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Climate variability and coastal maritime areas: Perceptions of artisanal marine fishermen in the municipality of Grand-Popo, Benin

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Abstract :

Benin, a West African country bordered by the Gulf of Guinea, derives a significant portion of its Gross Domestic Product (GDP) from the agricultural sector, with fishing making a notable contribution. The fishing sector in Benin comprises inland fishing, artisanal marine fishing, and industrial marine fishing, which account for approximately 75%, 24%, and 1% of the national fish production, respectively. Grand-Popo stands out among Benin's five major coastal municipalities due to its substantial contribution to national output from artisanal marine fishing. For several years, Grand-Popo has been facing significant climate variability, which increasingly affects the output from artisanal marine fishing. The study aims to assess the impact of climate variability on the coastal areas of Grand-Popo. To this end, local rainfall data, national artisanal fishing statistics, and a socioeconomic survey of fishermen in the municipality were analyzed. An analysis of rainfall data collected in Grand-Popo between 1970 and 2017 highlights a correlation between drought episodes (severe or moderate), notably in 2000, 2005, 2007, 2011, and 2017, and notable declines in national artisanal fishing production. The year 2000, marked by a severe drought, recorded the lowest production (5,320 tons) during the period from 1998 to 2018. Nearly all artisanal marine fishers (99.58%) perceive this climate variability and report that it manifests through irregular rainfall distribution, rising temperatures, and its impacts include ecosystem degradation, migration and disappearance of certain species, rising sea levels, and coastal erosion. In conclusion, climate variability hurts fishing statistics in Grand-Popo and at the national level.

Keywords: Grand-Popo, Climate variability, Artisanal marine fishing, artisanal marine fishers

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1. INTRODUCTION

Benin, one of the West African countries located on the coast of the Gulf of Guinea, is characterized by a subhumid tropical climate that is increasingly subject to substantial variability or changes according to time and analysis scales. The consequences of this remain harmful to sustainable development (Chede, 2020). According to the DHP, Benin's fishing industry plays a significant role in the national economy. According to INSAE 's national accounts department, national production fell from 30626 tonnes in 2003 to 20196 tonnes in 2015, a reduction of 3894 tonnes (INSAE, 2024). As a result, this sub-sector is in decline. This fall can be explained by natural disturbances (rising sea levels, silting up of coastal areas, etc) and man-made factors (pollution, use of unregulated fishing methods and gear). Marine resources are in real danger and may no longer survive in the face of this phenomenon. Several studies have been carried out to investigate this problem. Still, few have focused on the city of Grand-Popo, where the population is directly dependent on marine resources and is highly exposed to climate change and its impact on artisanal fishing activities. This study aims to analyze the vulnerability of Grand-Popo's maritime coastal areas to the effects of climate variability.

2. MATERIALS AND METHODS

2.1. Presentation of the study zone

Grand-Popo is a coastal town in the Mono department, bordered to the north by the communes of athiémé, comé, and houeyogbé, to the south by the Atlantic Ocean, to the southwest by the Communes of Ouidah and Kpomassè, and the west by the Republic of Togo. Geographically, it lies between latitude 6°17' North and longitude 1°49' East, at an altitude of 5 m above sea level (Agbossou, 2010). The commune is 35 km long, with a surface area of 289 km² (Dossa, 2007), including 10 km² of barrier beach (Capo-chichi, 2006). Like the rest of the coastal region, Grand-Popo enjoys a sub-

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equatorial Guinean climate, with two dry seasons (early November to mid-March and early August to mid-September) and two rainy seasons (late March to late July and late September to late October). Due to the maritime influence, temperatures (ranging from 23°C in August to 34°C in March, with an annual average of 27.7°C) are characterized by slight diurnal and annual variations, with high relative humidity between 70% and 90% (Atidégla, 2016). From 1970 to 2017, the average yearly rainfall was around 948.56 ± 235.41 mm (ASECNA, 2019).

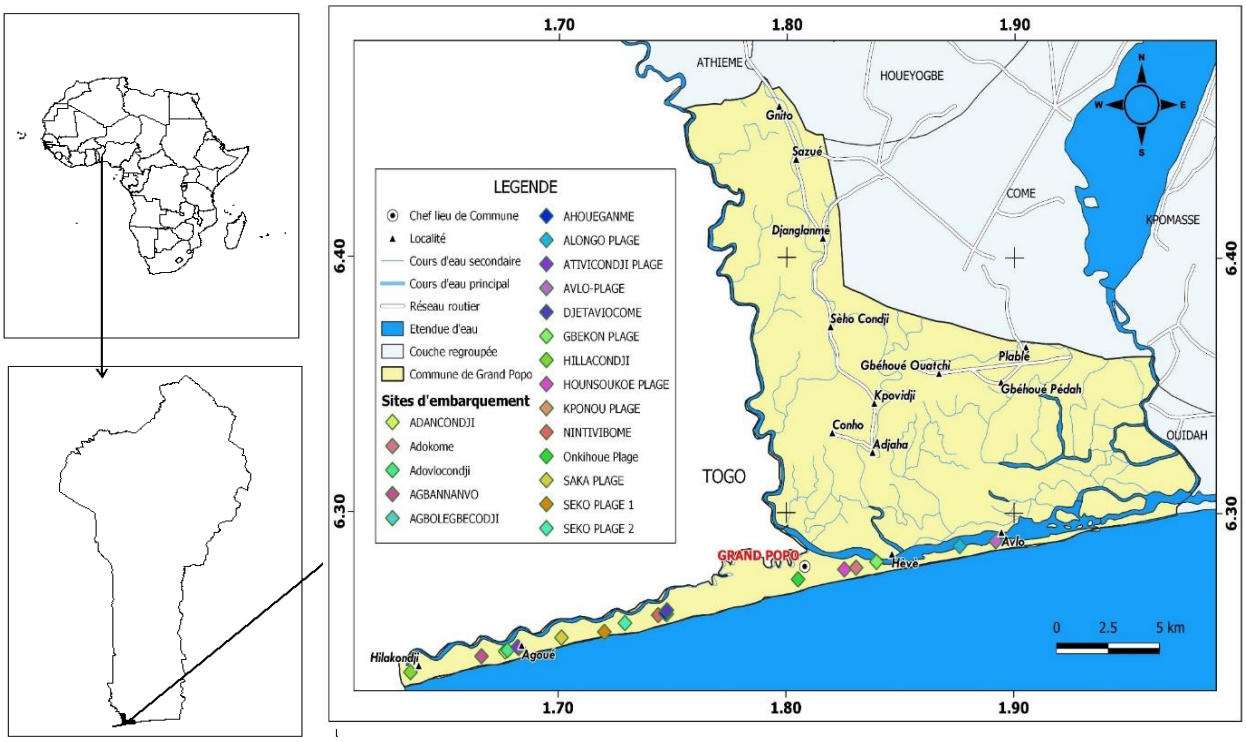

Figure 2.1. Map of the Municipality of Grand-Popo

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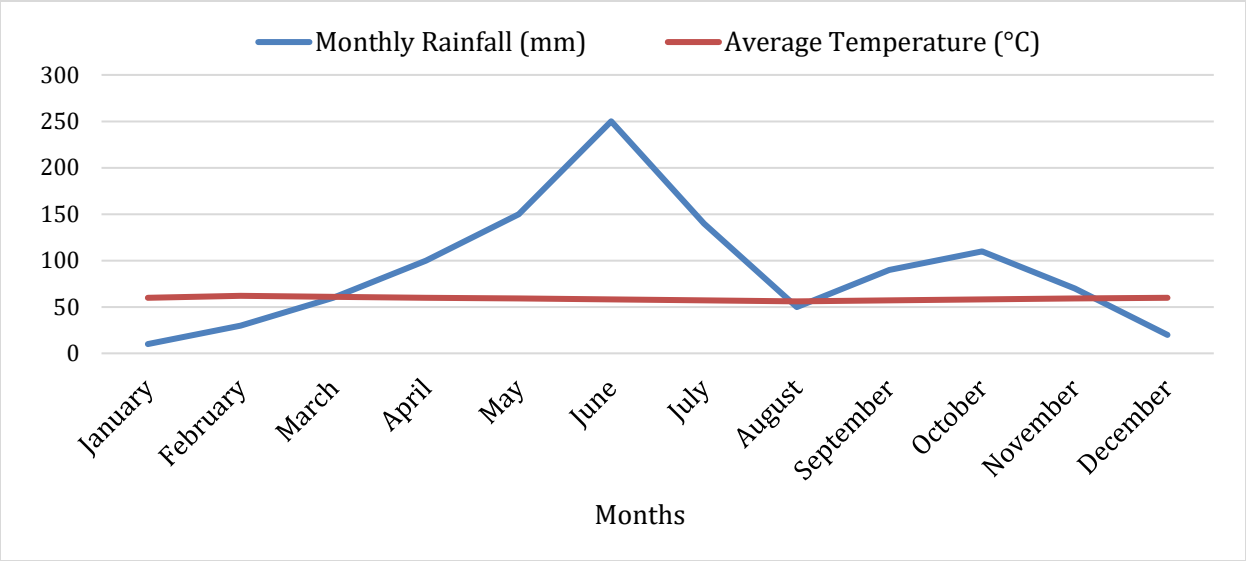

Figure 2.2. Umbro thermal diagram for the commune of Grand-Popo (METEO-Benin, 2019)

2.2. Data collection & analysis

2.2.1. Climatic Data of Grand-Popo

For this study, the data used are rainfall data for the commune of Grand-Popo available from 1970 to 2017 on a daily scale in the database of the national meteorological agency (METEO-Benin). The annual rainfall deficit is estimated by calculating the rainfall variability index, the deviation from the mean index, using an Excel spreadsheet. This deviation from the mean is the difference between a year's rainfall height (mm), xi, and the mean annual rainfall height (mm) $\bar{X}$ of the series, averaged by the standard deviation **(**LAMB**,** 1985**)**.

$$I_{(i)} = (Xi - \bar{x}) / \sigma$$

2.2.2. Socio-economic data (Survey)

Socio-economic data were collected through an individual survey on artisanal marine fishermen's demographic and socio-economic characteristics and their perceptions of climate variability. A total of 240 fishermen living along the coast were randomly selected and surveyed according to well-defined criteria: gender, age: (J) young

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people (age ≤ 35 years); (A) adults (35 years < age ≤ 60 years) and (V) elderly people (age > 60 years), level of education, fishing experience, length of time living on the coast (Assogbadjo, 2008). The size of the sample surveyed (n) is determined by Dagnelie's formula:

$$(1) \quad n = \mu^2_{\left(1-\frac{\alpha}{2}\right)} \frac{p(1-p)}{\delta^2}$$

- n is the sample population of the artisanal marine fishermen population;
- (1-α/2) is the value of the reduced centered normal distribution for a 95% confidence level, and corresponds to 1.96;
- P is equal to the estimated proportion of the artisanal marine fishermen population of the thirteen villages visited to the total artisanal marine fishermen population;
- δ is the margin of error of the estimation of any parameter that could be calculated in the study, and the value of 5% is considered.

Table 2.2.2. Demographic and socio-economic characteristics of respondents.

VARIABLES		Ages et sexes						
		JH	JF	AH	AF	VH	VF	Total
Municipality	Grand-Popo	87	0	120	0	33	0	240
Maritime Fishing Experience (X)	0<X≤10	31	0	16	0	2	0	240
	10<X≤20	44	0	23	0	1	0	
	20<X≤30	12	0	38	0	3	0	
	X>30	0	0	43	0	27	0	

JH= Young man; JF= Young woman; AH= Adult man; AF= Adult woman; VH=Old man; VF=Old woman

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2.2.3. National Artisanal Marine Fishing Production Data

Due to the lack of specific data on artisanal marine production in the municipality of Grand-Popo, national-level data were collected from the BENIN Data Portal to assess the fluctuations in artisanal marine production across the country from 1998 to 2017.

3. RESULTS

3.1. Climate Analyses and Perceptions of Respondents

3.1.1. Analysis of rainfall interannual variability

The municipality of Grand-Popo has recorded quite variable rainfall patterns over time. Rainfall data collected between 1970 and 2017 have been analyzed, and the results are presented in the graphs below.

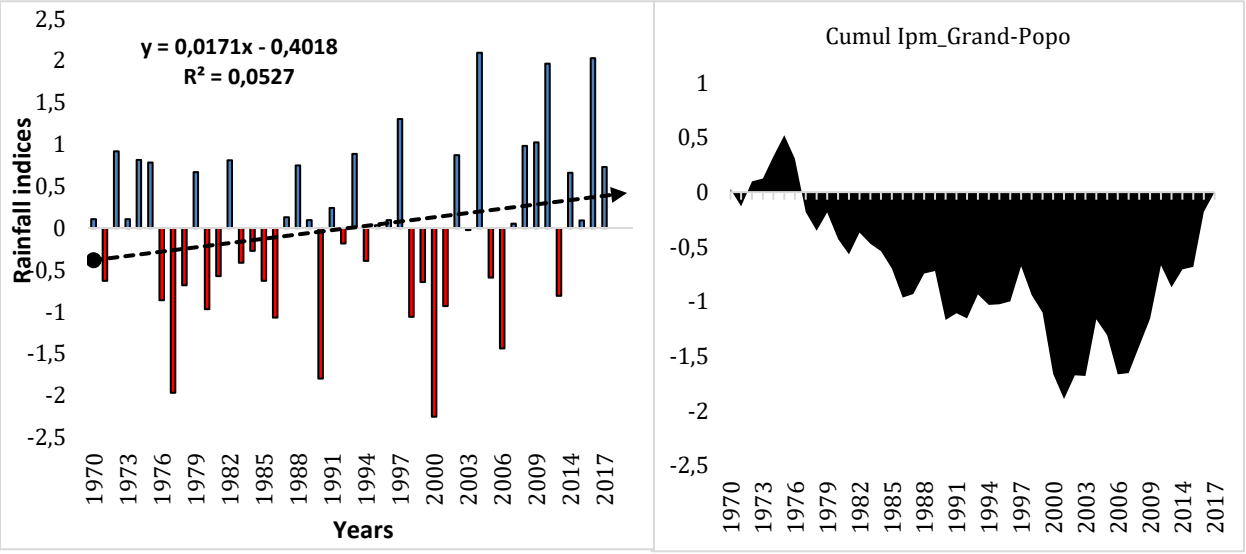

Figure 3.1.1: Graphs of IP and cumulative Ipm rainfall indices for the Commune of Grand Popo

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Examining the graphs of the IP and cumulative Ipm rainfall indices for the Commune of Grand-Popo reveals two main periods:

* The first period, from 1970 to 1992, is known as the deficit period, which is characterized by a preponderance of dry years interspersed with a few wet years. It was characterized by an average annual rainfall of 900.94 mm.
* The second period, known as the surplus period, spans 1971-2017 and averages 996.17 mm, which can be divided into two subperiods: the first period is 1971-2017, and the second period is 1971-2017, and averages 996.17 mm:
  - Corresponding to the period 1993-2006, this cycle, referred to as surplus, is characterized by the dominance of wet years. An average of 913.87 mm characterizes it.
  - Defined between the decades 2006-2017, it is called a period of high surplus due to the predominance of wet years combined with a low number of dry years. Its average is 1124.2 mm.

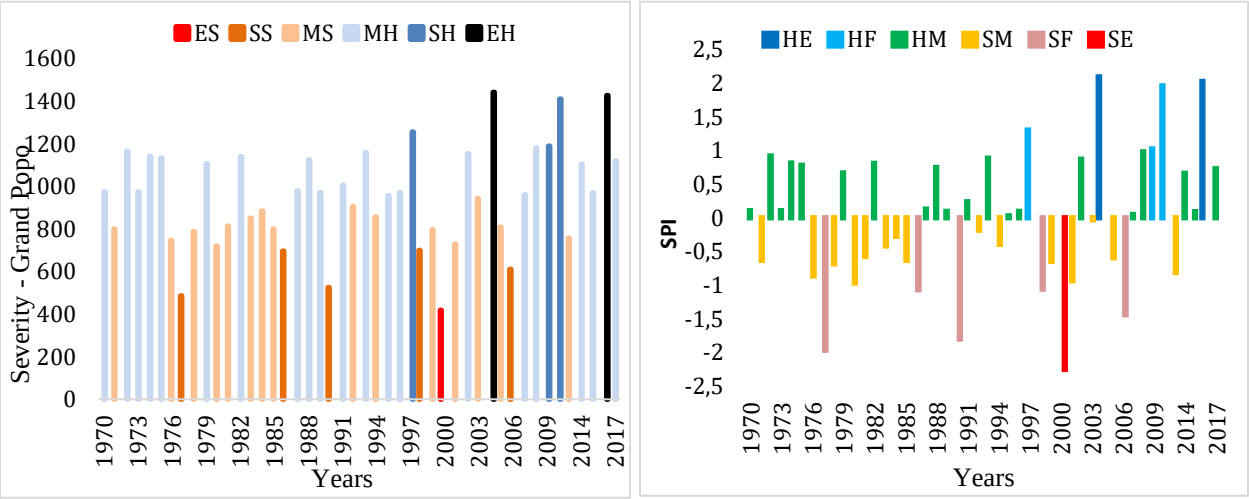

Figure 3.1.2: Characterization of years based on severity graphs

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Moderate rainfall (MH) was recorded in most years, indicating a predominance of wet years in the commune of Grand-Popo from 1970 to 2017. Highly wet years (SH & EH) have been observed since the 2000s.

Periods of drought (ES, SS & MS) were more frequent before the 2000s, with the year 2000 being the driest. From 2004, most years became predominantly wet, with extreme peaks in 2004 and 2016.

In the commune of Grand-Popo, there is a general trend of increasing precipitation, especially after the 2000s, with more frequent droughts before this period. This suggests a possible climate change or significant inter-annual variability affecting rainfall in the region.

3.2. Perceptions of Respondents

3.2.1. Perception of Climate Change

Almost all (99.58%) of the fishermen interviewed perceived climate variability as a real phenomenon in the commune of Grand-Popo. The perceptions according to socio-economic groups are presented as follows:

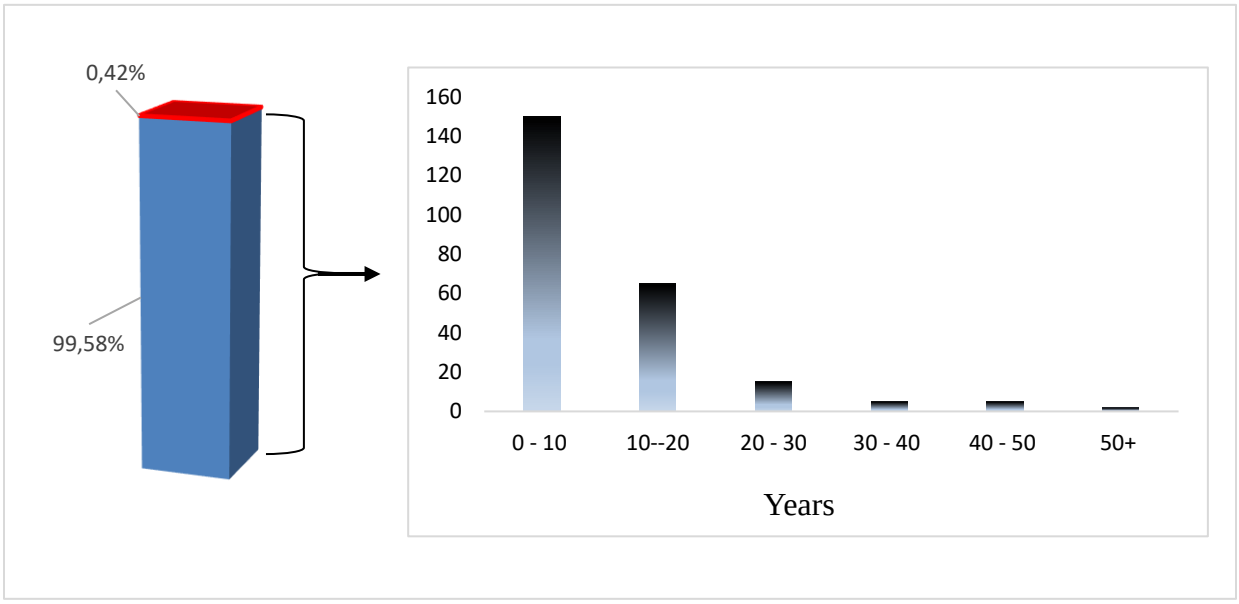

Figure 3.2.1: Perceptions of Grand-Popo coast marine fishermen about climate variability

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This figure presents a detailed diagram that highlights the artisanal marine fishermen who have positively acknowledged the observation of climate change, based on the date of observation. For example, 62.33% of the respondents believe that climate change has occurred only in the last decade, while 25.94% of this population claim to have observed this change between the decade of 1989-1999. On the other hand, 6.69%, 2.51%, and 1.67% of artisanal fishermen stated that climate change had occurred in the following periods: 1989-1999, 1989-1979, and 1979-1969, respectively. In addition, 0.83% verbally state that they have observed changes in climatic parameters more than fifty years ago.

3.2.2. Perceptions of the climatically modified parameters

The modification of climatic parameters (rainfall, temperature, wind, sunshine duration) due to climate change is perceived differently by the fishermen interviewed. These perceptions of the change in climatic parameters are presented in the following figure.

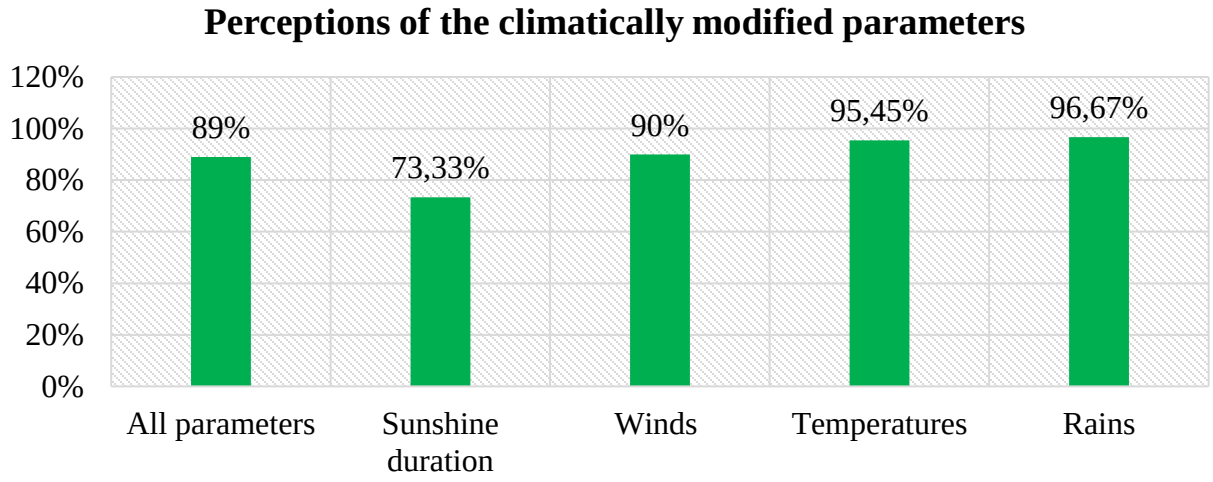

Figure 3.2.2: Perceptions of the climatically modified parameters

Climate variability in the municipality of Grand-Popo is perceived differently by the surveyed fishermen depending on how certain climatic parameters are modified. Indeed, 96.67%, 95.45%, 90%, and 73.33% of the respondents affirmed the respective modification of rain, temperature, wind, and sunshine duration.

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3.2.3. Perceptions of climate variability manifestations

Climate variability is manifested through an increase in areas of drought, a longer period of intense sunlight, an increase in solar intensity, uneven rainfall distribution, rising temperatures, rainfall variability, and a decrease in rainy days. The figure below provides insights into the fishermen's perceptions of the manifestations of climate change in the Grand-Popo community.

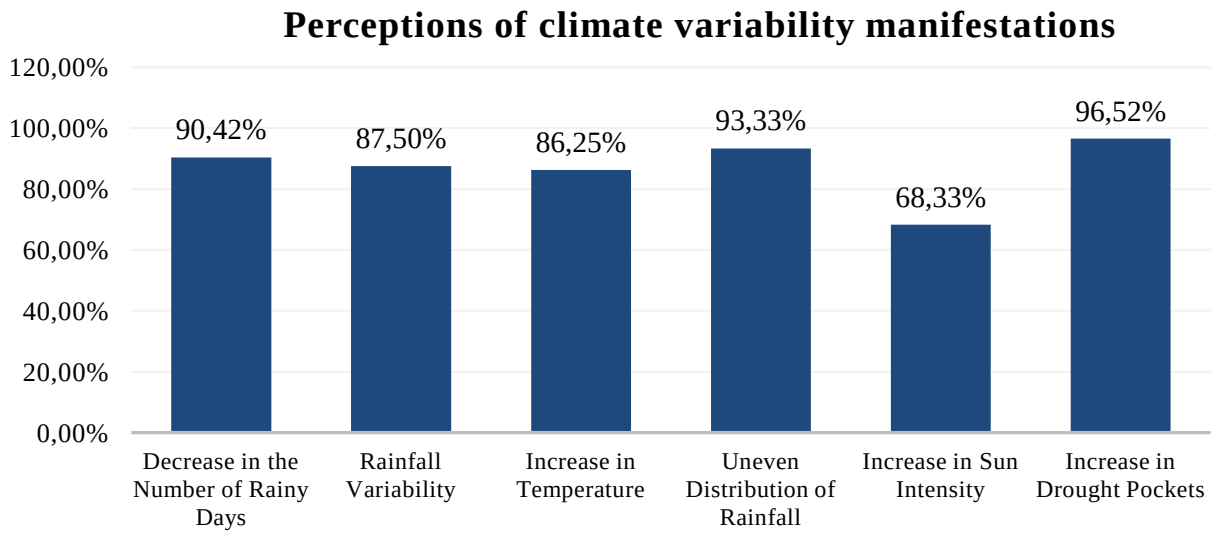

Figure 3.2.3: Perceptions of climate variability manifestations

According to the previous figure, all respondents describe their perceptions of climate variability through several parameters. For example, 87.5% of the fishermen interviewed observed a gradual decrease in rainfall, and 90.42% stated that the number of rainy days per year was also decreasing. In addition, 86.25%, 68.33%, and 93.33% of the fishermen have observed an increase in temperature, an increase in sunlight intensity, and an uneven distribution of rainfall, respectively.

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3.2.4. Perception of the impacts of climate variability

The results of the field surveys show that farmers identify the impacts of climate variability as: sea level rise (89.58%), ecosystem degradation (70.25%), species migration (68.75%), sea advance (100%), increase in the speed of ocean currents (73.33%), and decrease in the intensity of coastal rise (52.08%).

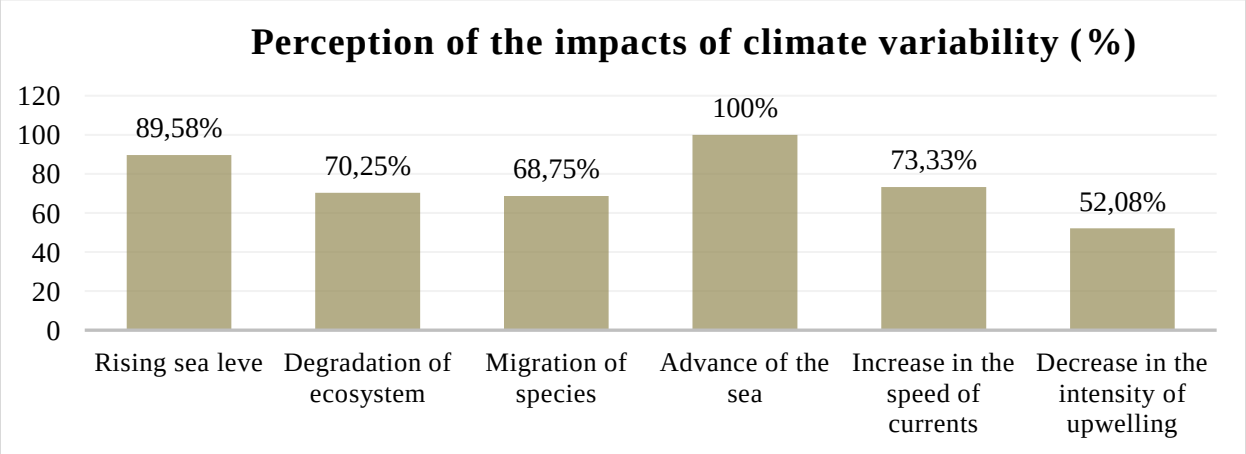

Figure 3.2.4: Perception of the impacts of climate variability

3.2.5. Fishermen's perceptions of the decline in fish catches

The decline in catches is strongly observed in the commune of Grand-Popo. About 87.5% of the respondents confirm this, compared to 3.3%. On the other hand, 5% of the surveyed fishermen report a variation in catches, while 4.2% observe no change.

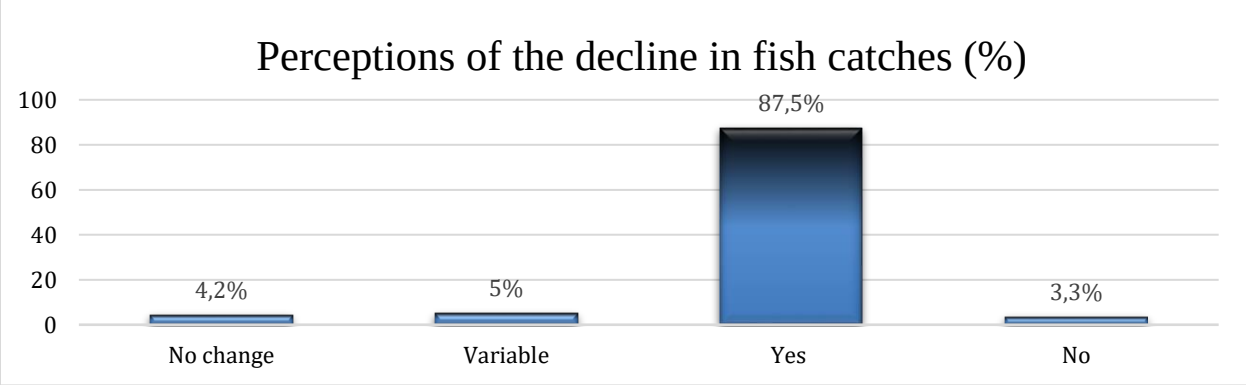

Figure 3.2.5: Perceptions of the decline in fish catches

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3.3. Artisanal marine fishing catches in Benin

The distribution of the total fisheries catches in Benin between 1998 and 2017 is categorized into three main sectors: industrial marine fisheries, inland fisheries and aquaculture, and artisanal marine fisheries. Inland fisheries and aquaculture account for 74.25% of the country's total production, which amounts to 614.177.353 tons. This shows that the majority of fishery resources come from inland waters and aquaculture. Artisanal marine fisheries account for 24.66%, which is a significant share but still much lower than inland fisheries.

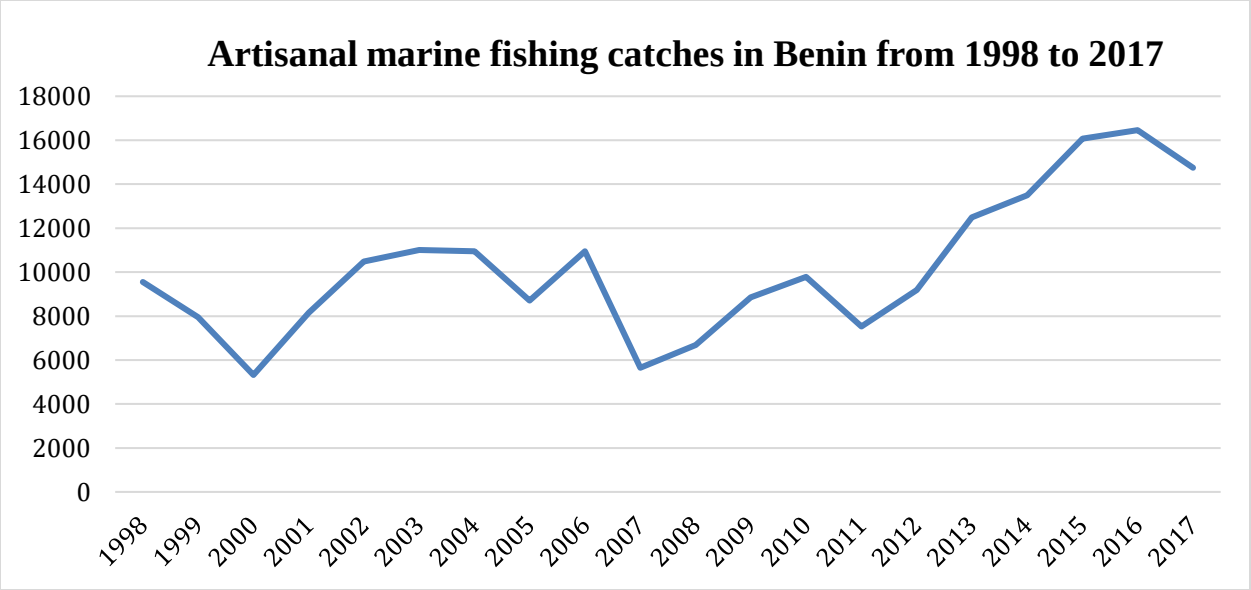

Figure 3.3: Artisanal marine fishing catches in Benin from 1998 to 2017 (in tons)

The graph shows the catches of artisanal marine fisheries in Benin from 1998 to 2017, expressed in metric tons. There are strong fluctuations in catches from 1998 to 2012, with significant declines observed in 2000 and 2007, indicating years of low production. Despite these fluctuations, significant increases are observed in 2002, 2003, and 2006. Since 2013, production appears to have been steadily increasing. The highest values were recorded in 2015 and 2016, when they exceeded 16,000 tons.

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4. DISCUSSIONS

As perceived by 99.58% of the artisanal marine fishers, the rainfall data confirm a climatic variability in the commune of Grand-Popo from 1970 to 2017. This climatic variability, with a humid trend, is characterized by several periods of severe drought (1977, 1986, and 1990) and extremely severe drought (2000). The year 2000 was the driest in the commune of Grand-Popo, coinciding with the lowest artisanal marine fishing yield (5,320 tons) recorded during the period 1998-2017.

After 2000, there was a shift marked by a gradual increase in rainfall, with peaks in 2004 and 2016. These years were more favorable in terms of marine resources, with production reaching 16,458 tons in 2016.

The years 2005, 2007, 2011, and 2017, characterized by periods of severe or moderate drought, correspond to periods of decline in the production of artisanal marine fisheries. Climate variability in Grand-Popo commune is characterized by irregular rainfall distribution and increasing temperature (Audrey, 2015). The increase in temperature, combined with rainfall variability, negatively affects fishing activities (FAO, 2012).

Increases in sea surface and ambient air temperatures alter the physicochemical properties of water, leading to decreases in oxygen and pH, coupled with sea-level rise. This phenomenon disrupts marine ecosystems, causing the migration or disappearance of species that are unable to adapt to these new conditions. The growth of the few species that can adapt is also affected, leading to a change in trophic networks, a loss of biodiversity, and a decrease in marine productivity (Laubier, 2003). In Benin, climate change has slowed the growth of fish larvae, increased the mortality rate of certain fish species, and proliferated ichthyotoxic plants, making fishing activities more difficult (Dessouassi, 2013). Coastal erosion, one of the impacts of climate change, affects coastal habitats and landing structures, leading to a redistribution of species and a decline in the abundance of key marine resources (Periasamy, 2023).

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5. CONCLUSIONS & RECOMMENDATIONS

The analysis of rainfall data reveals that the municipality of Grand-Popo has experienced climate variability. This variability has varied in intensity over the period from 1970 to 2017. This variability has a significant negative impact on fishing activities in Grand-Popo and across the country as a whole. Changes in rainfall patterns and coastal conditions have contributed to a decline in artisanal marine fishing yields. The perceptions of local fishermen further confirm the growing challenges associated with climate instability, which affect both their livelihoods and the sustainability of marine resources.

To deal with the effects of climate change in the coastal areas of Benin, particularly in Grand-Popo, targeted recommendations are directed toward government authorities:

- Establish a fisheries monitoring committee tasked with identifying the challenges faced by fishermen and proposing appropriate solution-oriented approaches,
- Encourage the expansion of studies and research in the field of marine ecology,
- Promote alternative livelihoods to reduce the economic vulnerability of coastal communities,
- Support fishermen through capacity-building programs focused on climate adaptation and sustainable fishing practices,
- Implement coastal protection measures to mitigate the effects of sea-level rise and coastal erosion,
- Establish financing banks dedicated to supporting fishermen, and allocate a research support budget to facilitate scientific studies.

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