observed increase of temperature.
The used methodology to analyze each risk is clearly described below:
Risk 1: fall of the cumulated rainfall
For the analysis of that risk, first, the inter-annual evolution of rainfall has been studied; then the **Test de Petit** has been used to determine the breaks in the chronological series, and compare the averages before and after the breaking dates, through the **Average comparisonTest or Test of Student.** Still about the analysis of that risk, the **Lamb RainfallIndex** that has helped to appreciate the inter-annual variability and the periods of rain, has been calculated.
The Lamb rainfall indexis defined as followed:

$$I = \frac{X_i - \overline{X}}{S}$$

With I = rainfall index, Xi = year i rainfall, X = inter-annual rainfall over the period of reference, and S = standard deviation of the inter-annual rainfall over the period of reference.
Risk2 : flood
To analyze that risk, ***R99***has been calculated**,** representing highly rainydays. This corresponds to the 99th percentile, the nits inter-annual evolution has been studied.
Risk3:observed increase of temperature
This climate risk has been studied with the evolution of daily minimal and maximal inter temperature observation, and with the Lamb index, which has allowed to appreciate their inter-annual variability.

- **Method of analysisof the impacts of climate variability on the market-gardening**

The methodology has consisted in collecting data through the results of enquiry from farmers and other local representatives.

- ✓ The impacts of climate variability and climate change over the systems of studied cultures;
- ✓ Those farmers' means of subsistence;
- ✓ And the adaptation strategies et les strategies set up to face the climate variability and climate change.

The occurrence probability of the identified risks
The occurrence probabilityof climate risksare made available by the 4th GIEC report, work group I (2007). Then, for the main identified risks, the following probabilities have been assigned to them:
Risk 1 : The rise of observedtemperatures: extremely probable (probability >95%).
Risk2: floods:very probable (probability >90%);
Risk3: decrease of the cumulated rainfall: probable (probability>66%);
For each occurrence probabilitya characteristic color is associated, as shown through table 1 below:

TableI: The occurrence probabilityand associated colors

	>95%	Extremely probable
	>90%	Very probable
	>66%	Probable

Source :*Field enquiry 2020*

The climate factors are then put in the order following importance of their occurrence probability in the table's left column, and are colored based on the colors that are assigned to the occurrence probability.

- **Method of identification of theimpacted elements**

The climate risks being identified beforehand through the perception and analysis of observed data, the next step has consisted in determining how each risk will impact each variable or element the culture systems. These variables were defined before in the questionnaire, as being the main elements of the systems that can be impacted by climate variability and climate change. These elements have been considered following the enquiry results. A matrix is then formed with the identified risks and the impacted variables, with the risks in the first left column, and the variables on the first line. The matrix is presented as follow (table II):

TableII: Matrix of the impacts

Matrixof impacts	**Impacted variables**							
	Farmed land area	**seeds**	**seedling**	**Cultures cycles**	**Growth of the cultures**	**Phytosanitary problemses**	**The yields of cultures**	**Water availability**
Risi Rise of temperatures								

	Floods								
	Fall of rainfall cumulations								
	Draughts								
	Delayed beginning of farm activities								

Source : Data from *field investigation, 2020*

The next step has consisted in listing the impacts. Those impacts were listed basing on the collected results from the enquiry with the local populations.

- **Methodof evaluation ofphytosanitaryimpacts**

The impacts are evaluated basing on the climate risk occurrence probability, and the consequences. The consequences are determined through expertise judgements and enquiry. They vary from minor (1), to moderate (2), to major (3) andto severe (4). The value of the risk is obtained by matching the consequences of the risks with the occurrence probability of the climate risk. It varies from weak to extreme, as illustrated in table III below.

TableIII: Potential Values of impacts and associated colors

Occurrence probability	**Consequences**			
	Minor	***Moderate***	***Major***	***Severe***
unlikely	Weak	Weak	Weak	Weak
Probable	Weak	Moderate	Moderate	High
Very probable	Weak	Moderate	High	High
Highly probable	Weak	Moderate	High	Extreme

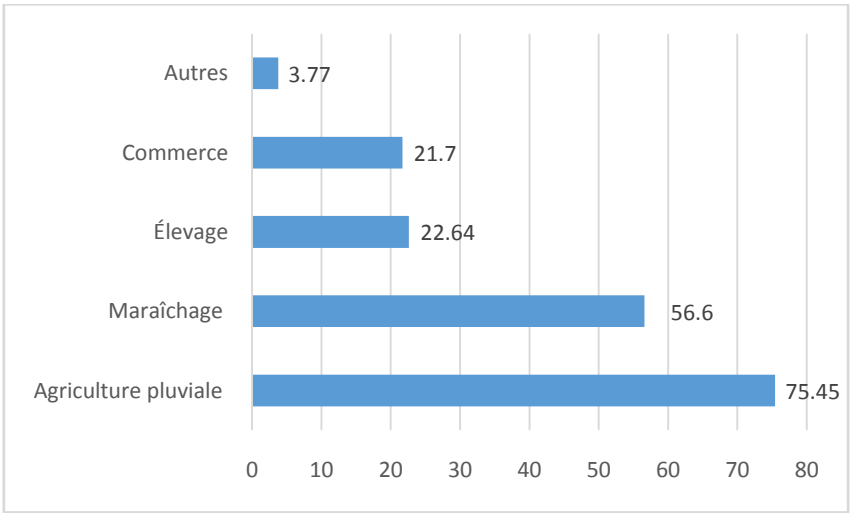
Source :Data from*field investigation, 2020*

III. RESULTS

2-1- Impacts climate variabilityover market-gardening cultures

✓ ***The main activities of market gardeners 20-30 years ago***

Figure 2presents statisticsabout market-gardeners' activities 20-30 years ago.



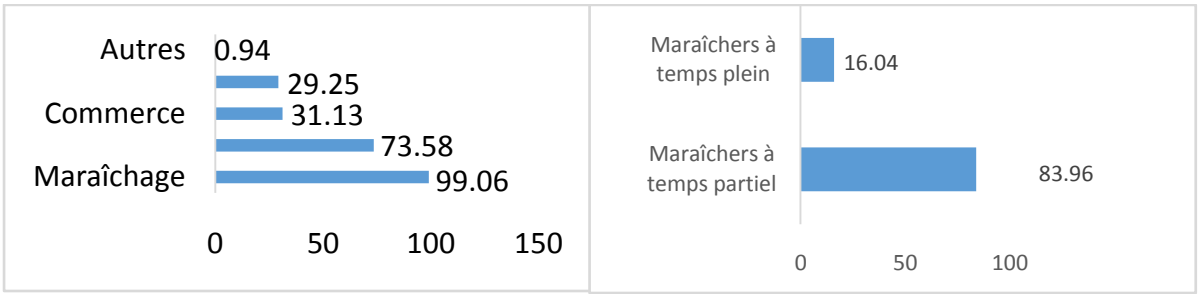
Source :*Data from field investigation, 2020*

Figure 2 : Market-gardeners' activities 20-30 years ago

Analysis of figure 2 revealsthat the majority of market-gardeners (75.45 %) were concerned with rain-fed agriculture; only 56.6 % of the investigated farmers practiced market-gardening 20-30 years ago.

✓ **Main activities of market-gardeners today.**

Figure 3 presentsmarket-gardeners' activities today, in the area of study.



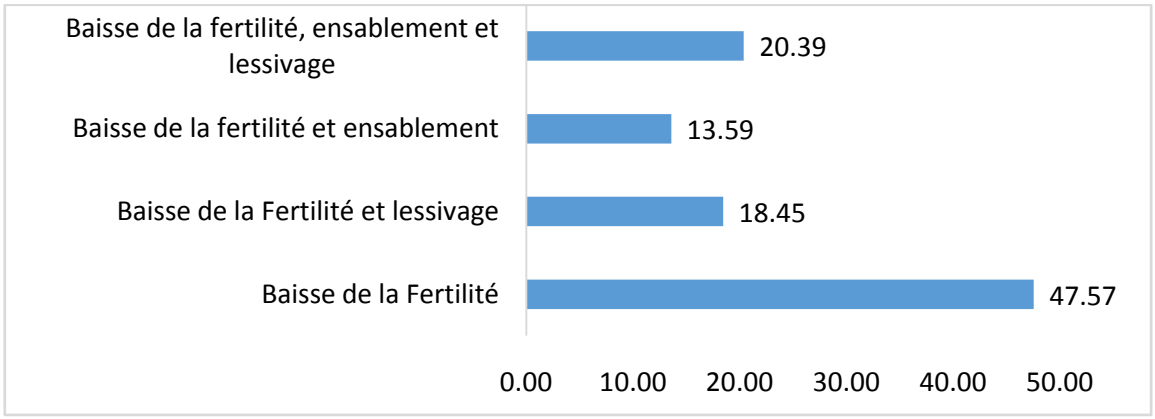
Source :*Data from field investigation, 2020*

Figure 3: Main activities of market-gardeners today

Analysis of figure 3 shows that today, 73.58 % of market-gardeners are concerned with water-fed agriculture, in addition to market-gardening. Only 16 % of the interviewed market-gardeners really practice pure market-gardening. Those concerned with other activities refer to market-gardening just food security, and for financial income. In addition to those reasons,there is the fact that market-gardening activities are limited in the rainy season.The most grown market-gardening produces are gumbo, cabbage, lettuce, onion, tomato, carrots and pepper.

✓ ***Impacts of climate variability on the soil, according to market-gardeners.***

Figure 4 presents statistics based on market-gardeners' point of view about the impacts of climate change on the soil in the field of study



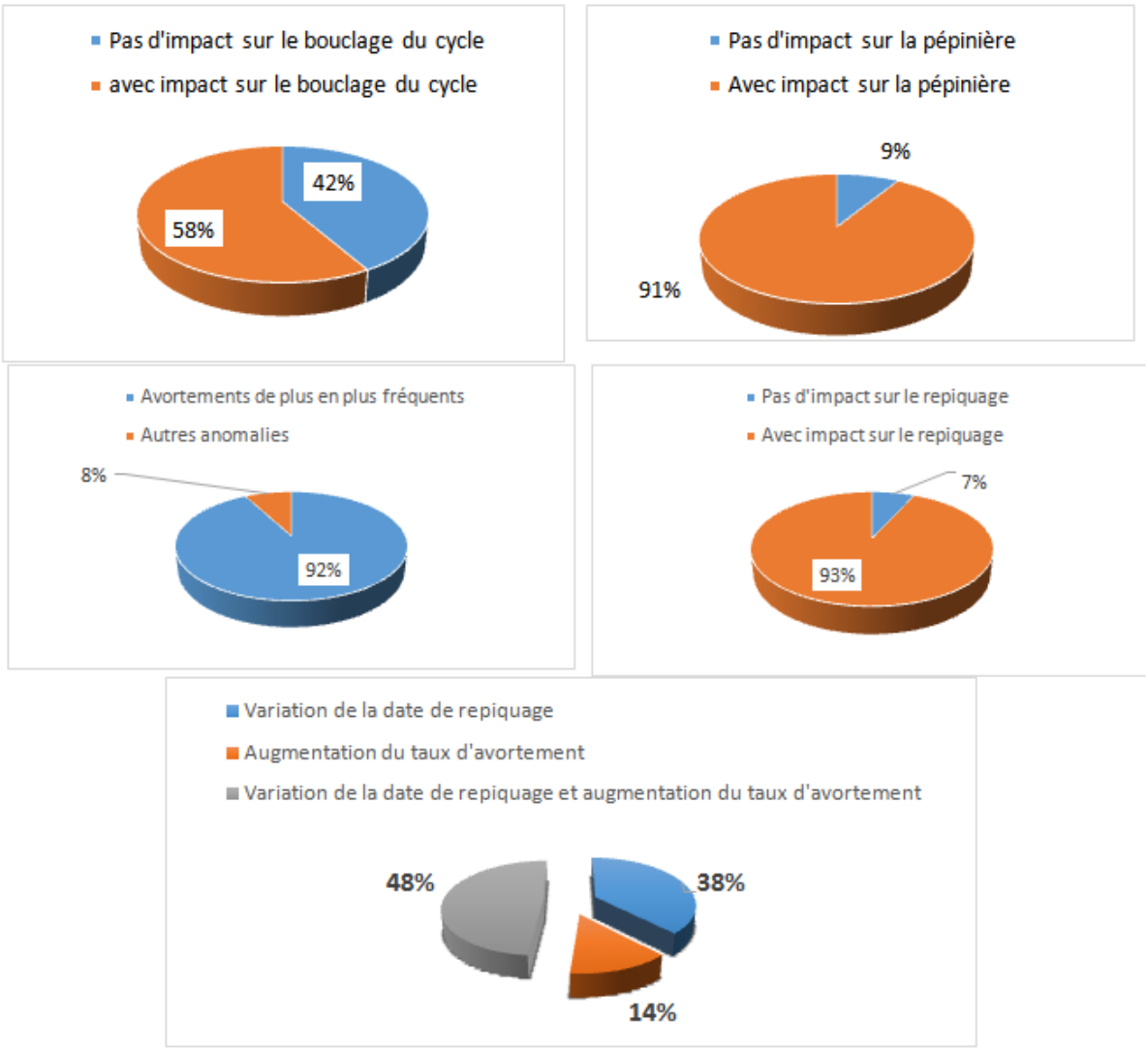
Source :*Data from field investigation, 2020*

Figure 4 : Impact of climate change on the soils according to the market-gardeners in the field of study

From analysis of figure 4, it appears that market-gardeners approve of the idea that climate variability has impacted the soils. As such, about 48% of those market-gardeners have asserted that soil fertility has decreased. 18% of them think that there is decrease of soil fertility together with sol leaching, while about 14% think that there is decrease of fertility with sol silting as well. The remaining 20% of the market-gardeners affirm the three consequences simultaneously, that is: decrease of soil fertility, land leaching, and soil silting.

Impact of climate variabilityon the cycle looping, on the nursery, and on the transplanting of market-gardening cultures

Figure 5 presents the point of view of market-gardeners about the impacts of climate variability on the cycle looping, the nursery, the transplantation of cultures and the modification of transplantation dates. Market-gardeners in the one hand, and water-fed farmers, in the other hand, have very different point of view about the effects of climate change over their activities.

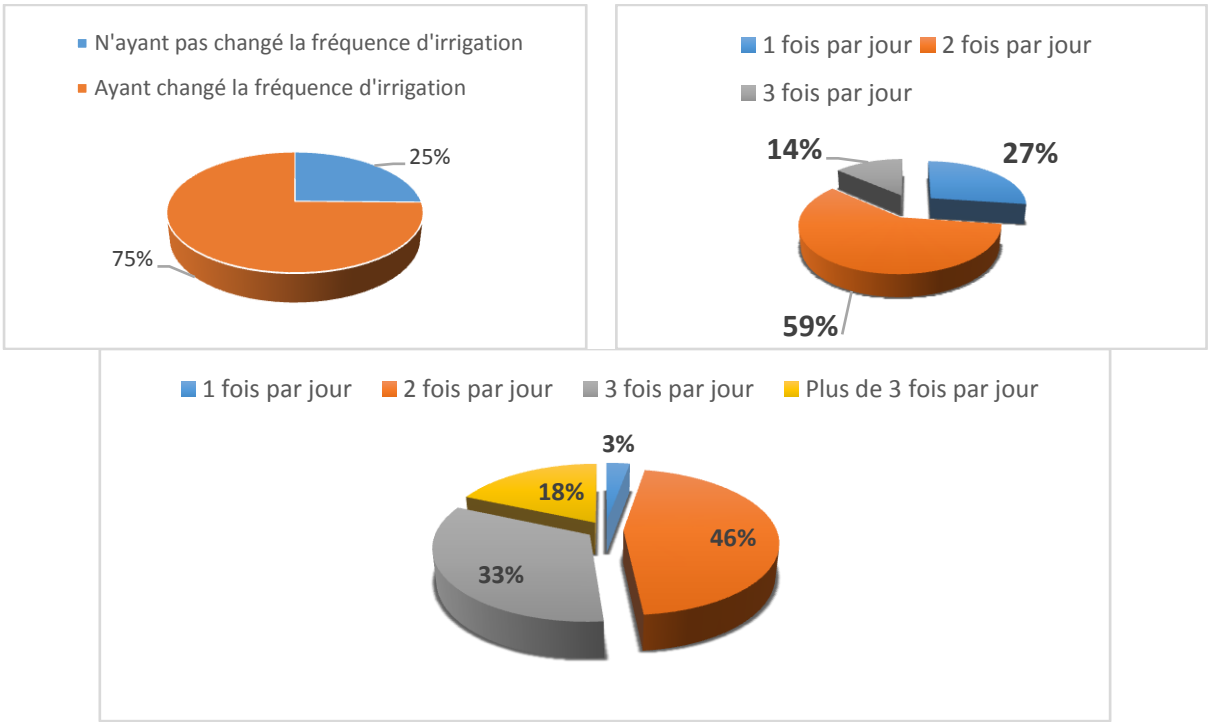


Source :*data from field investigation, 2020*

Figure 5: Impacts of climate variabilityon the market-gardening cultures

From analysis of graphs in figure 5, it appears that climate variability has had consequences on the looping of the market-gardening cultures' cycles, the nursery of those cultures, and their transplantation. In effect, more than En 58 % of market-gardeners think that climate variability has an impact on the cultures' cycle looping; 91 % of those market-gardeners affirm that climate variability impacts the cultures at their nursery stage. Also, 92 % of the market-gardeners have said that climate variability because more and more frequent abortion of the cultures, and about93 % of them think that it has an impact on the transplantation of the cultures. Moreover, market-gardeners think that climate variabilityhas a negative impact on the transplantation of the cultures. Then, about 14 % of market-gardeners affirm that climate variability has caused the increase of the abortion rate of cultures; about 38 % ofthem have rather focused on variation of transplantation dates. As for the remaining 48 %, the two last impacts come simultaneously.

Figure 6gives the statistical viewpoint of market-gardeners about the impacts of irrigation that have forced them to changing or not changing their irrigation practices.



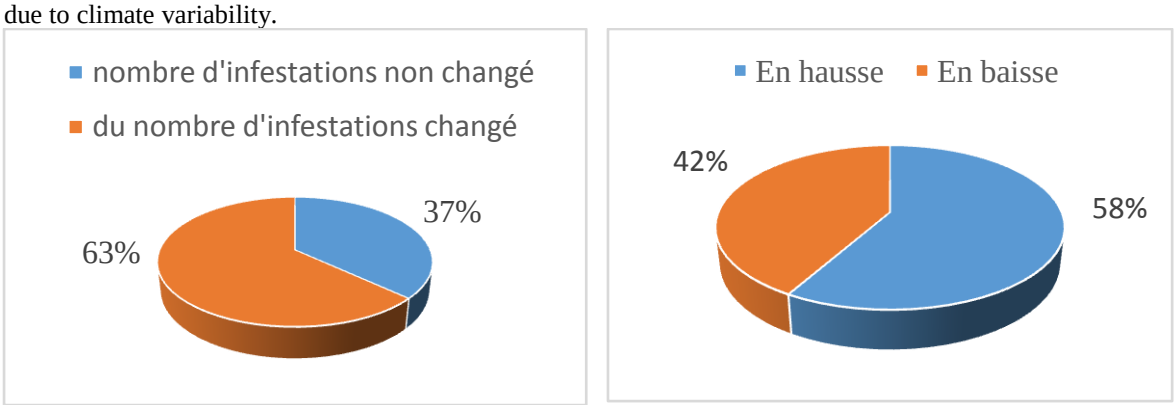
Source :*Data from field investigation, 2020*

Figure 6 : Distribution of market-gardeners basing on their point of view about the impact of climate change on irrigation of cultures.

From analysis of graphs in figure 6, almost three-quarter (¾) of the interviewed market-gardeners have changed their frequency of irrigation contrarily to the other quarter (1/4) who have not. In the past, the majority of them (59 %) would irrigate their cultures twice a day; a little more than a quarter of the market gardeners would do this three times a day. At last, 14 % of the have continued to irrigate their cultures once a day. On the opposite, nowadays, and during this field investigation, only 3 % of the market-gardeners have continued to irrigate their cultures daily. 33 % of them do it three times a day. And at last, the remaining 18 % irrigate their cultures more than three times a day.

Infestations ot the market-gardening cultures

Figure 7 indicates the statistics on market-gardeners' point of view about change of the number of infestations due to climate variability.



Source : *Data from field investigation, 2020*

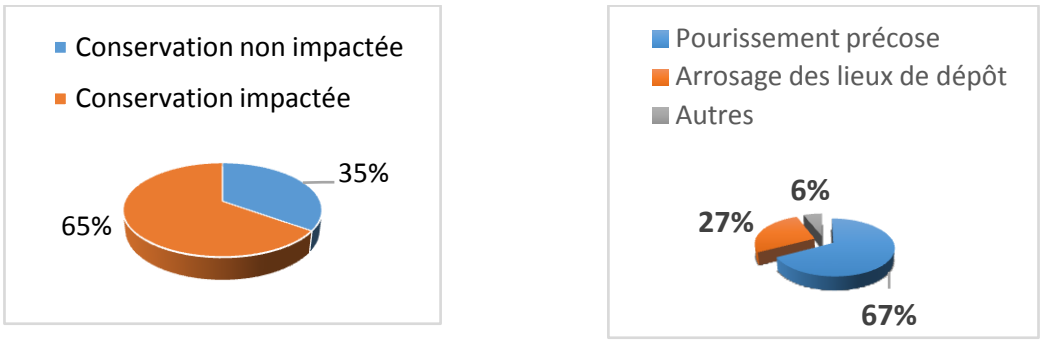
Figure 7:Distribution of market-gardeners, basing on their viewpoint about the impact of climate variability on the number of infestations of the market-gardening cultures.

Analysis of figure7shows that the majority of the investigated market-gardeners think that the number of culture infestation has changed due the climate variability. While about 63 % of them affirm noticing a change in the number of culture infestation, only 37 % have noticed no change. As such, those market-

gardeners, in their large majority, think that this change in the number of infestations is on the rise. While about 58 % of them say that there is a rise in the number of infestation, the other 42 % think the opposite.

Impacts on the market-gardening products conservation

Figure 8indicates the statistics on the point of view of the market-gardeners about the impacts of climate variability on market-gardening products conservation.



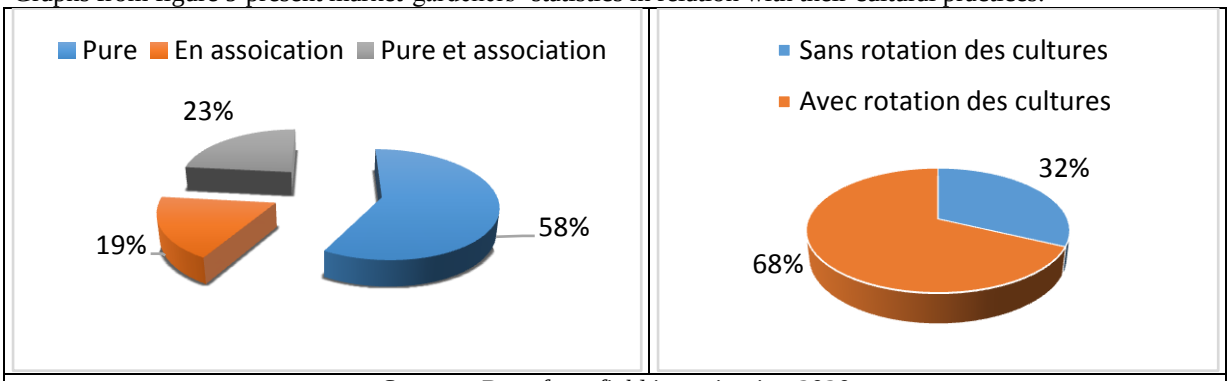
Source : *Data from field investigation, 2020*

Figure 8: Distribution of market-gardeners basing on their opinion about conservation of cultures due to climate variability.

Analysis of the graphs from figure 8shows that the point of view of the majority of the market-gardeners is that climate variability has an impact on the conservation of products: 65 % of them have responded positively, while 35 % have had the opposite viewpoint. The majority of the market-gardeners have evoked a precocious deterioration of the produces. As such, 67 % of them affirm that climate variability provokes a precocious rotting of the produces. 27 % of them, however, think that a regular watering of the storage premise will guarantee sustainable conservation; the remaining 6 % think that there are other impacts on the conservation of the produces.

✓ ***Market-gardeners' cultural practices***

Graphs from figure 9 present market-gardeners' statistics in relation with their cultural practices.



Source : *Data from field investigation 2020*

Figure 9: Distribution of the market-gardeners basing on their cultural practices

Analysis of graphs from la figure 9 reveals that more than half of the market-gardeners are practicing a full cultural mode. As such, 58 % of them are practicing a totally cultural mode, and 23 % and 19 % respectively practice a mode of cultures association, and the two modes simultaneously. The majority of the investigated market-gardeners are practicing rotation of cultures, while a minority of them does not refer to that cultural technique. In effect, the 68 % of investigated market-gardeners have practiced cultures rotation, and only 32 % of them do not do that.

✓ ***Analysis of the impacts climate variability and climate change over the market-gardening systems, through the climate matrix risks method***

✓ ***List of impacts of climate risks des on the market-gardening cultures systems***

TableIVpresentsthe listof the impacts of identified climate risks on the elements of the market-gardening cultures systems.

TableIV: list of the impacts of identified climate risks on the elements of the market-gardening cultures systems

Matrixof impacts		Impacted Variables						
		Phytosani-tary problems	**Seedlings or transplantation**	**Yield of cultures**	**Water availability**	**SSeeds**	**Farmed land area**	**Cultures' cycle**
Identified climate risks	**Rise of temperatures**	Rise of phytosanitay troubles	Rise of abortion rate : nursery and transplantation	Decrease of yield, drying up of cultures	Decrease of water availability	None	None	Increase of the cultures' cycle
	Flooding	None	None	Loss of the production	Water excess	None	Loss of farmed land area	None
	Decrease of rainfall accumulation	None	None	Decrease of yield, drying up of cultures	Decrease of water availability	None	Under exploitation of the farm lands	None

Source : *Data from field investigation, 2020*

✓ **Consequence level of the listed impacts**

The level of consequences of the listed impacts are furnished through table V below

TableIV : Consequence level of the listed impacts

Matrix of impacts	**Impacted variables**						
	Phytosanitairy problems	Seedling or transplantation	Yield of cultures	Water availability	Seeds	Farmed land area	Cultures cycle

Identified climate Risks								
Hausse des températures	Increase of phytosanitairy, problems (2)	Increase of abortion rate: nursery and transplantation(2)	Decrease of yields, drying upof cultures(3)	Decrease in water availability(3)	None	None	Increase of cultures cycle (2)
Flooding	None	None	Loss of production (4)	Water excess(3)	None	Loss of farmed land area (4)	None
Decrease of the rainfall cumulation	None None	None	Decrease of yieldsDrying up of cultures (3)	Decrease of water availability(3)	None	Under exploitation of thelands (2)	None

Source : *Data frrom field investigation, 2020*

None: Absence of impacts; 2= Moderate, 3=Major, 4=Severe.

IV. IDISCUSSION

Market-gardeners think that climate variability and climate change have had impacts on the soil. They evoke for impacts of climate variability: the decrease of soil fertility, erosion, land silting up and leaching. These phenomena have contributed to land degradation. More than half of the market-gardeners (58 %) think that climate variability has an impact on the cultures' cycle looping. The quasi-total market-gardeners have noticed an impact on the nursery. These results are similar to those obtained Mr. Nouhou Koutcha (2012 p. 46) through his study, where he concludes that climate variability and climate change also have impacts over rainfed cultures, since the decrease of the yield has been revealed by 100 % of the investigated farmers in Damana, 95 % in Farié Haoussa and 80 % in N'Dounga. To all these, one has to add modification of sowing and transplantation dates.. This result goes along with the one obtained by A. Abdou Bagnan, (2016, pp. 10-11) which concludes on disturbance in the agricultural planning, coupled with the non-access of farmers to weather forecast information, which in some years, forces market-gardeners to practices multiple sowing before effective beginning of the farming season. Agricultural planning has become more and more complex in such a context of observed variability in the rainfall regime. .

V. CONCLUSION

The present study has allowed identifying the impacts of climate variability over market-gardeners in the townships of Malanville, Kandi and Banikoara. This impacts are concerned with soil degradation, decrease of yields, change in farmer agricultural planning, loss of farm lands, and persistence of various threats onto the cultures.

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