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Demonstrations of hydro climatic constraints and populations' adaptations in Okpara watershed at Nano outlet

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ABSTRACT
Global warming of the planet and weather forecasts bring out an increasing risk of climatic events which are not without consequences on the functioning of the populations activities. The demonstrations and the identification of population's strategies to face climate problems are essential for any understanding of climate issues. The objective of this study is to analyze the demonstrations of hydro climatic constraints and the adaptation strategies of populations in the Okpara watershed at the Nano outlet.
The methodological approach adopted consisted in the analysis of hydro climatic variability through climatologically (rain) and hydrometric (flow) data from 1971 to 2018. The study of adaptation strategies is carried out through the supported CAP approach based on field observations and socio-anthropological investigations. The manifestations of the hydro climatic variations observed by the populations are, among others, drought, increased temperatures, the disruption of the rainy seasons with increasingly rare and insufficient rains and strong winds. These manifestations are perceived differently by the populations through the sunshine, the high heat, the drying up of the rivers and as a result the development of various adaptation strategies.
Keywords: Opkara watershed, hydro climatic variability, manifestations, perception, adaptation strategies

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I. INTRODUCTION

Nowadays, the man realized his effects on the disappearance of the biodiversity and the warning of the planet. This is expressed through the increasing of mean world temperatures of the atmosphere and the ocean, the general melting of the snow and the ice, and the raising of the world mean sea level (GIEC, 2007). Moreover, climatic variability is expressed through a change of the regimen and the rhythm of rainfall (frequency and intensity), affecting like this directly the importance and the synchronization of the flow and the intensity of the floods, flooding and droughts (Mahé, 2006) ; Amoussou *et al.*, 2015). As responses to this situation, it is recorded some repercussions on annual rainfall rhythms which are expressed through extreme hydro climatic events (GIEC, 2014; Kodja, 2018). The permanence of droughts linked to climatic pejoration, handicaps and increases the incertitude of agro-pastoral practices. This situation disturbs the agro-pastoral production systems by compromising the survival of local populations. The absence of data for a retrospective analysis of the climate on a long period constitutes a heavy handicap, from where the necessity to have recourse to the local knowledge. Indeed, various studies have shown that those latter remain indispensables for the knowledge of climate evolution in Sahel (Tidjani *et al.*, 2016). Some studies have also shown that the population has always managed to cope with the different cyclic perturbations through their own ways or know-how. The taking into account and the vulgarization of that local knowledge through agricultural policies is indispensable in order to face the diversity of the nature (Dipama, 2016). Indeed, nowadays, the populations notice a decrease of the annual rainfall as well as the water level in the soil related to climate degradation. As agricultural production is dependent on annual rainfall, a drop of agricultural production is therefore established, with regards to the little availability of the water resources. This variation related to the rainfall and temperatures, as well as the non linear effects on the humidity, the evapotranspiration and the soil, have some consequences on the quantity and the quality of water resources, agriculture, fishery and breeding (GIEC, 2007) and on the populations' life. In the same line, the work done by Ogouwalé (2015) in the Okpara watershed showed a decrease of the heights of rain and an increasing of the minimal and maximal temperatures. It is a situation which contributes to the drop of the water resources availability in Okpara watershed. Now, in some many cases, the flooding plains and /or watersheds give excellent technical and economic opportunities like the case in Okpara watershed at Nano outlet. That is the reason of the present study which aims to show the demonstrations of hydro climatic variability and to analyze the adaptation strategies developed by the populations.

II. PRESENTATION OF STUDT AREA

Okpara watershed is located in latitude between 7°30' and 9°54' north on one side, and in longitude between 1°30' and 3°18'east on second side. It's spread on a area of about 12 710 km². Many under watersheds are drained by the water of this watershed of which the under watershed of Nano (figure 1) which covers the Communes of Nikki, Pèrèrè, N'Dali, Parakou and Tchaourou. Located at the north of Okpara watershed, it covers an area of 2314 km² from Goua (Commune of Bembèrèkè) until Kpassa in the district of Kika, Commune of Tchaourou in the length direction and the district of Ouénou (Commune of N'Dali) until the urban centre of Pèrèrè in the width direction. It is located in latitude between 9°16' and 9°58' north on one side, and in longitude between 2°35' and 3°04' east on second side. The medium rainfall pattern in Okpara watershed is unimodal with an optimum from the month of June. Annual rainfall has average 44 mm in march, 178 mm in August-September and 90 mm in October and by reaching the minima of 4 mm and 2 mm respectively in December and January. Somewhere else, the evolution of the flows in Okpara watershed shows the first phase of 1971 to 1987 where the maximum annual flows are 300.82 m^3/s This phase is the consequence of the distinct drop of the annual rainfall observed in the west African region during the same period and which had some important repercussions at hydrological, economical and social levels (Mahé, 2006; Vissin, 2007). Finally, the second phase is that from 1988 to 2018 with a distinct renewal ($655m^3/s$)

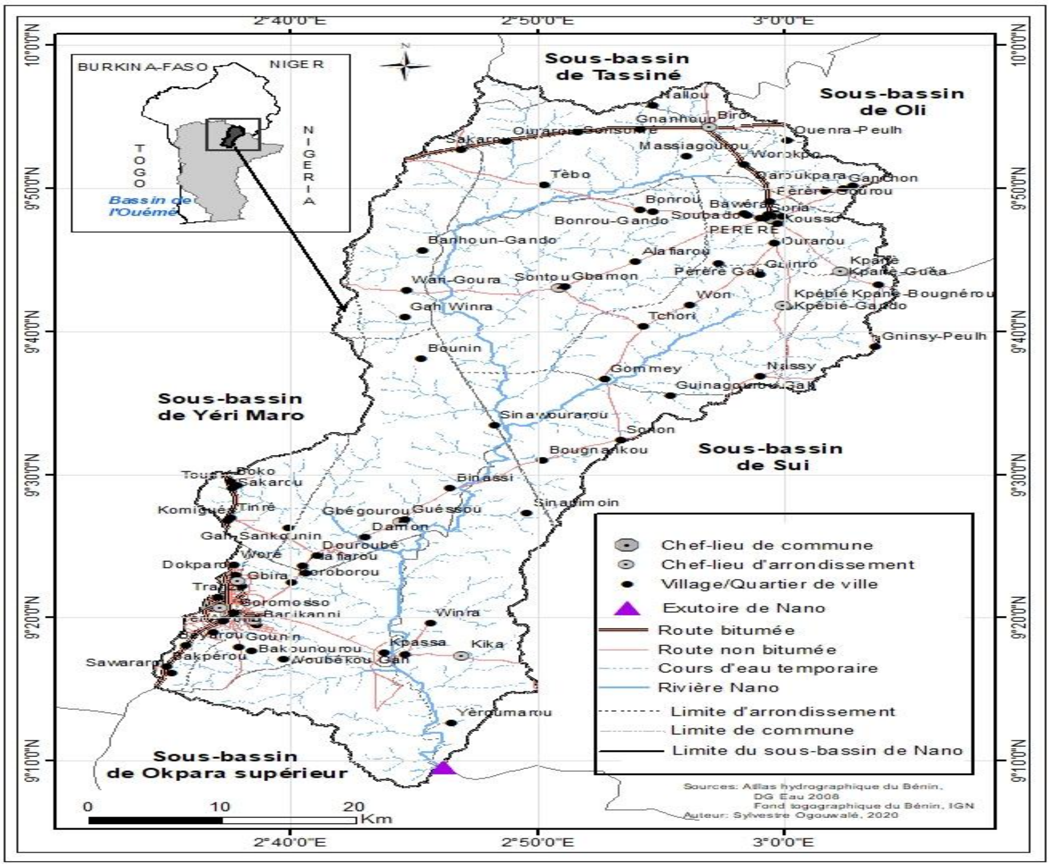

Figure 1: Location of under watershed of Nano river

III. DATA AND METHODS

3.1 Data collection

Climatic, hydrological, qualitative and quantitative data were used for this study. The climatic chronics are: heights of rain (monthly and annual) of rainfall stations located in the immediate environments of the basin of Nano river, extracted from the files of the stations and climatic posts of National Direction of meteorology (NDM) from 1971 to 2018. Hydrological chronics covered the period from 1971 to 2018 and are printed from the data basis of the Hydrology Office of the General Direction of Water.

3.2 Data analysis

Stratified questionnaire-based interview and focus group discussion were conducted by using respectively the questionnaire and interview guide in order to collect information from the target persons. The approach KAP (Knowledge, Attitudes, Practices) is used to collect data related to hydro-rainfall variability and to grasp the communities' perceptions and knowledge. Direct field observations enable to better identifying the farmers adaptations' strategies to the hydro climatic variability in Okpara watershed at Nano outlet. Questionnaires were addressed to the stakeholders of the agricultural sector of whom 108 farmers. The size of the sample was defined through the method of Schartz 2002).

Rainfall variability was determined from the central reduced anomalies. The computation of the rainfall indexes enabled identifying the wet years (excess) and the dry years (adverse). Those indexes were obtained through the following formula:

$x_i' = \frac{x_i - \bar{x}}{\sigma(x)}$ with x representing the total rainfall of year i ; $\bar{X}$ the average annual rainfall over the indicated period and σ representing the standard deviation.

To analyze the fashions of rainfalls in Okpara watershed at Nano outlet, the hydrologic budget was used. According to Barbé et *al.*, (1993), it is determined during one period through the following formula:

$P = E + L + I + (S1 - S0)$

With: P=Rainfall (in mm); E = evaporation (in mm); L = water flow (in mm); I = refill (infiltration) (in mm), S1-S0 = variation of underground water stock available in Okpara watershed at Nano outlet (in mm). Among the five terms of this equation, two are not quantifiable through direct measures. To reduce the numbers of unknowns, the period was chosen so that the variation (S1-S0) will be neglected and "I" varies according to the soil nature and the quantity of rainfall (Vissin, 2007). All those works allows obtaining the following results.

IV. RESULTS AND DISCUSSION

4.1 Hydrologic statement analysis in Okpara watershed at Nano outlet

The following figure (Fig. 2) shows the hydrologic behavior of the watershed of Nano river in relation with the climatic budget.

4.1 Hydrologic statement analysis in Okpara watershed at Nano outlet

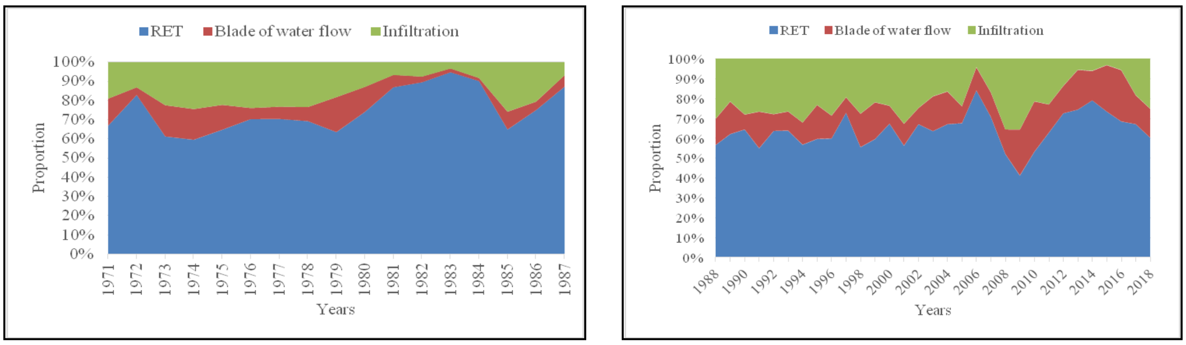

Figure 2: Change of the hydrologic budget per sub-period in Okpara watershed at Nano outlet, from 1971 to 2018

Legend: RET = Real Evapotranspiration

After analysis of Fig. 2, it arises that the rain is the fundamental element which conditions the other parameters of the hydrologic budget. Thus, some average rainfalls of 107.89 mm had involved an average water flow of 139 mm, average infiltration of 226 mm and evapotranspiration of 713 mm. It follows that for 100% of rainfall in the watershed, 66% are destined to evapotranspiration, 12% to flow and 20% to infiltration. Evaporation rate is very higher in the whole watershed. We can notice that the period of rainfall recession (1971-1987) records less evaporation and water flow than that of rainfall return (1988-2018) in the watershed. That confirms effectively the impact of rain on the other parameters of hydrologic budget mainly the flow of the waterways. Table I shows the proportion of each term of the hydrologic budget.

Tableau I: Proportion of each parameter of hydrologic budget for 100% of rainfall per sub-period in the basin

	Rainfall	Water flow (%)	RET (%)	Infiltration (%)
1971-1987	100	9	76	15
1988-2018	100	12	66	20

Legend: RET = Real Evapotranspiration

From table I, we deduce that the smallest part come back to the flow whereas the most important one is imputed to evaporation through enormous losses.
The application of the test of Spearman at the level of acceptance of 95% to these different parameters brings out the main correlations existing between Rain/Water flow on one side, and Water flow /refill on second side, in the basin (Table II)

Tableau II: Matrix of correlation (Spearman test)

	Rainfall	RET	Water flow	Infiltration
Rainfall	1			
RET	**0,95***	1		
Water flow	**0,75***	0,26	1	
Infiltration	**0,56***	0,37	0,24	1

Legends:
REP = Real Evapotranspiration
*= Significant correlation between budget terms at the level of 95%

Table II reveals the existence of high positive correlations (r > 0.5), significant at the level of 95% between the rainfall and the other hydrologic budget's parameters in Okpara watershed at Nano outlet. Correlation between rain and evaporation is more important (r = 0.95) than with the other hydrologic budget parameters. That testifies the high relation between this parameter and the blade of water flow precipitated in the basin. Likewise, there is a not less important correlation between the other parameters (infiltration and water flow) and the precipitations. The above results and analysis prove that rain is the parameter which conditions the other parameters of hydrologic budget in the basin. The table III shows the mean of the blade of water flow precipitated for these last for decades versus the heights of rain, evaporation and refill (infiltration)

Tableau III: Comparative change of rainfall fluctuations and other parameters of the hydrologic budget in mm in Okpara watershed at Nano outlet over the period 1971-2018

Okpara watershed at Nano	Changes over the period 1971-2018	
Rainfall (mm)	1971-1987 (P1)	1039,5
	1988-2018 (P2)	1105,2
	Gap P1-P2 (%)	**6,3**
Water flow (mm)	1971-1987 (P1)	91,8
	1988-2018 (P2)	147,3
	Gap P1-P2 (%)	**60,5**
RET (mm)	1971-1987 (P1)	730,3
	1988-2018 (P2)	713,2
	Gap P1-P2 (%)	**-2,3**
Refill (mm)	1971-1987 (P1)	217,4

	1988-2018 (P2)	248,0
	Gap P1-P2 (%)	**14,1**

Legend: RET = Real Evapotranspiration
Source: Ogouwalé, 2019

Comparatively to the sub-period 1971-1987, rainfall heights have increased during the sub-period 1988-2018 at Nano. Thus, a rainfall shortage of 6% was recorded at Nano. This decrease of the rainfall has induced some repercussions on the water flow (60.6%, both ten times the rainfall shortage and the refill (14.1%, either two times the rainfall shortage) which has considerably increased. On the other hand, the evaporation has recorded a decrease of 62.3%, either the third of rainfall shortage. This decrease of evaporation in the basin could be explained through the anthropic activities (inducing the degradation of the covered vegetable) which highly influence the evaporation process in the basin and also the quality of surface water of this basin. Moreover, the compared change of all the parameters of this budget between the sub-periods 1971-1987 and 1988-2018, revealed that for the rainfall shortage of about 6%, water flow and refill shortages record respectively 60.5% and 14.1% (either respectively six and two times the observed rainfall shortage) in the watershed of Ouémé at Nano.

4.2 Demonstrations of hydro climatic variations

Results from data analysis revealed that populations have known since four decades (period equivalent to the beginning of years 1970) the changes happened in rainfalls and temperatures regimen. Fig. 3 shows the different demonstrations of hydro climatic change in the study area.

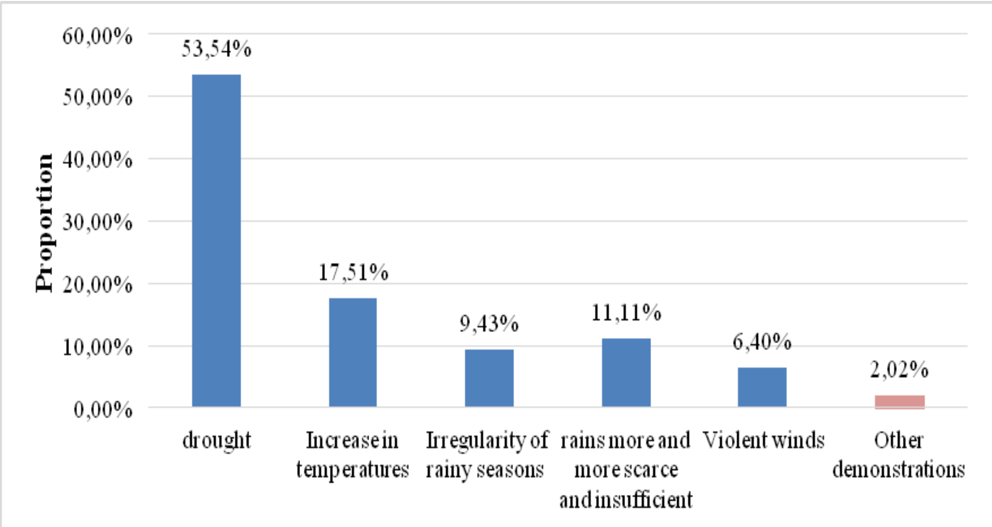

Figure 3: Demonstrations of hydro climatic variations in the watershed going from Okpara to the outlet of Nano

From Fig. 3, we deduce that the observed demonstrations of hydro climatic changes by the populations are among other the drought (53.54%); the increase in temperatures (17.51%); the irregularity of rainy season (9.43%) with the rains more and more scarce and insufficient (11.11%) and violent winds (6.40%). According to these populations, abundance of rains has progressively diminished during the seasons from years 1970 which correspond to a climatic dry period. The beginning of the rainy season occurs more and more lately compared to periods before 1970. This perception is confirmed by the works of Tidjani *et al.*, (2016) and Ogouwalé (2013). Moreover, the field collected data has shown that many indicators (Fig. 4) allow populations of the basin to best surrounding hydro climatic demonstrations.

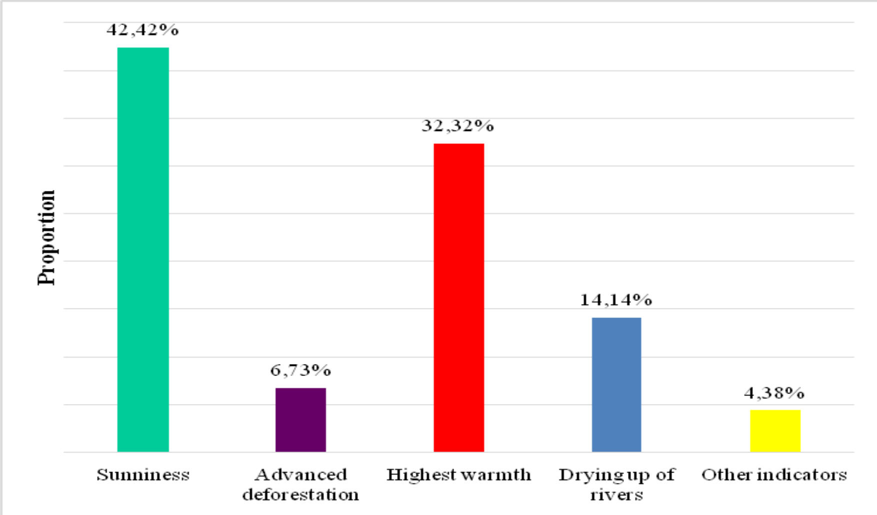

Figure 4: Indicators of hydro climatic variations in Okpara watershed at Nano outlet

Thus, in the study area, the first indicator underlined by 42.42% of the populations is the sunniness followed by some highest warmth by 32.32% of the populations. The drying up of rivers and streams and the advanced deforestation evoked respectively by 14.14% and 6.73% enable understanding likewise the effectiveness of hydro climatic variations in the study area.

Effects of hydro-climatic variations

The consequences of hydro climatic variability in Okpara watershed at Nano outlet are various. Fig. 5 illustrates those consequences in the study area.

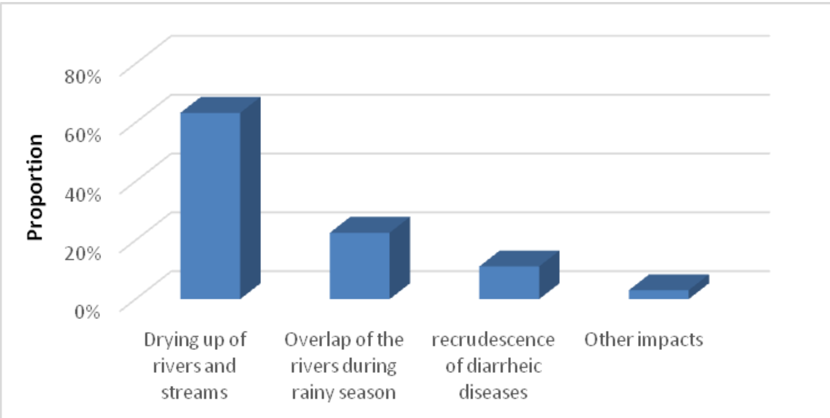

Figure 5: Consequences of hydro climatic changes in the study area

Indeed, from Fig. 5, we deduce that the drying up of the rivers and streams (63.30%) and the overlap of the rivers during rainy season (22.56%) are the main consequences induced by the hydro climatic variations in the aforesaid basin. It follows a general decrease of the ground waters' level reducing like that, the natural soil front of humidification, the biodiversity, the vegetable cover and the ecosystem resource productivity. All these effects constitute some elements of soils degradation in line with climatic variability. It is also noticed the recrudescence of diarrheic diseases which affect about 11% of the basin population. Likewise, the irregularity of the rains and the rise of temperatures have as consequences the loss of biodiversity, the reduction, and even, the disappearance of vegetable cover and a modification of the vegetation's look. For Ouassa, (2014), farmers know by their own way the hydro rainfall variability and its shocks on agricultural activities.

Farmers' perceptions are among other, the shift of rainy season and cropping calendar, the decrease of rainfall and flows, the extension of rainy season, the bad rains distribution and the projection of the desertification. Thus, populations of Okpara watershed at Nano outlet have developed some strategies in response to hydro climatic variations.

4.3 Adaptations' strategies to the hydro-climatic variability

Face to the continual alteration of their living conditions in the current context of climatic variability, local populations have developed various adaptations' strategies (Fig. 6).

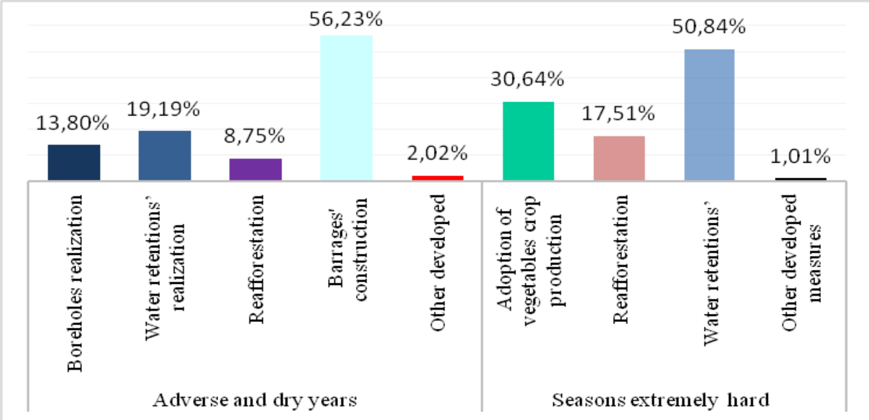

Figure 6: Adaptations' strategies in Okpara watershed at Nano outlet

From Fig. 6, we deduce that the strategies defer from one period to another one. Indeed, during the adverse and dry years, barrages construction (56.23%) and the boreholes realization (13.80%) are the most adopted. The water retentions' realization (50.84 %) and the vegetable cropping clarification (30.64 %) are preferred during the extremely dry seasons in the basin. Besides, with the shortening of the rainy season, all the enquired declare that they were obliged to change the sowing dates. The use of improved seeds with short production cycle is made by 16.20% of the enquired. The other adaptations concern the collective prayers for rains request, the crop diversification and association. The use of organic fertilizer, the penning, the mulching in the production field and the use of chemical fertilizers which nevertheless remain little developed are nowadays promoted in order to fight against the decrease of cropping soils' fertility. Beyond those strategies, populations adopt some strategies which are in phase with environment protection. Therefore, 56.60 % of the enquired populations use to do crops rotation, 18.86 % for agro forestry and 14.14 % for integrated lands management. Other practices are community forest establishment (4.04%) and environmental education (4.38 %). Fig. 7 shows the aforesaid adopted strategies.

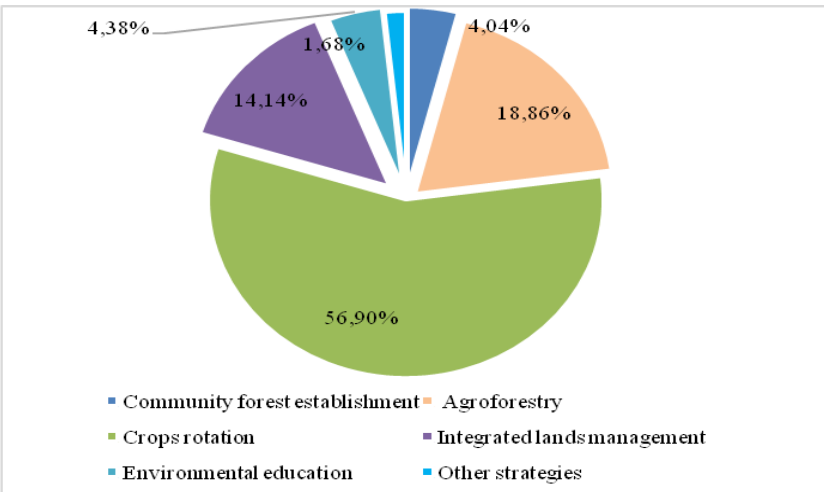

Figure 7: Strategies of environment protection in the study area

In consideration of the different adopted strategies, we can say that the communities perceive directly or indirectly the effects of climatic variability also responsible of the decline of the natural resources productivity and farming systems. However, though the adopted strategies practiced by the rural communities are surely adequate for the moment, it is clear that certain become inefficient and disastrous at medium-dated or long term.

V. DISCUSSION

The planetary climatic system in which West Africa and Benin are enrolled through the Department of hills, undergoes some changes at big scale which are amplified by natural and anthropic factors as much as regional or local. The analysis of hydrologic conditions in Okpara watershed show that the high variability of rainfall during the period 1971-2018 has got some repercussions on the average water flow of Okpara watershed at the outlet of Nano. These results corroborate those obtained by Kouassi *et al.*, (2010) in Ivory Coast and Ogouwalé (2013) in Benin. According to the latter, on 100% of rainfall in Okpara watershed, 83% are intended to evaporation, 5 to 7 % to infiltration and 12 to 15 % to flow. But, the present study reveals that for 100 % of rainfall in the basin, 66% are intended to evapotranspiration, 12% to the flow and 20% to infiltration. In all cases, it is noticed that evaporation remains higher in the basin to the detriment of the other hydrologic budget parameters. The study shows also the hydro climatic variations which are expressed to the populations through different ways. The decrease of rainfall with regards to that of years before 1970, the reduction of the rainy season duration, the increase of the temperature, the violent winds, and according to GIEC (2014), this phenomenon will continue and contribute certainly to increase natural resources degradation already weakened by recurrent drought. The works of Tidjani *et al.*, (2016) in the oasis system of Gouré (South-East, Niger) confirm those demonstrations of the hydro climatic variability. The barrages' construction (56.23 %) and the realization of boreholes (13.80 %), the realization of water retentions (50.84 %) and the vegetable cropping setting up (30.64 %) were revealed as alternatives in the basin in order to cope with hydro climatic consequences. These different populations' strategies even they are little effective during their application because without modern technique, illustrate the populations' capacities to be adapted to hydro climatic variations. However, according to Ouassa, (2014), in general, adaptation' strategies present some limits and constraints during application. Rains can become rarefied after the realization of some water' stoppage' points. On this basis, the practices to be promoted should be proposed by consultation way and by taking into account the agro ecological and socio economical realities of the recipients if the sustainability dimension of the strategies will be affected.

VI. CONCLUSION

As outcomes of this study, we can retain the variations that affected the rainfalls and the rate of rivers' flows. These variations are expressed through the decrease of the rainfalls from years 1970 followed by the lowering of water flows varying from 30 to 50%. This situation has had some consequences on the populations' activities in Okpara watershed at Nano outlet. In response to these changes, populations of study area have developed several strategies. Among these ones, the sustainable adaptations' options to hydro climatic variability are among other: the water' retentions, the boreholes, the agro forestry, the crops rotation, etc.

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