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Impacts of Climate Extremes on Human Health and the Living Environment in the Municipality of Dangbo in the South of Benin (West Africa)

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Abstract

Climatic extremes (droughts, floods) have effects on human health, the living environment, economic activities etc ... The objective of this research is to study the impact of climatic extremes on human health and the living environment in the commune of Dangbo.

The methodological approach adopted revolves around the collection of climatological, demographic and socio-anthropological data, data processing and analysis of the results. The collection techniques used mainly concern documentary research and real-world investigations in order to collect all the data and information necessary for the realization of this study. The application of the reduced centered indices to the rainfall and hydrological series made it possible to highlight the rainfall variability.

The results obtained show that there are indeed flooding and drought phenomena of a very large scale in Dangbo. These phenomena lead to diseases such as intestinal parasitosis, malaria, respiratory ailments, gastroenteritis, cholera etc ... They also cause damage to the living environment, namely: the destruction of material goods, the flooding of schools, the flooding of homes, the reduction of the quality of life, the degradation of the earth, the upsurge of pollution etc ... In response to these constraints, home care, the abandonment of establishments are respectively one of the means to mitigate the repercussions on health and on the living environment. Additional measures such as the protection of children and pregnant women as well as the construction of homes adapted to climatic extremes have been proposed.

Keywords: Dangbo commune, climatic extremes, health, living environment.

1. Introduction

The warming of temperatures linked to atmospheric enrichment in anthropogenic CO2, affects aquatic and terrestrial environments, modifies the marine biotope, which explains droughts,

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storms, floods and devastating fires (Swynghedauw and Weméau 2020). It modifies biodiversity, bio-invasions in particular by vector-borne diseases. The enrichment of the atmosphere with particles has profound effects on cancers, cardiorespiratory and metabolic diseases, allergies. Children, elderly or socially disadvantaged subjects, human settlements as well as animals are the most at risk (Swynghedauw and Weméau, 2020; IPCC, 2022).

Benin, a country in sub-Saharan Africa, is vulnerable to environmental and climate crises. The damage caused by environmental disasters is noticeable on all environmental and social components of the country. The work carried out within the framework of the concerted assessment of the vulnerability to climate change in the most vulnerable geographical areas of Benin has made it possible to establish that drought, floods and late and violent rains constitute three major climatic risks in Benin. The occurrence of localized climatic risks such as sea level rise, having a weak geographical influence, but capable of great economic and social impacts is also retained (UNDP, 2011). The floods of 2010 had major impacts in all the municipalities at risk. According to the Post-Disaster Needs Assessment report (UNDP, 2011), the floods of 2010 caused significant damage to housing, schools, health centers, roads, marketplaces, places of worship, drinking water supply and sanitation networks, and other public goods and services. The floods have led to a significant deterioration in the living conditions of households such as the availability and / or limited access to health services, increased risks of diseases which in turn may have consequences on the nutritional status of the most vulnerable populations, in particular women and children under five years of age. As an incidence there is an increase in the number of cases of acute malnutrition and micronutrient deficiencies (Houngbo 2020). The Municipality of Dangbo, an integral part of the lower Ouémé valley, is experiencing floods due to the combined effects of extreme rainfall and hydrometric events, which result in a decrease in agricultural yields, significant damage to infrastructure, housing, health services and sometimes loss of human lives.

1.1 Area of study

The Municipality of Dangbo, is an integral part of the lower Ouémé valley, it is located in the southern part of Benin between 6o31 ’ and 6o40’ north latitude and between 2o25’ and 2o38’ east longitude. The Municipality of Dangbo is located in the Ouémé department in south-eastern Benin (Figure 1). It covers an area of 149 km2 (INSAE, 2002) with a density of 644 inhabitants / km2. It is limited: to the north by the Municipality of Adjohoun; to the south by the Municipality of Aguégués; to the east by the Municipality of Akpro-Missérété; to the west by the Municipality of So-Ava. It has 41 administrative villages distributed in seven (07) districts that are: Dangbo, Dèkin, Gbéko, Hêtin-Houédomey, Hozin, Késsounou and Zounguè.

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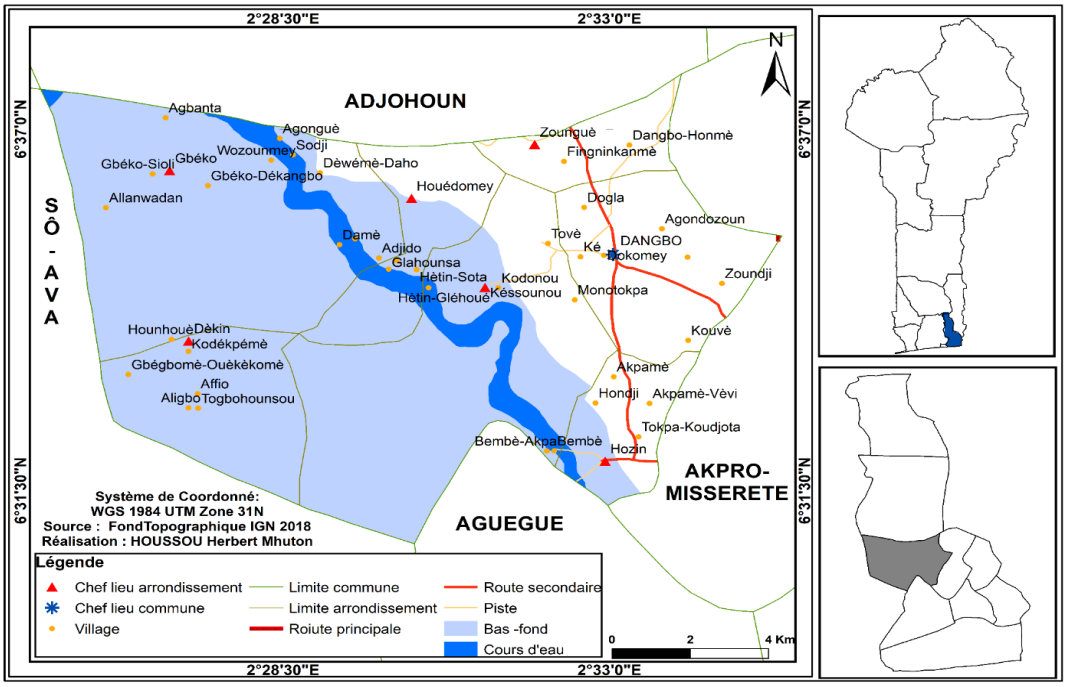

Figure 1**:** Geographical location of the Municipality of Dangbo

2. Data and methods

2.1. Data used

The data collected as part of this research are essentially rainfall data, flow data for the period 1981 to 2020 respectively from the Cotonou synoptic station and the Bonou hydrometric station; demographic statistics from the censuses from 1979 to 2013 obtained at INStaD; statistics on the impacts of climate extremes on populations; statistics on the evolution of these impacts; statistics relating to the impacts of climate extremes on the living environment and health.

2.2. Methods used

The collection techniques used mainly concern documentary research and real-world investigations in order to collect all the data and information necessary for the realization of this study.

To carry out the socio-anthropological investigations, the determination of a sample and the use of appropriate techniques and tools were necessary.

Sampling

The sample size is determined by the formula of Schwartz (2002).

$X = Za2 \times p\ q/i2$;

with: X = the sample size; Za =1.96 Reduced deviation corresponding to an α risk of 5%; p = n/N; with p = proportion of the selected households (n) compared to the number of households in the districts (N) of Dangbo.

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N = total number of households in the districts;
Z α = deviation set at 1.96 corresponding to a degree of confidence of 95 % ;
P = number of households in the districts/ total number of households in the Municipality. Q = 1-P, I2 = margin of error which is equal to 05% (0.05).
The choice of villages followed a reasoned approach to identify those that suffer the most impacts from extreme phenomena, in order to collect representative information. The size of the surveyed sample is presented in Table 1.

Table 1: Distribution of the surveyed population

Districts	Villages	Number of people surveyed	Sampling rate
Dêkin	Affio	44	11,67 %
	Hounhouè	55	14,59 %
Hêtin-Houédomey	Adjido	77	20,43 %
	Houédomey	63	16,71 %
Késsounou	Késsounou I	71	18,83 %
	Kodonou	67	17,77 %
	Total	**377**	**100 %**

Source: Field Survey, 2022

A total of 377 people were interviewed as part of this research.

2.2.1. Method for determining climatic extremes

Several studies conducted on the town of Dangbo demonstrate that flooding and some pockets of drought are the climatic extremes that impact the population.

➢ **the Floods**

* **Rain-fed flooding**

There are several methods for determining the risk of flooding. Table 2 makes it possible to determine the magnitude of the flood thanks to the rainfall heights.

Table 2: Thresholds for determining the risks of rain-fed flooding

Type of risk	Thresholds of rainfall heights
Limited risk	505 to 706
Moderate risk	737 to 1081
Significant risk	1116 to 1350
Critical risk	≥ 1350

Source: Totin, (2016)

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• River flooding

To characterize the fluvial flooding, the SFI index (Standardized Flow Index) is recommended since it makes it possible to highlight the floods as well as their year from the annual flows. Here is a formula that makes it possible to characterize the flooding from the flow rates by the following formula :

$$Z = (Y-\mu) / \sigma$$

With: Z: SFI index; Y: annual flow rate; μ: average flow rate of the series; σ: standard deviation of the series.

Table 3: Thresholds for determining the risks of river flooding

Threshold values	Flood categories	Observations
SFI ≥ 2	Catastrophic	Criticism
1,5< SFI <1,99	Serious	Significant
1<SFI<1,49	Negligible	Moderate
0<SFI<0,99	No effect	Limited

Source: McKee et *al*. (1993)

➢ **The Droughts**

*** Meteorological drought**

The meteorological drought is the one that is the easiest to notice, and it is the one that everyone knows: it occurs when it does not rain for a long period. The SPI is an index to measure the meteorological drought. This is a probability index that is based only on precipitation. The probabilities are standardized so that a SPI of 0 indicates a median amount of precipitation (compared to a reference average climatology, calculated over 30 years). The index is negative for droughts, and positive for wet conditions (McKee et al., 1993). The use of this index is also recommended by the World Meteorological Organization. To obtain it, we proceed as follows :

$$I_P = \frac{(X_i - \bar{X})}{\sigma}$$

With: pi: the precipitation of the year i; pm: average precipitation; σ: standard deviation or standard deviation.

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Table 4: Risk determination thresholds

Values and meaning of the SPI :
SPI > 0: more precipitation than normal (more humid) ;
SPI < 0: less precipitation than normal (drier) ;
-0.99 < SPI < +0.99: precipitation close to normal ;
SPI < - 2.0: extremely dry ;
SPI > 2.0: extremely humid.

Source: McKee et *al., (*1993)

• Hydrological drought

We speak of hydrological drought when the groundwater tables, lakes, rivers, and rivers present a low level. This type of drought can occur under the effect of several factors: no precipitation and / or an absence of infiltration deep into the soil to the groundwater, either because the rainwater flows instead of being absorbed by the soil (impermeable soil, compacted soil ...), or because the water is captured by the vegetation before reaching the subsoil.

The standardized hydrological index (IHN) is suitable for studying droughts of a certain duration on water resources. Its mathematical formula is:

$$IHN = \frac{(Di - Dm)}{S}$$

With: Di: the flow rate of the months or of the year i; Dm: the average flow rate of the series on the time scale considered.

Table 5: Classification of drought sequences according to the IHN

IHN workbook	Drought sequence
IHN ≥0	Ordinary
-1,5≤ IHN ≤ 0	Moderately dry
-2 ≤IHN < -1,5	Severely dry
IHN < -2	Extremely dry

Source : Gibbs et al., 1967

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2.2.2. Method for analyzing the vulnerability of the health system and the living environment to climate extremes

- **On the sanitary system**

The procedure was carried out in stages. These are the three steps that are as follows :
1- Make an inventory of the ailments or diseases encountered in the study area during the flood and drought in the town of Dangbo.
2- Evaluate the impact of climate extremes on human health in the town of Dangbo based on the impact sensitivity matrix.
3- Evaluate the level of adaptation in health of the population in the face of flooding and drought in the municipality.

• On the system of the living environment

Three stages made it possible to determine the impacts of climatic extremes on the living environment.
1-List the disturbances of the flood on the living environment in the town of Dangbo.
2- Evaluate the impact of climatic extremes on the living environment in the town of Dangbo based on the impact sensitivity matrix.
3- Evaluate the level of adaptation of the population to the living environment in the face of flooding and drought in the commune of Dangbo.
The following tables 6 and 7 will allow the different evaluations.

Table 6: Scale of assessment of climatic extremes

Magnitude scale of the degree of vulnerability	Magnitude of the risk
1	Low
2	Quite weak
3	Medium
4	Strong enough
5	Strong

Source: PANA-Bénin, 2008

Table 7: Formal presentation of a sensitivity matrix

Exposed systems	Climatic extremes		Climatic extremes
	Drought	Flood	
Health			
Living environment			
Impact index			

Source: PANA-Bénin, 2008

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With as a scale :
- 0 to 25%: Low impact, the repercussions are negligible at this level.
-25 to 50%: Medium impact, the fallout is considerable and can disrupt the system under consideration.
-50 to 75%: High impact, the consequences are increased and upsets the normal order of things.
-75 to 100%: Very high impact, we are talking about a catastrophic situation causing enormous damage to the sector under consideration.

3. Results

3.1. Analysis of climatic extremes in the commune of Dangbo

According to the various surveys and investigations carried out on the ground, it emerges that floods and droughts are the major climatic extremes recorded in the commune of Dangbo.

3.1.1. Floods

- **Rain-fed flooding**

Figure 2 shows the interannual evolution of rainfall recorded in the commune of Dangbo from 1981-2020.

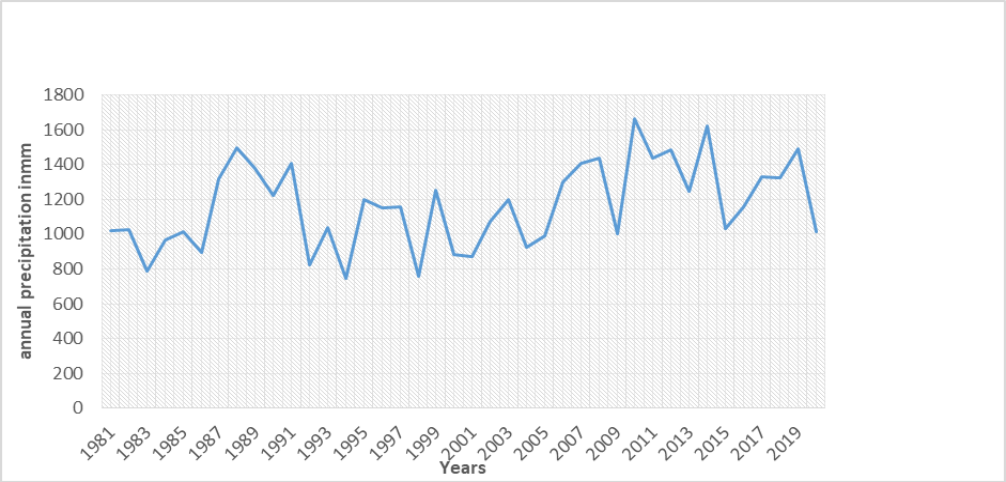

Figure 2**:** Interannual evolution of rainfall recorded in the commune of Dangbo from 1981-2020.
Source: Weather-Benin, 2020

It emerges from the analysis of Fig. 2 that the concentration of heavy precipitation is at the base of the various peaks observed. Thus, the strongly and eminently rainy years of the commune of Dangbo over the study period have been determined (Table 8).

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Table 8: Compendium of the years characterized by pluvial floods

Thresholds of rainfall heights	Type of risk	Years
505 à 706	Limited	Aucune
737 à 1081	Moderate	1981, 1982, 1983, 1984, 1985, 1986, 1992, 1993,1994, 1998, 2000, 2001, 2002, 2004, 2005, 2009, 2015, 2020
1116 à 1350	Significant	1987, 1990, 1995, 1995, 1996, 1997, 1999, 2003, 2006, 2013, 2016, 2017, 2018
≥ 1350	Criticism	1988, 1989, 1991, 2007, 2008, 2010, 2011, 2012, 2014, 2019

According to the analysis of Table 8, it emerges that the years 1981,1982,1983,1984,1985,1986,1992,1993,1994,1998,2000,2001,2002,2004,2005,2009,2015,2020 were characterized by a moderate type of rainwater flooding. In addition, some years are marked by significant rainfall such as those of 1987, 1990, 1995, 1995, 1996, 1997, 1999, 2003, 2006, 2013, 2016, 2017, 2018 resulting in heavy flooding. On the other hand, we notice that the years 1988, 1989, 1991, 2007, 2008, 2010, 2011, 2012, 2014, 2019, have been characterized by excessive rainfall leading to extreme flooding.

- **River flooding**

Fig. 3 shows the interannual evolution of the flows recorded in the commune of Dangbo.

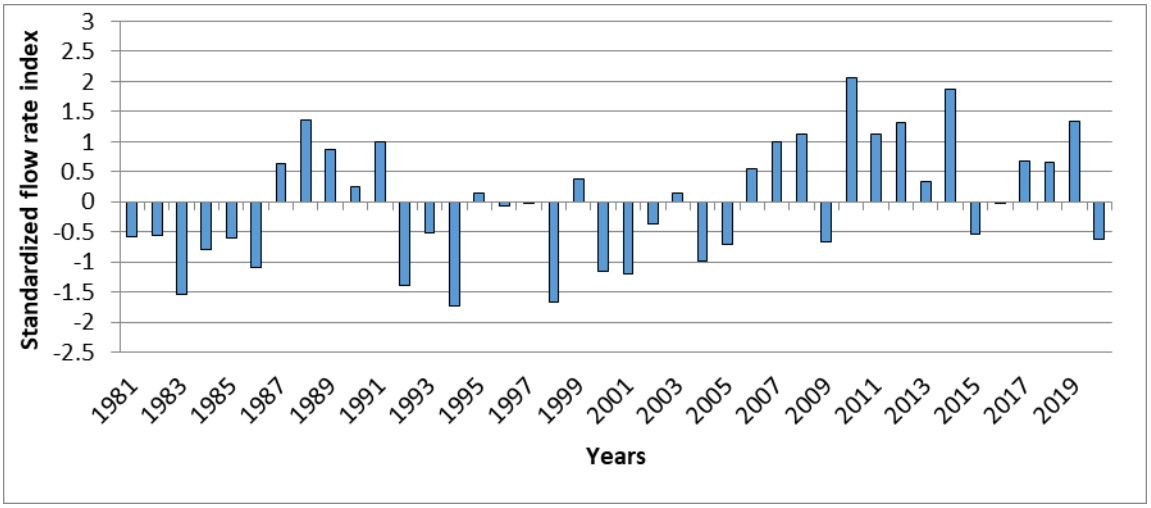

Figure 3: Interannual evolution of the standardized flow index in the municipality of Dangbo from 1981-2020

Source: Météo-Benin, 2022

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It can be seen from the analysis of Fig. 3 that the standardized positive flow rate indices are between 0 and 2.059. Which leads to an overflow of the Ouémé River. The year 2010 was characterized by an extreme river flood.

Table 9: Compendium of the years characterized by river floods

Appreciations	**years**
Limited	1987, 1989, 1990, 1995, 1999, 2003, 2006, 2013, 2017, 2018
Moderate	1988, 1991, 2007, 2008, 2011, 2012, 2019
	2014
Significant	2010

De l'analyse du tableau 9, on retient que les inondations fluviales sont pour la plupart limité (1987, 1989, 1990, 1995, 1999, 2003, 2006, 2013, 2017, 2018). Les années 1988, 1991, 2007, 2008, 2011, 2012, 2019 ont été caractérisées par une inondation fluviale modérée. Par contre l'année 2014 a été marquée par une inondation fluviale significative. Il est à notifier que la commune de Dangbo a connu une crue critique en 2010.

3.1.2 Droughts

- **Meteorological drought**

Figure 4 shows the interannual evolution of the precipitation standardization index over the period of (1981-2020).

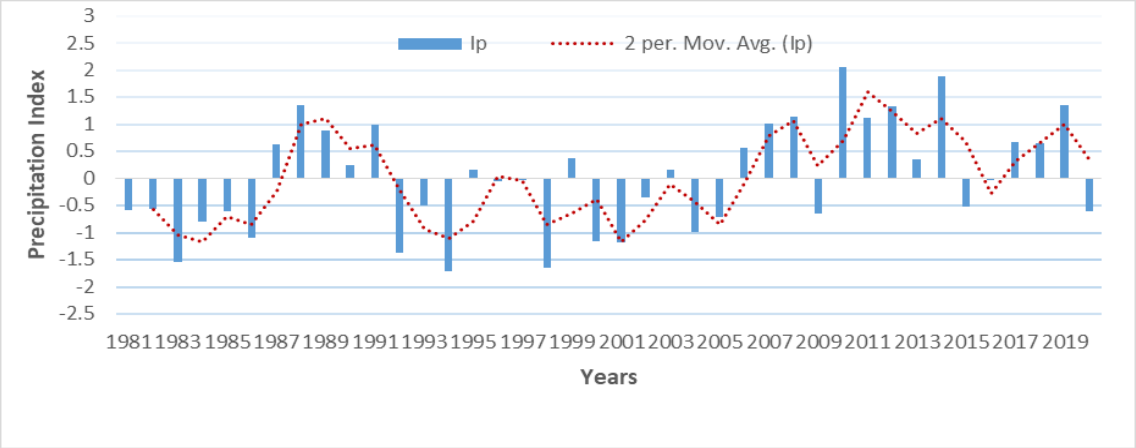

Figure 4: Interannual evolution of the precipitation standardization index (SPI) in the municipality of Dangbo from 1981-2020

Source: Météo-Benin, 2022.

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It appears from the analysis of this Figure 4 that the negative rainfall anomalies are between 0 and -1.19. From this, it can be seen that the years 1983, 1984, 1985, 1986, 1994, 1998, 2001 and 2005 have experienced strong drought.

Table 10: Compendium of years characterized by meteorological droughts

Appreciations	**Yéars**
Moderate	1982, 1987, 1992, 1996, 1997, 1999, 2000, 2002, 2003, 2009, 2015, 2020
Strong	1983, 1984,1985, 1986, 1994, 1998, 2001,2005
Extreme	None

According to the analysis of Table 10, it should be remembered that the town of Dangbo has experienced several years of moderate meteorological drought. We have the years 1982, 1987, 1992, 1996, 1997, 1999, 2000, 2002, 2003, 2009, 2015, 2020. As for severe weather droughts, the years 1983, 1984,1985, 1986, 1994, 1998, 2001,2005. On the other hand, it was notified there that the extreme weather droughts were not recorded during the study time.

- **Hydrological drought**

Figure 5 shows the interannual evolution of the standardized hydrological indices (IHN) over the period from 1981 to 2020.

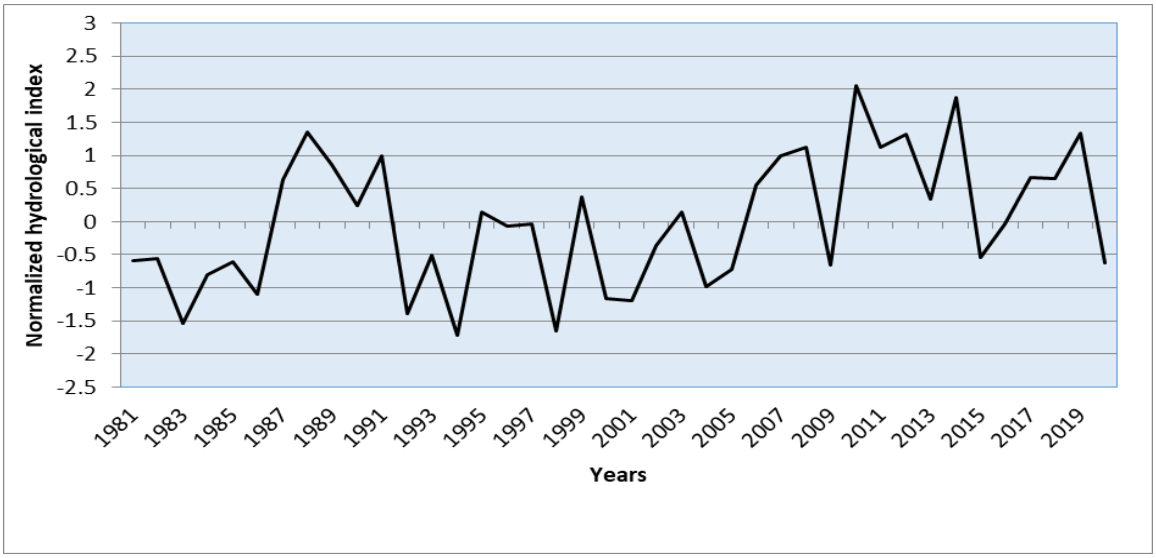

Figure 5**:** Interannual evolution of the Normalized Hydrological Index (IHN) on the Ouémé basin in Dangbo from 1981 to 2020
Source: Météo-Benin, 2022.

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The analysis of Fig. 5 shows that hydrological deficits characterize the phases of drought.

Table 11: Compendium of years characterized by hydrological droughts

Appreciations	**Yéars**
Ordinary	1987, 1988, 1989, 1990, 1991, 1995, 1999, 1998, 2003, 2006, 2007, 2008, 2010, 2011, 2012, 2013, 2014, 2017, 2018, 2019
Moderately dry	1981, 1982, 1984, 1985, 1986, 1992, 1993, 1996, 1997, 2000, 2001, 2002, 2004, 2005, 2009, 2015, 2016, 2020
Severely dry	1983, 1994, 1998
Extremely dry	None

According to the analysis of Table 11, it should be remembered that the town of Dangbo is often confronted with moderately dry and ordinary droughts. The years of ordinary drought are : 1987, 1988, 1989, 1990, 1991, 1995, 1999, 1998, 2003, 2006, 2007, 2008, 2010, 2011, 2012, 2013, 2014, 2017, 2018, 2019. Moderately dry ones are : 1981, 1982, 1984, 1985, 1986, 1992, 1993, 1996, 1997, 2000, 2001, 2002, 2004, 2005, 2009, 2015, 2016, 2020. Only the years 1983, 1994, 1998 were severely dry. On the other hand, it was notified there that the extreme hydrological droughts were not recorded during the time of study.

3.2. Impact of climate extremes on human health in the commune of Dangbo

As Dangbo is one of the at-risk municipalities in Benin, its population is the victim of several diseases or illnesses related to flooding and / or drought. The arrondissements of Dêkin, Gbéko, Hêtin-Houédomey, Késsounou are the most impacted because they are risk areas of the municipality.

Certainly the main diseases encountered in the town of Dangbo are among others malaria which is the first condition that plagues the study area, acute respiratory infections, intestinal parasitosis, gastroenteritis follow.

3.2.1. Diseases related to the flood in the commune of Dangbo

Figure 6 shows the diseases related to the flood suffered by the population in the commune of Dangbo.

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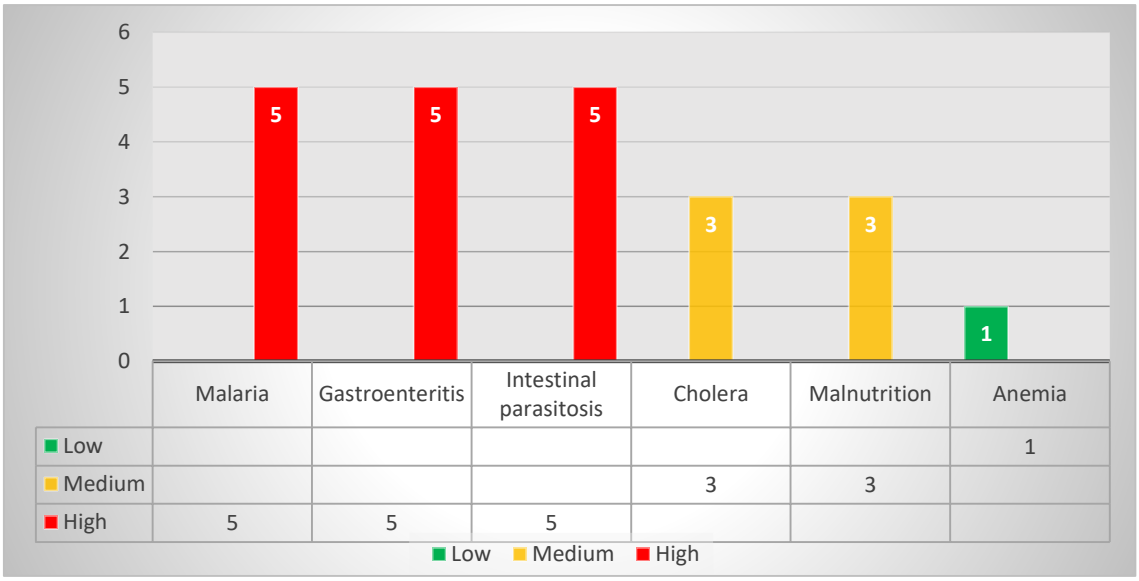

Figure 6: Flood-related ailments in the Municipality of Dangbo
Source: Field surveys, October 2022.

The analysis of Fig. 6 shows that malaria, gastroenteritis and intestinal parasitosis are the diseases with a high frequency of occurrence during floods in said municipality. Malaria, gastroenteritis and intestinal parasitosis account for more than 60% of all recorded diseases. On the other hand, cholera and malnutrition are the diseases whose frequency of occurrence is average. They are located between 25% and 35%. The low-frequency disease of which flooding is the cause in the municipality of Dangbo is anemia (less than 10%). Floods increase the risk of fecal-oral diseases transmit pathogens such as malaria, cholera, intestinal parasitosis, gastroenteritis etc .... People can also be injured by falling trees, power lines or other debris.

Indeed, water and faecal hygiene is precarious in said localities. Surface waters generally contain microorganisms (bacteria, viruses, protozoa) and chemical substances (lead, benzene etc ...) that can affect human health. As a result, the waters resulting from the floods are the main reservoirs of the parasites that are at the origin of gastroenteritis, intestinal parasitosis and cholera from which the population suffers because of the use of these waters for drinking and for other uses. Also the flood ravages the crops which leads the population to unhealthy consumption. This causes malnutrition. Moreover, an ineffective treatment of this malnutrition can lead to anemia.
The flood forces the closure of some health centers which makes access to care much more difficult for the population sometimes causing human losses given the journey to reach a health center that is still operating during this crisis. Plate 1 shows the Késsounou health center completely flooded.

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Plate 1: Flooded Késsounou health center
Shooting: Sodji, October 2022.

Plate 1 shows the Késsounou health center which was invaded by water during the floods, which led to the abandonment of the latter.

3.2.2. Diseases related to drought in the municipality of Dangbo

Figure 7 shows the drought-related diseases suffered by the population in the municipality of Dangbo.

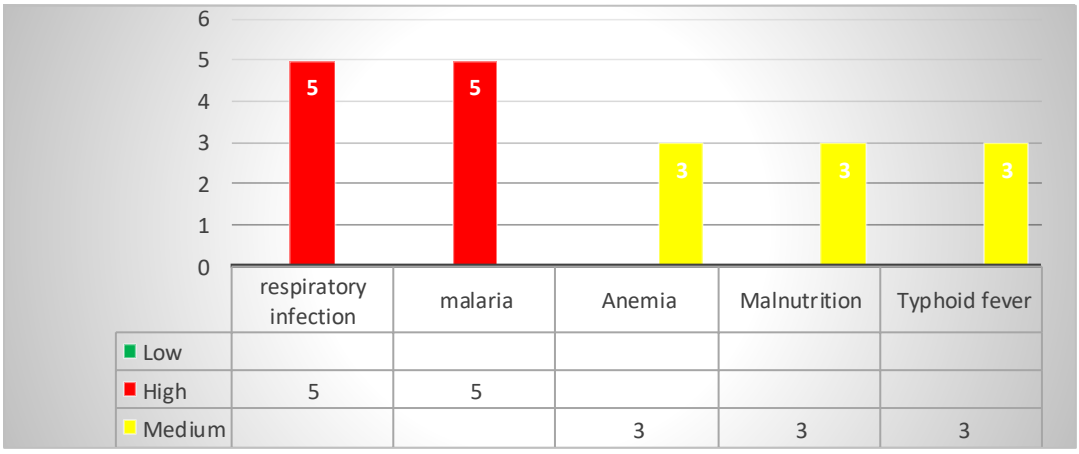

Figure 7: Drought-related diseases in the municipality of Dangbo.
Source: Field Surveys, October 2022.

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The analysis of Figure 7 shows that respiratory diseases malaria and are the most frequent drought-related diseases in the municipality of Dangbo. Malnutrition, typhoid fever and anemia have an average frequency of occurrence during droughts.

Indeed, there is a strong appearance of malaria during this period. It should also be noted that during this time, the heat promotes the effect of dust, which leads to respiratory ailments. Anemia comes from acute malaria in children from 0 to 5 years old, which leads to high mortality in children.

Some localities at risk, part of the population find it difficult to acquire good food during the drought since they are poor; which leads to poor nutrition. This poor diet causes malnutrition and typhoid fever. Figure 8 shows the categories of people most affected by the diseases observed in the municipality of Dangbo.

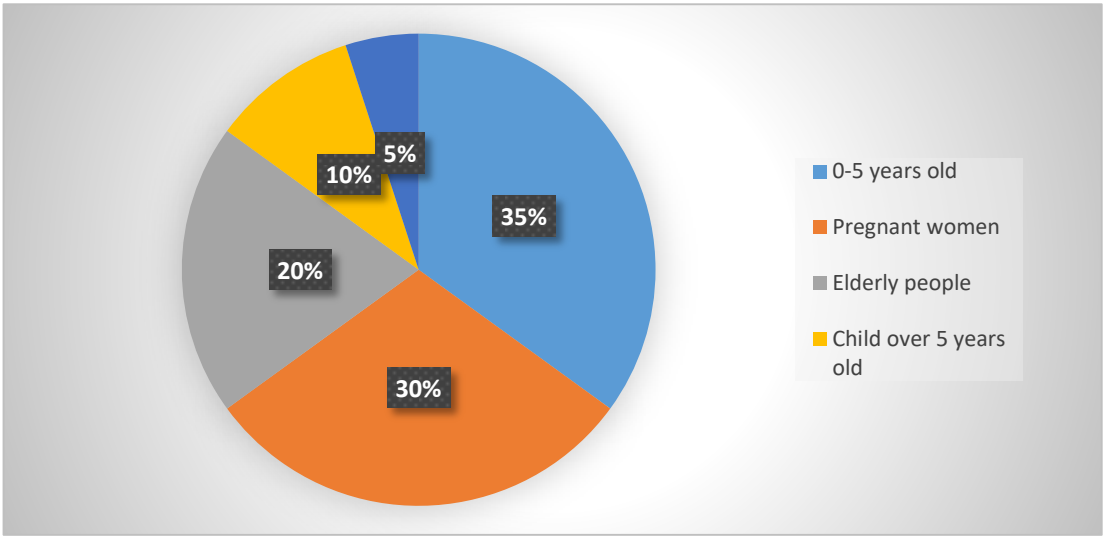

Figure 8: Vulnerability rate of categories of people to climate extremes
Source: Field Surveys, October 2022

The analysis of Figure 8 shows that children under the age of 05, pregnant women and the elderly represent more than 85% of the types of vulnerable people. According to the surveys carried out in the commune of Dangbo, children from 0 to 5 years old, pregnant women and the elderly are the most vulnerable and the most affected by diseases linked to extreme events. This refers to the writings of the PAS-PNA 2019 stipulating that children under the age of 5, pregnant women and the elderly are the units most vulnerable to climatic parameters.

3.3. Impacts of climate extremes on the living environment in the commune of Dangbo

There are many impacts that climate extremes have on the living environment in the commune of Dangbo. We have disturbances or difficulties negatively impacting the living environment.

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3.3.1. Problems of the living environment related to the flood in the commune of Dangbo.

Figure 9 shows the main living environment disturbances related to the flood in the town of Dangbo.

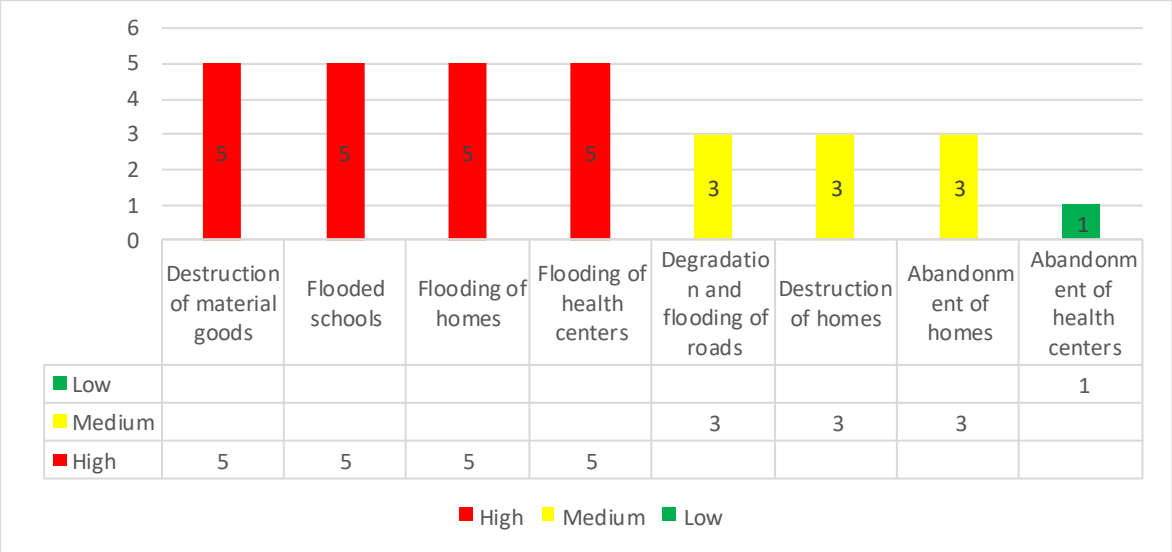

Figure 9: Disturbances of the flood on the living environment in the commune of Dangbo
Source: Field Surveys, October 2022

The analysis of Figure 9 shows that the flooding of health centers, the destruction of material goods, the flooding of schools as well as the flooding of homes are the disturbances and difficulties with a high frequency of occurrence. The degradation and flooding of roads, the destruction of homes as well as the abandonment of homes have a medium frequency of occurrence. Finally, there is a low incidence of abandonment of health centers. The overflow of the river and the heavy rains contribute to the flooding of human settlements such as: homes, schools, health centers as well as roads which, moreover, inaccessible prevents access to schools and health facilities. The other reason is the fear of drowning of the students as well as the flooding of the classrooms which forces to postpone the start of classes. Plate 2 shows two completely flooded establishments

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Plate 2: View of the public primary school of Hêtin-sota (2.1) and Kédonou (2.2) flooded
Shooting: Sodji, October 2022.

Plate 2 shows the public primary schools of Hêtin-sota and Kodonou completely flooded which led to the postponement of the start of classes. Indeed, the flooding of homes leads to the destruction of material goods as well as the destruction of some homes which forces the victims to abandon their homes (plate 3).

Plate 3: Submerged dwellings in Adjido
Shooting: Sodji, October 2022.

Plate 3 shows submerged dwellings in Adjido that users must have abandoned during periods of floods.

3.3.2. Living environment problems related to the drought in the municipality of Dangbo.

Figure 10 shows the main disturbances in the living environment related to the drought in the municipality of Dangbo.

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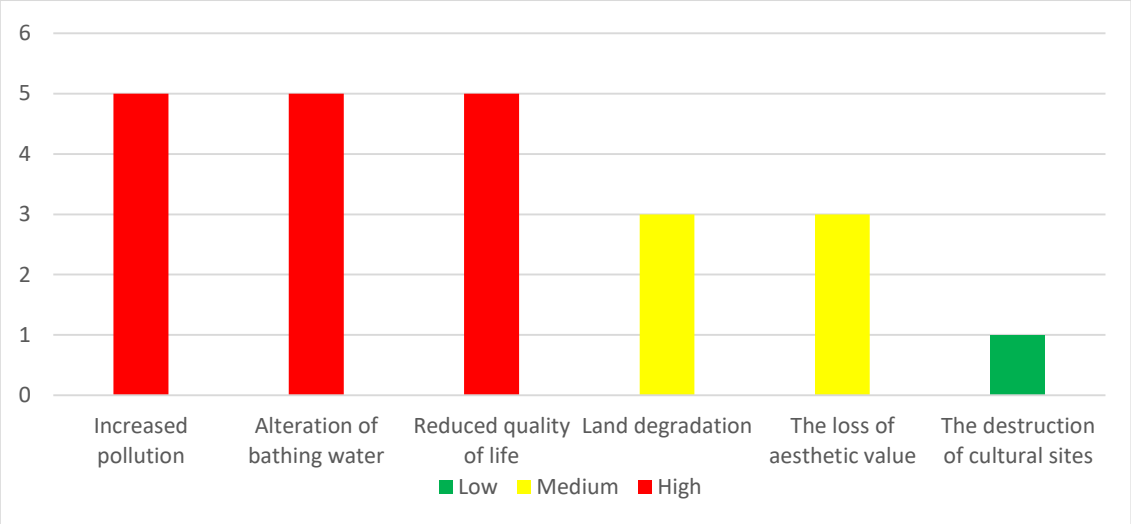

Figure 10: Disturbances or difficulties in the living environment related to the drought in the commune of Dangbo
Source: Field Surveys, October 2022

The analysis of Figure 10 shows that the increased pollution, the alteration of bathing waters and the reduction of the quality of life are the main disturbances of the living environment linked to the drought in the commune of Dangbo. Land degradation and loss of aesthetic value follow, while the destruction of cultural sites occurs at a low rate.

An increased pollution occurs in the absence of precipitation, which contaminates the waters as well as the surrounding area, which, moreover, subsequently contaminates humans. Subsequently, the alteration of bathing waters is observed by an increase in turbidity, the development of algae as well as cyanobacteria. As for the reduction in the quality of life, this is due to the change in lifestyle with an increased increase in poverty in general. Note the degradation of the land and the loss of aesthetic value is observed especially through the dwellings and cultural sites which are sometimes destroyed for the benefit of other ends.

Conclusion

This research on the impacts of climate extremes on human health and the living environment has made it possible to highlight that floods and droughts strongly impact human health and the living environment in the municipality of Dangbo.

Indeed, the results obtained show that floods and droughts are the main climatic extremes recorded in the municipality of Dangbo. They are caused by rain (rainwater flooding), the overflow of the river (river flooding). Moreover, the analysis of the impacts that these climatic extremes have on human health and the living environment reveals several diseases and disturbances on the living environment. Among these, there are among others: malaria,

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respiratory diseases, intestinal parasitosis, gastroenteritis, cholera etc ... as ailments and destruction of material goods, flooding of schools, flooding of homes, increased pollution, alteration of bathing water, reduction of quality of life etc ... disturbances on the living environment. The resurgence of climatic extremes, in particular floods and droughts, constitute a brake on the sustainable and economic development of the municipality of Dangbo and to succeed in adapting communities to climatic extremes, it is necessary to continue research but above all to promote the results of research that are already carried out in order to strengthen their resilience capacities in the face of these phenomena.

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