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Vulnerability of Environmental Components to Climate Change and Farming Strategies in the Adja-Ouere-Pobe Doublet in the South-Eastern Benin

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Abstract*— *This research studies the vulnerability of environmental components to climate change and the peasant strategies adopted in the doublet.Adja-Ouèrè-Pobè in the Plateau department in Benin.

The climatological data consist of rainfall amounts and temperatures over the period 1981-2017. The determination of the evolution of the climate was made usingclimate diagnostic analysis tools (moving average, indices, etc.) and descriptive statistics (average, standard deviation, etc.). The environmental impacts were evaluated through the Leopold matrix crossed with the reference framework of the ABE and the degree of vulnerability is measured from the resistance capacity of the environmental components in the face of the impacts.

The results obtained showa warming trend of around 0.9°C over the period 1981-2017 and a decrease in annual rainfall totals. These cumulative situations would disrupt agricultural activities. This weakens the main components of the environment between 1981 and 2006 with an average rate of regression of –12.42%. By 2050, if demographic and climatic trends continue, the environment of the study area will be increasingly degraded.

I. INTRODUCTION

Africa's vulnerability to climate change has been analyzed and projected in key sectors of this continent that ensure the protection of human life, livelihoods and ecosystems. Thus, according to forecasts, the population likely to be exposed to an increased risk of water stress will be 75 to 250 million people by 2020 and 350 to 600 million by 2050. In some countries, the Yield reductions could reach 50% by 2020 (World Bank, 2013, p.10). Although they have already demonstrated a great capacity to adapt to their environment, the rapidity with which climate change is manifesting requires an analysis of the current challenges in terms of vulnerability and adaptation (V. Larivière, 2011, p.xv).

In West Africa, climate change has manifested itself in a poor spatio-temporal distribution of rainfall, floods, increasingly frequent pockets of drought, violent winds and an increase in temperature (C. Roncoli, K Ingram & P. Kirshen., 2002, p.5 andYT Brou, F. Akindès and S. Bigot.,2005, p.1).

Climate change is one of the major challenges of this time. This is one of the threats to agricultural development today. The poorest peasant communities are undoubtedly those who will suffer the most violent impacts and will suffer disproportionately from its negative effects (B. Doukpolo, p.8). Although several disciplines agree to accept a common definition of vulnerability as "liable to harm", the use of the term changes according to disciplines and research sectors. Climate science views vulnerability in terms of the likelihood of occurrence of climate-related events and impacts (Nicholls et al., 1999).

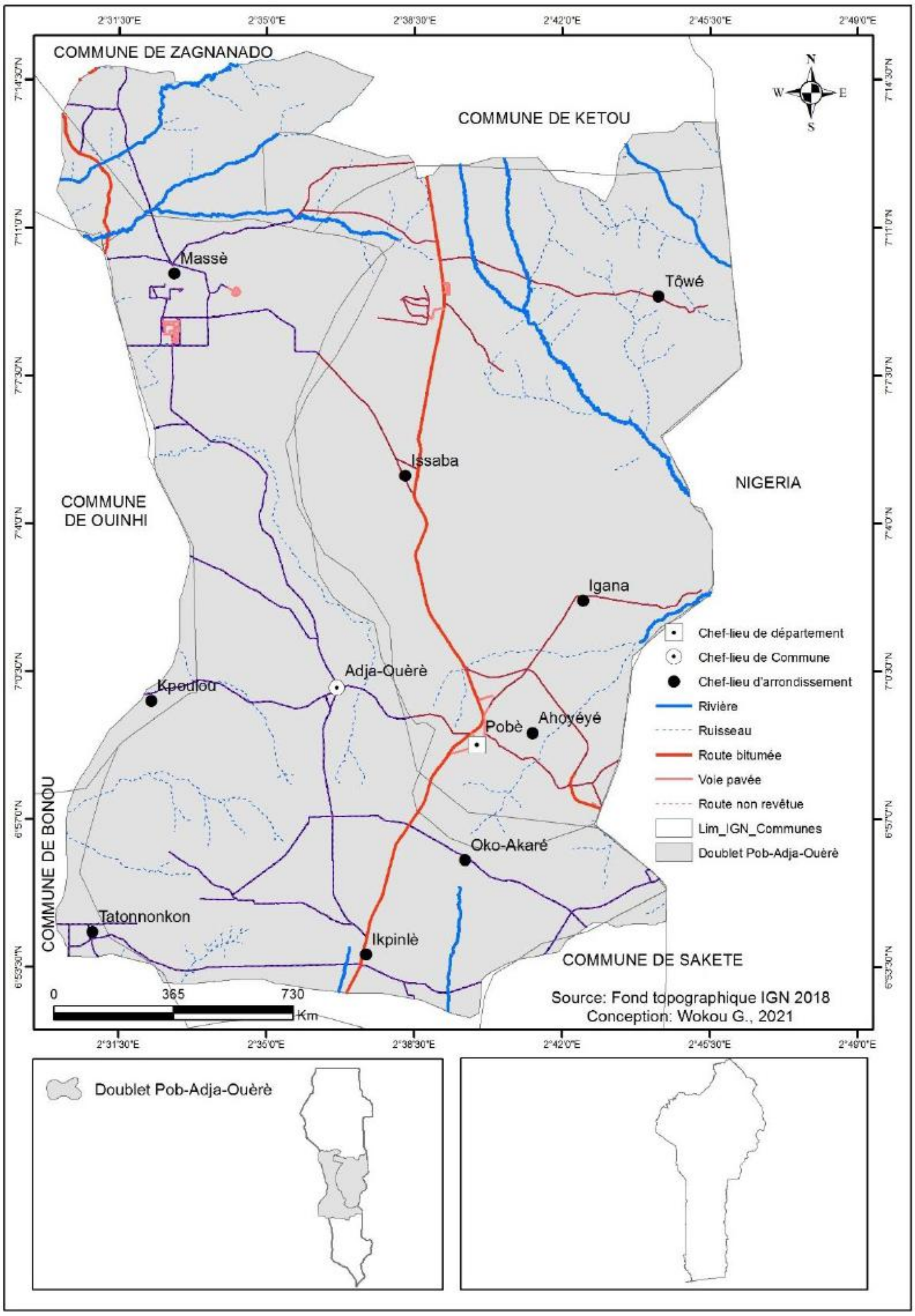

Fig.1:Geographical location of the Adja-Ouèrè-Pobè doublet

The living environment as it is designed for the majority of the populations of the Globe, and the system of production of consumer goods are strongly influenced by the ambient climate (Klein et al., 2007). These upheavals jeopardize the development of agriculture, which remains rainfed and therefore makes agricultural producers vulnerable in terms of food security (R. Dimon, 2008, p.7).

In Benin, the demographic pressure associated with the evolution of the climate loaded with risks for agriculture, weakens the capacity of the environment to meet the food needs of the rural populations. In response to this situation, farmers had to modify certain agricultural practices (GC Wokou, 2014, p.8).

In fact, the rearrangement of the agricultural calendar, the adoption of a new variety of crop, the practice of hoe-hilling, the increase in area sown, staggered and repeated sowing, the use of chemical fertilizers and phytosanitary products and the system agroforestry are all strategies developed to increase agricultural production and which directly or indirectly contribute to the deterioration of the environment in the study area (FS Djogbenou, 2008 p.7). Thus, adaptation is like one of the options that would allow the human community to reduce the effects of pronounced climate change. The Adja-Ouèrè-Pobè doublet is located between 6°52'14" and 7°15'11" north latitude and 2°35'54" and 2°46'16" east longitude, it is located in the southwest of the Republic of Benin in West Africa (figure 1). It covers an area of 914.84 km². It is bounded to the north by the commune of Kétou, to the northwest by the commune of Zagnanado, to the west by the commune of Ouinhi, to the south by the commune of Sakété and to the east by the Federal Republic of Nigeria.

II. MATERIALS AND METHODS

2.1 Mode of characterization of the climatic physiognomy in the study area

The determination of current temperature and rainfall trends (1981 to 2017) was made using the time series method. The equation of the trend line is of the form y = at + b where y represents the explained variable and t the time; a and b being constants, such that:

$$a = \frac{(\Sigma y)(\Sigma t2) - (\Sigma t)(\Sigma ty}{N\sum t^2 - (\sum t)^2} \qquad a = \frac{(N)(\Sigma yt) - (\Sigma t)(\Sigma}{N\sum t^2 - (\sum t)^2} \quad (1)$$

The Cotonou station was chosen to analyze the observed data and identify the related trends on the thermometric level. A wet year or a dry year is defined in relation to the Lamb index (1983) (the deviation from the mean normalized by the standard deviation) which is expressed by: $I(i) = \frac{\mathrm{Pi-Pmoy}^2}{\sigma(i)}$ (2)

Where $P_I$represents the average annual total obtained by krigingfor year i, Pmean and $\sigma(i)$ represent, respectively, the mean and the standard deviation of the series considered. The standard deviation, notedσ(i), is the square root of the variance and is expressed by the formula:

(3)

$$\sigma(i) = \sqrt{V}$$

Where V, the variance, is expressed by: $V = \frac{1}{n}\sum_{i=1}^{n}(Pi - Pmoy)^2$(4)

Thus, if -0.1 < index < + 0.1 then normal year; if index > 0.1 then wet year; if index < -0.1 then dry year.The climate balance is expressed by the following formula:$Bc = P - ETP$(9) withBc = climatic balance in mm; P = total annual rainfall in mm; ETP = actual evapotranspiration in mm. ETP is defined as the climatic demand for water vapour. If P - ETP > 0, then the balance sheet is in surplus; If P - ETP < 0, then the balance sheet is in deficit; If P - ETP = 0, then the balance sheet is balanced. The calculation of the probabilities of exceeding the rainfall thresholds and the sequential curves made it possible to analyze the monthly distribution of rainfall. Thus, when the start of the rainy season is fixed as being: the pentad of the year from which the rainfall threshold of 10 mm is reached or exceeded one year out of two (1), and this regularly (2) .

2.2 Estimation of climate change by 2050

Based on national development policies, and considering the results and recommendations of the Long-Term National Prospective Studies (Benin 2025) and the work of Ogouwalé (2006), Yabi (2008) and Issa (2012), the Analogue Scenario Dry (SAS) was chosen. With regard to the statistical protocol, the evolution of the temperatures is considered to follow an exponential type law with the mathematical formula: Yδt= Yref. e-α.δt (6)

Where: Yδt, represents rainfall and temperature at a projection horizon (δt); Yref, the weighted moving average of the variable centered on the reference year; α, the regression coefficient determined from the equation on the raph; δt, the time in years separating the reference year and ıe projection year The adjustment coefficient thus makes it possible to correct and adjust the projected values in accordance with the changes already known. Its mathematical expression is as follows: φ = (Yrefe-αδt)/Yδ't (7) From (6) and (7) we obtain: φ = Yδt/Yδ't with,

$Y_{\delta t}$, the temperature at a defined projection horizon (δt);$Y_{\dot{\delta t}}$, the temperature at the same projection horizon (δt) for which readings have already been taken; and where 0 <φ ≤ 1. The closer the value is to 1, the stronger the correlation between the simulated trends and the values already observed. The multiplier coefficient which gives the margin of error of the forecast is therefore applied to all the other projection years. The corrected simulations made it possible to simulate the value of each parameter up to 2050.

2.3 Vulnerability assessment

The evaluation of the vulnerability of the populations requires the use of several techniques and tools, in particular the crossing and the analysis of causal links between different localities using statistical methods, as well as the combination and the superimposition of the different sources. Information via Geographic Information Systems (GIS). Most vulnerability analysis studies use statistical techniques such as regression, correlation, principal component analysis, with the aim of reducing the dimensionality of a large number of variables into a grouping of dependent variables, and multi-criteria analysis tools. The objective of this research is to identify the most vulnerable sectors and populations according to a combination of specific factors. These methods lead to the development of synthetic indicators, and the establishment of a risk index by aggregating all the indicators considered. Other approaches combine the CART1 algorithm (Classification And Regression Tree; Breiman et al., 1984), principal component analysis and the "Fuzzy Set" procedure (Eastman and Jiang, 1996). The CART algorithm was used to measure and analyze the various indicators of food security in Ethiopia (Seyoum, 1995), in particular to assess the average number of people requiring food aid. The data then analyzed includes the Normalized Vegetation Index (NDVI),

In other words, the vulnerability of populations is linked on the one hand to the exposure of the territory and to the sensitivity of economic activities to natural hazards. This is the case, for example, of the Sahelian zone where the seasonality of the rains makes it very vulnerable to variations in the quantity of precipitation and its distribution within the wet season, significantly affecting agro-pastoral activities (cyclical vulnerability and structural). The system's level of conjunctural vulnerability also depends on the individual and institutional capacity to cope with the impacts of climate variability, while structural vulnerability mainly affects the poorest groups of individuals in society.

III. RESULTS

3.1 Evolution of the climate in the study area from 1981 to 2017

Figure 2 presents the evolution of the minimum and maximum temperature in the department of the plateau.

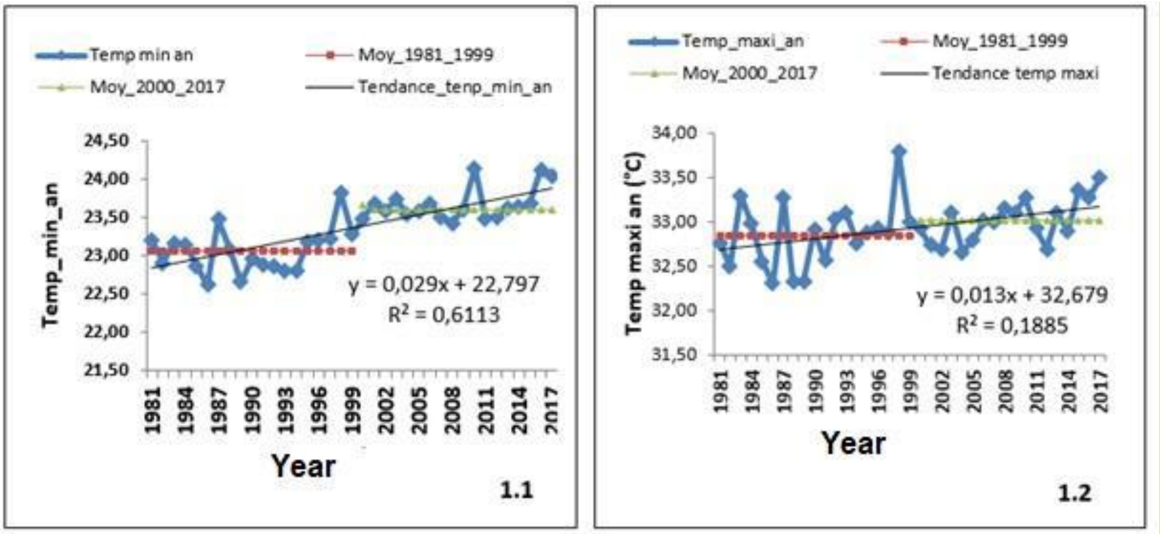

Fig.2 : Evolution of the minimum (1.1) and maximum (1.2) temperature over the period 1981-2017 (Cotonou station)

Source :ASECNA data, April 2012

Analysis of the figure reveals a general upward trend in temperatures (minimum and maximum) over the period (1981-2010). In addition, the minimum temperatures increase more quickly than the maximum ones. The years 1986 and 2010 recorded the extreme values of minimum temperatures. These values are 22.61°C and 24.15°C respectively. The highest value of maximum temperatures was recorded in 1998 and the lowest value in 2002. These values are 33.78°C and 30, 18°C. This temperature rise confirms the work of IPCC (2007) which showed that warming has accelerated by 0.8°C in one century, and by 0.6°C over the last thirty years. According to WMO and UNEP (2002),the yield of rain-fed agriculture could fall by 50% by 2020 due to the deterioration of climatic parameters. As a result, agricultural production and access to food will be severely affected in many countries, with serious consequences in terms of food security.The rain parameter cannot remain immune to this phenomenon.

3.2 Rainfall variability

Rainfall experienced significant spatio-temporal variability in theAdja-Ouèrè-Pobè doublet (figure 3)

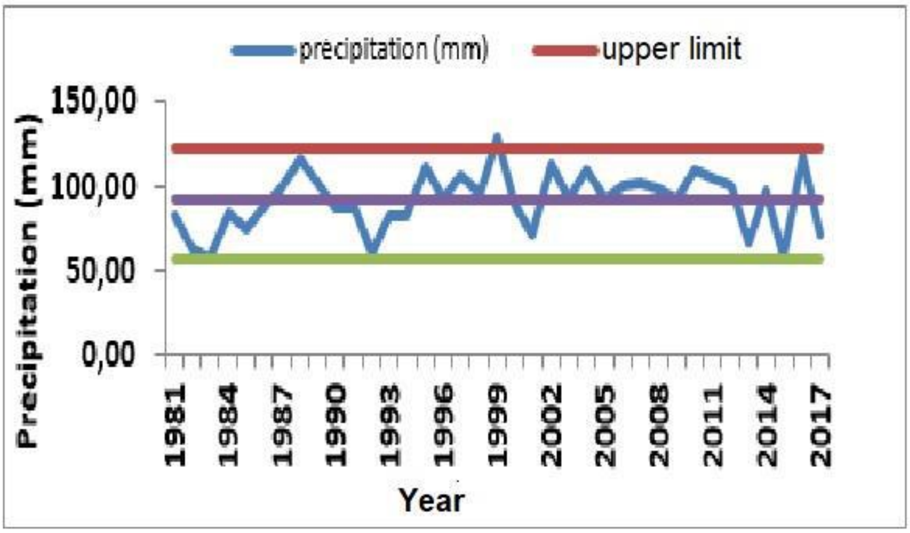

Fig.3 : Interannual variation in rainfall in the plateau department over the period 1981-2017 (Cotonou station)
Source: ASECNA data, April 2020

Figure 3 presents three periods distinguishing average, surplus and deficit years over the observation period (1981-2017). A year is said to be in deficit when the arithmetic sum of the annual precipitation is lower than834.16mm(mean of the series minus the coefficient of variation), excess when it is greater than1170.22mm(average of the series plus the coefficient of variation) and average when it varies between 834.16 mm and 1170.22 mm. In total, the observation period recorded nineteen (19) average years, seven (7) surplus years and four (4) deficit years which alternate asymmetrically. This alternation between average, surplus and deficit years justifies the interannual variability of rainfall over the study period. It also makes agricultural activities in the plateau department uncertain. The rainfall indices of the various stations in the study area made it possible to assess the rainfall evolution.

3.3 Evolution of rainfall indices in the study area

The reduced centered indices have experienced a significant evolution in the Plateau department over the period (1981-2017) (Figure 4).

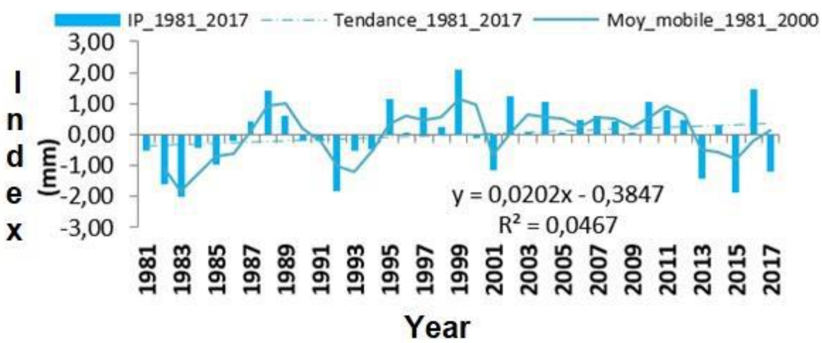

Fig.4: Evolution of the rainfall index over the period 1981-2017 (Cotonou station)

Source : ASECNA data April 2020

Analysis of the figure shows that the linear regression lines show upward trends. These reflect a period which as a whole is marked by the abundance of the quantities of rain that fell.

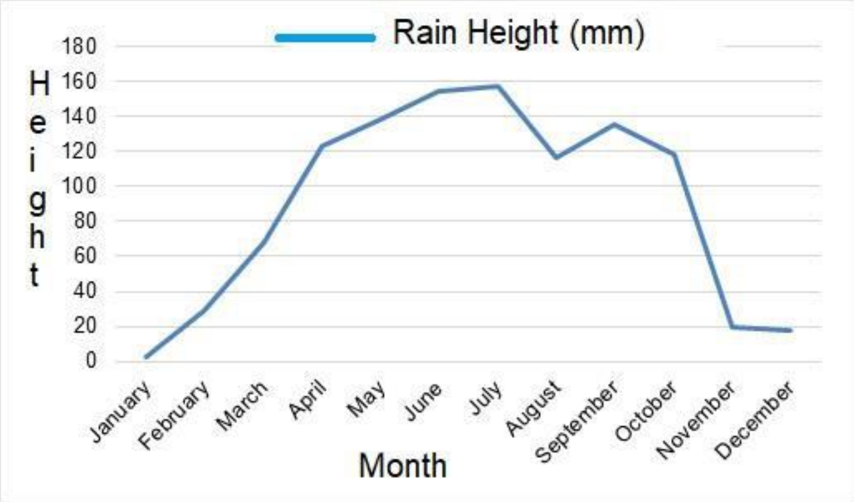

Fig.5 : Rainfall regime (period 1981-2017 : Cotonou station)

The analysis in Figure 5 shows an uneven intermonth distribution over the four years. Indeed, the years 1985, 1994 and 2002 recorded two rainy seasons interspersed with a dry season which covers the month of August. On the contrary, the year 2007 presents a unimodal pluviometric regime, characteristic of the Sudanese climate whereas we are in a subequatorial region. Furthermore, the inter-monthly distribution of rainfall does not follow a regular rhythm from year to year, although these are average years when the risks are supposed to be lower. In this context, we note a break in the rain in June 1985 and in May 2002, a dwindling of the rains from April to June 1994 followed by excessive rains in October.

3.4 Climate change by 2050

The rainfall situation at the annual scale in 2050 is indicated in thetable III

Table IIII: Rainfall projection for 2050

Annual rainfall (mm)		
Average (1981-2017)	**Value in 2050**	**Change (%)**
1099	1010	- 8.10

Source of data:*ASECNA (2011) and projection results*

Legend : Favorable situation

The study area therefore records rainfall levels that will reach 1000 mm, the minimum rainfall threshold for good cereal yield. However, agricultural activities are more intense in all the localities of the Plateau department where the rainfall drop is significant. At the same time, the maximum and minimum temperatures will increase. The comparison of future maximum temperatures and those of the period 1981-2017 shows that the increase would exceed 2°C (Table IV).

Table IVII: Temperatures by 2050 in the Plateau department in southwestern Benin

Stations	Temp	Jan	Feb	Tue	Apr	May	Jul	Jul	August	Seven	Oct	Nov	Dec
Cotonou	max	37.5	38.9	38.5	37.3	35.5	33.4	31.7	31.6	32.7	34.2	36.2	36.4
	min	24.0	25.3	25.6	25.4	24.6	23.6	23.0	22.7	23.0	23.4	24.2	23.8

Source*: Projection results*

Legend : Temp = Temperature; max = maximum; min = minimum

	Favorable situation

The possibility of climate change would aggravate the vulnerability of environmental components. The rise in temperature would cause an increase in potential evapotranspiration (ETP), a factor on which crop water requirements are highly dependent. This will negatively influence yields and therefore lead to a change in certain agricultural practices. All in all, the climatic uncertainties expected by 2050 will be manifested by a downward trend in rainfall totals; a contraction of the wet season and an increase in temperatures (maximum and minimum).

3.5 Vulnerability of environmental components to climate change

The vulnerability of a natural or human system is the fact of being sensitive to injuries, attacks or experiencing difficulties in recovering a balance that has been jeopardized after a natural disaster (Moss, 1996). There is no universally accepted consensus on the definition of vulnerability. The notion of vulnerability is now commonly used to designate a state of fragility, a propensity to suffer damage or a low capacity to cope with disastrous events. It designates both individual and collective situations, both material and moral frailties, people as well as things or even territories. The term vulnerability, which has its origins in the literature of natural hazards, poverty, food insecurity and development, is widely applied to impact studies in the face of climate change (Downing, 2003; FAO, 2000). In this context, the term vulnerability has many meanings.

The results resulting from the application of the Leopold matrix crossed with the reference framework for the identification of environmental impacts of the EBA are presented in table V.

Table III: Identification/assessment of environmental impacts

Activity	**Components affected**	**impactsPhysical environment**	**Importance**
Shifting cultivation on slash and burn/Ecobuage	Floor	Cleared for seeding	Mean
		Destruction of nutrients	Mean
	Air	Air pollution by dust and fumes	Mean
Plowing by agricultural machinery/plow	Floor	Soil degradation by disturbance or compaction	Mean
		Destruction of nutrients	Weak
Use some products synthetic chemicals	Floor	Soil degradation (loss of organic matter) byheavy metal buildup	Weak
	Water	Degradation of water quality byheavy metal buildup	Strong
	Air	Air pollution by harmful gases and foul odors	Weak
Use of agricultural residues and animal droppings	Water	Degradation of water quality by filling and pollution	Weak
	Air	Air pollution by harmful gases and foul odors	Weak
Shifting cultivation on slash and burn/Ecobuage	Vegetation	Destruction of vegetation and disappearance of species (Parkia biglobosa, Annona senegalensis, Vitellaria paradoxa, etc.)	Strong
	Wildlife	Reduction of animals and birdssheltered by destroyed vegetation	Mean
		Disappearance or rarity of certain animal speciessheltered by destroyed vegetation	Weak
Use	Vegetation	Destruction of vegetationby accumulation of heavy metals	Strong

some products synthetic chemicals	aquatic fauna	Decrease in fish species due to the degradation of water quality and the phenomenon of filling	Mean
Use of agricultural residues and animal droppings	aquatic fauna	Decrease in fish species due to the degradation of water quality and the phenomenon of filling	Mean

Legend

High vulnerability	
Medium vulnerability	
Low vulnerability	

Examination of Table V shows that several positive and negative environmental impacts are linked to climate change in the study area. It should be noted that the positive impacts are temporary. The major agricultural practices identified negatively affect the environment. These impacts are permanent and therefore their actions endure. With this already critical situation, what will be the future trend of the components of the environment.

3.6 Coping strategies in the face of vulnerability

Faced with future global climate changes, the UNFCCC (United Nations Framework Convention on Climate Change) has proposed emphasizing two fundamental strategies for responding to climate change: mitigation and adaptation (UNFCCC, 2006; Niasse et al., 2004). While mitigation seeks to limit climate change by reducing greenhouse gas (GHG) emissions, adaptation aims to alleviate adverse impacts through a wide range of actions on specific systems (Füssel and Klein, 2002). It is with this in mind that several Sahelian states came together to found in 1973 the Inter-State Committee for the Fight against Drought in the Sahel (CILSS). The means developed by CILSS to reduce the vulnerability of populations to the impacts of climate change consisted, among other things, in setting up: (i) the Early Warning System; (ii) the AGRHYMET Research and Training Center (AGRiculture HYdrology and METeorology) based in Niamey (Niger); and (iii) PRESAO (Seasonal Forecast of Rainfall and Runoff in West Africa).

The environmental components, namely water, soil, air, fauna and flora are altered in the face of the strategies adopted by farmers in order to improve agricultural yields which are weakened due to the current evolution of the climate in the department of Plateau like the other departments of the Republic of Benin. Plate 1 shows the use of pesticides for crops and an agricultural machine for soil disturbance. These practices are not without consequences on all agricultural components.

Board 1: Use of pesticides in Adja-Ouèrè and soil stirring machine in Pobè

***Shooting**: Wokou C. Guy, June 2021*

From the observation of plate 1, it is observed on picture 1.1, the use of pesticides. Indeed, this practice, which aims to improve yields, leads to the disappearance of earthworms and insect pests, to the destruction of weeds that can be harmful to crops. Also, in picture 1.2, a tool is used to stir and shake the soil. This machine participates in the decomposition of organic matter in the soil. This form of development is destructive to the physical environment. To avoid these inconveniences on the environmental components, some farmers use biological methods. Picture 3 shows the use of plants as a solution to pesticides.

Picture 3: Use of plants as pesticides in Adja-Ouèrè

***Shooting**: Wokou C. Guy, June 2021*

Plants as alternatives to pesticides.Many pests affect agriculture in the study area. And cause millions of dollars in economic losses, threatening the food security of thousands of people. To control these pests, farmers use pesticides. Studies show that pesticidal plants can replace it in certain cases. It remains to organize the knowledge.

IV. DISCUSSION

The results of thisresearch goes in the same direction as those of SF Djogbenou (2008, p.7) in the sense that it has identified the different peasant adaptation strategies in the face of climate change contributing directly or indirectly to the deterioration of the environment. In fact, the development of lowlands, the reorganization of the agricultural calendar, the adoption of new crop varieties, the practice of hoeing, the increase in area sown, staggered and repeated sowing, the use of chemical fertilizers and phytosanitary products and the agroforestry system are all strategies developed to increase agricultural production in the department. Faced with this situation and in a perspective of sustainability of good management of water resources of the Adja-Ouèrè plateau, like those of Comè and Allada, HS Vodounon Totin (2005, p.7), corroborates and emphasizes the low efficiency of current methods of water resource management given the projected reduction in its availability after analyzing the evolution of the hydro environment. climate of the plateaus of southern Benin. The conclusions of HS Vodounon Totin (2005, p.7), I. Yabi (p.6) then of G. Wokou and M. Boko (2009, pp.68-69) agree on the degradation of the various components of the environment in the face of the current evolution of the climate, which has become variable. For HS Vodounon Totin (2005, p.7), the future management of water on the plateaus of Comè, Allada and Pobè will require an improvement of natural and artificial systems of productivity and use of water. . Consequently, strategic options adapted to the principles of precaution and anticipation are essential. For Yabi (p.6), the evocation of environmental degradation is rather linked to cashew-based agroforestry in addition to its socio-economic utility which tends to stabilize the farmer on the same crop area for several years. years. G. Wokou and M. Boko (2009, pp.68-69) in turn specify the soil component of the environment. For them, soil degradation is one of the consequences of climate variability because their study has shown that the climatic dynamics of the Agonlin plateau, analyzed using climatological statistics, shows a downward trend in rainfall and a increase in maximum and minimum temperatures. Since several authors agree on better adaptation, M. Fanta (2010, p.23) has developed vulnerability criteria, in order to promote a better ability to adaptation of Sahelian populations to climate variability. Thus, the development of perimeters and the development of rice cultivation on the Agonlin plateau requires precautions and more robust adaptation to soil conditions (drying and impoverishment of the soil) and climatic conditions (aggressive rainfall, flooding, runoff, excessive heat, high temperatures).

V. CONCLUSION

This research contributes to a better understanding of the vulnerability of environmental components to climate change and adaptation strategies in the Plateau department.The climatic evolution in the Plateau department analyzed using climatological statistics shows a downward trend in rainfall and an increase in maximum and minimum temperatures. In addition to this critical situation, a warming trend of around 0.9°C over the period 1981-2017 and a decrease in annual rainfall totals. These cumulative situations would disrupt agricultural activities. In response to such a situation, farmers have had to change cultivation practices. This weakens the main components of the environment between 1978 and 2006 with an average rate of regression of –12.42%. By 2050, if demographic and climatic trends continue, the environment of the Zou watershed will be increasingly degraded (regression of –12)

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