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(RESEARCH ARTICLE)

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Impacts of climate variability and change on Lake Guidimouni (Zinder/Niger) and its provided ecosystem services

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Abstract

Extreme climatic events are becoming more and more severe and frequent. In Niger, Lake Guidimouni an international value eco-geographic area which is home to significant biodiversity is not spared from the effects of climate change. The objective of this study was to assess the impacts of climate variability and change on the Lake Guidimouni. In this order, tendencies and variabilities of climatic factors were examined, while the ichthyological and avian faunas were studied. To complete these data, field observations were organized and surveys were conducted among local populations and municipal technical services. It appears from the results that, floods and invasive plants such as *Typha australis*, *Eichornia crassipes* are among the most common occurrences of climate variability and change effects according to 62% of respondents. According to 38% of respondents, there was an increase in the surface area of the lake Guidimouni, which has a strong impact on the socio-economic activities of populations, particularly fishing and transport throuth the lake. These events lead to a decrease in the abundance of some species of fish such as *Bagrus bajad* and *Heterotis niloticus* and birds (e.g. *Burhinus senegalensus*). In terms of fish and aquatic birds' diversity, 7 species of fish divided into 4 orders, 6 families and 7 genera have been identified with a decrease of 320 tons in the fish stock between 2021 and 2022, while 34 bird's species belonging to 10 orders, 16 families and 24 genera were recorded. These findings could be a database and a milestone for future studies.

Keywords: Lake Guidimouni; Climate Change; Environment; Ecosystem Services; Natural Resources

1. Introduction

The world is now facing extreme weather events. The impacts of climate change on ecosystems and populations will severely affect Africa particularly the Sahel region [1]. Precipitation tendencies are highly uncertain and forecasts range from a slight decrease to a sharp increase in the total amount of annual precipitation. Both dry and wet periods are expected to become more extreme [2].

Disruptions linked to climate change would particularly affect water resources, agriculture, ecosystem services, health and infrastructures. Indeed. climate warming influences water temperature, stratification processes in the water column. lake mixing dynamics and nutrient availability. These changes in the lake's physicochemical parameters will in turn disrupt plankton phenology. Significant changes could observe in plankton seasonal dynamics and the development dates of key species for fish populations [3]. However, the seasonality varies from one region to another. Tropical lakes, which are home of high biodiversity will be the first to be face to unprecedented conditions when global warming reaches approximately 2.4°C above pre-industrial conditions [4].

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In Niger, Lake Guidimouni is one of the few wetlands listed on the Ramsar list as an international importance site in term of ecosystem services it provides [5]. Indeed. this lake plays a vital role in maintaining biological diversity and the socioeconomic development in the region. However. climate disturbances could impact its functioning. particularly by modifying hydrological regimes and the dynamics of some populations of aquatic organisms. The objective of this study was to identify the impacts of climate change and variability on the resources of Lake Guidimouni in order to propose adaptive measures to local populations.

2. Material and Methods

2.1. Study area and used material

Located in the rural township of Guidimouni in the southeastern part of the Damagaram Takaya district in the Zinder region of Niger (Figure 1). Lake Guidimouni is a rich area in natural resources including fish, amphibians, reptiles and waterbirds. Its biophysical and ecological characteristics have led to its inclusion on the list of Wetlands of International Importance [5]. The material used during this study including survey sheets. fish and waterbird counting sheets, pair of binoculars for birds' observation and identification keys for fish and bird species.

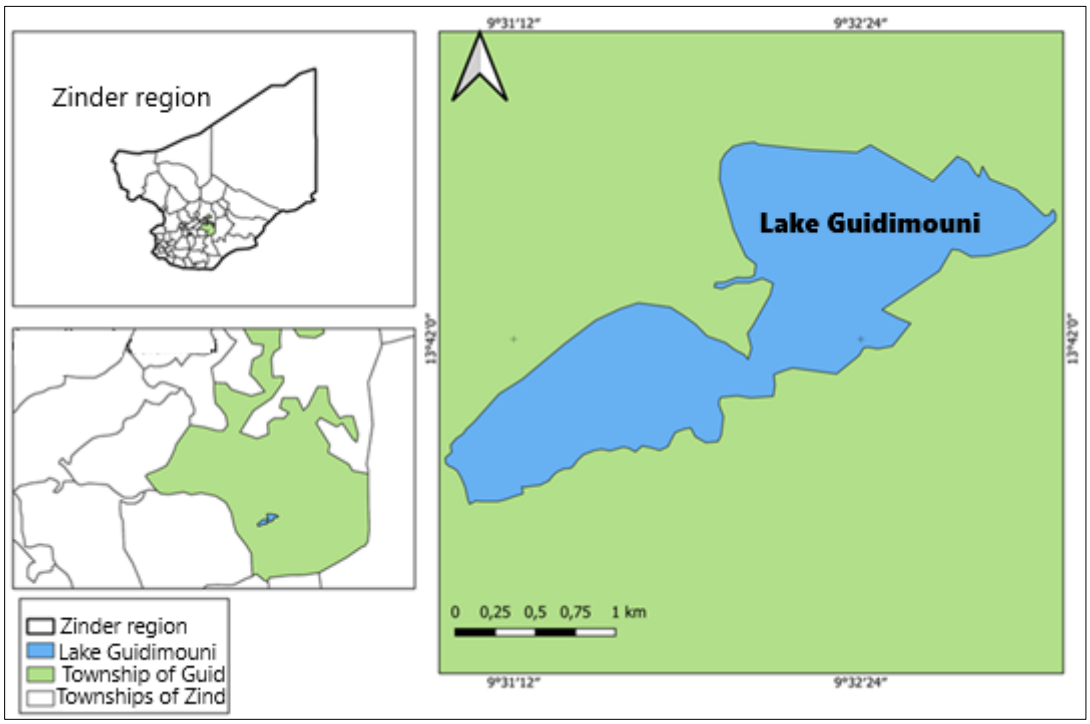

Figure 1 Location of the study area

2.2. Determination of rainfall and temperature tendencies

To highlight the main features of rainfall variability. The rainfall analysis was focused on the tendencies and variability of the cumulative annual and average rainfall from 1994 to 2023. The anomalies (extra and deficits) of the variables are expressed as deviations from the 1994-2024 average. To support the information on rainfall tendencies. The annual temperature averages in the area from 2010 to 2024 were also analyzed.

2.3. Study of fish and bird Fauna

The inventory and identification of fish species were conducted through fishermen's catches from November to December 2023 weekly between 6:00 a.m. and 10:30 when most of fishermen came back from fishing. The captured fish were systematically sorted and identified using identification keys to characterize their population.

With regard to water birds' observation campaigns were organized monthly in the morning between 8:00 and 11:30 and in the evening between 16:00 and 18:00. For this purpose. The birds were systematically observed using a pair of binoculars. identified using identification keys and counted along the shoreline of the Lake.

2.4. Sampling and Survey

The survey was conducted in the rural township of Guidimouni. To collect much data on the impact of climate change on Lake Guidimouni and its ecosystem, the method of reasoned choice was used to select respondents. In fact, 120 people living near the lake at least 30 years. were surveyed.

Data collection was conducted using quizzes developed and administered individually during 30 to 40 minutes per respondent. The quizzes focused on the characteristics of the respondents, the tendency in climate change over the last 30 years and their perceptions on the impacts of climate change on the lake's resources.

2.5. Data processing and analysis

Processing and analysis were performed based on each type of data collected. Data from surveys and identification of fish and bird species were entered, processed and analyzed in Word and Excel. then transferred to SPSS software for statistical analysis. Rainfall records over 30 years were analyzed using average rainfall and rainy days. This allowed us to assess deviation averages from the 1994-2023.

3. Results and Discussion

3.1. Rainfall and temperature tendencies and variabilities

The analysis of rainfall deviations from the average observed between 1994 and 2023 revealed a general sawtooth pattern in rainfall quantities (Figure 2) in the rural township of Guidimouni. Annual rainfall in the study area changed from 232.9 mm to 726 mm. Thus. 2021 was the wettest year (726 mm) with an extra of 305.24 mm. while 2009 was the least rainy year (374.6 mm) with a deficit of -187.86 mm compared to the global average. With regard to the number of rainy days. it varies from 19 to 38 days according to the years (Figure 3). In a Sahelian country, such rainfall is sufficient for runoff and infiltration into the soil, allowing the rise of the lake water level. This result was different from that obtained by Aurélie et al. [6], indicating a decrease in the water level of Lake Fitri in Chad. The increase in rainfall in the lake area is combined with a rise in temperature. These results corroborated those obtained by Abdou Aziz and Larwanou [7] who indicated strong rainfall variabilities with highest rainfall recorded in July and August, and an upward tendency in evaporation and monthly temperature averages in Fakara (Niger).

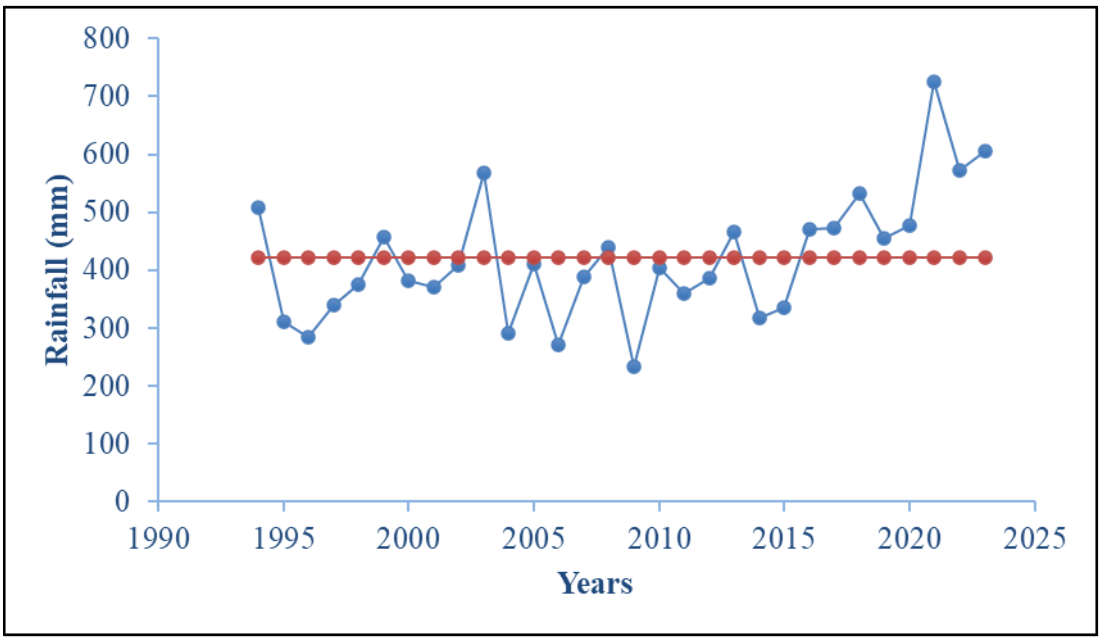

Figure 2 Evolution of rainfall from 1994 to 2023

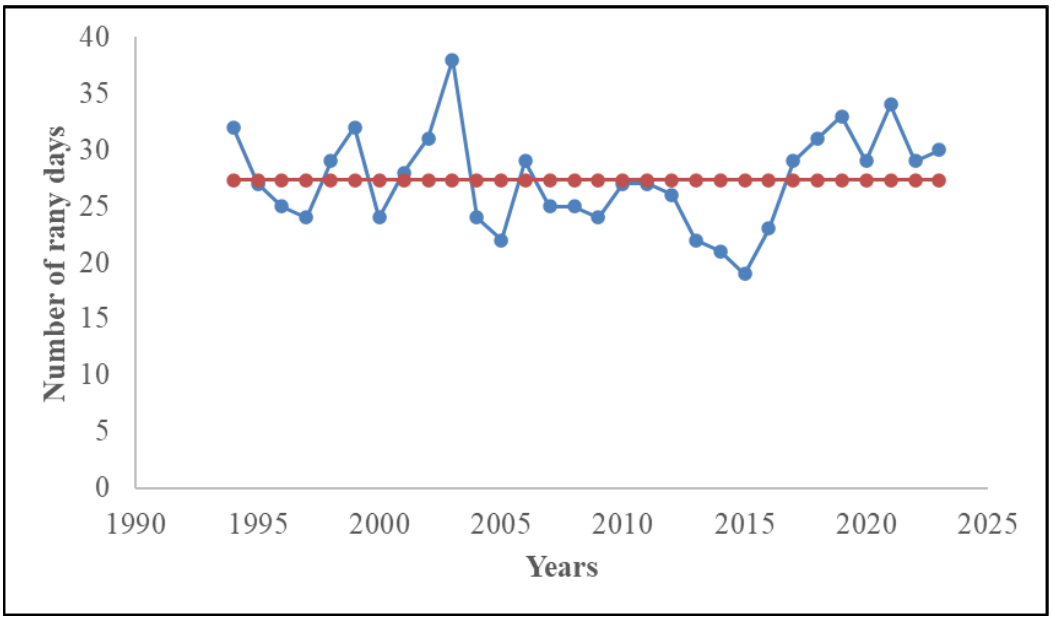

Figure 3 Evolution of rainy days number from 1994 to 2023

To understand the rainfall variability linked to climate disruptions. average annual temperatures from 2010 to 2024 were analyzed (Figure 4). This analysis showed increasing tendency in local temperatures change, while 2020, 2023 and 2024 were the hottest years with respectively 35°C, 36°C and 37°C of temperatures. These findings corroborate those of FMECD [2] who noted that temperature in Niger is expected to increase by 2.0°C to 4.6°C by 2080.

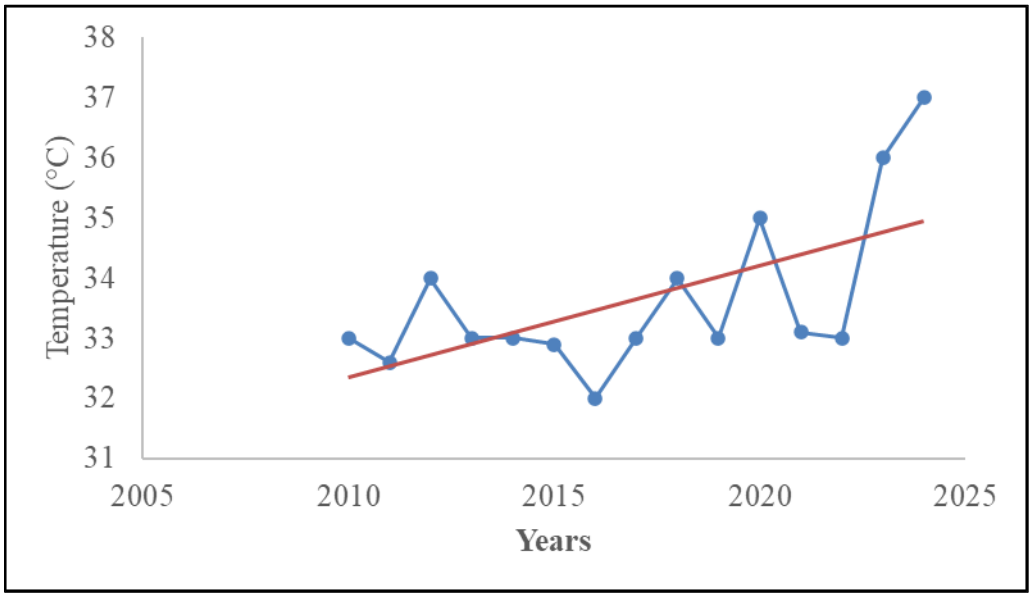

Figure 4 Temperature evolution in the study area from 2010 to 2024

3.2. Study of fish and bird fauna

Seven fish species divided into four orders, six families and seven genera were identified. Cichlid is the most represented family (Table 1). In terms of abundance *Oreochromis niloticus* is the species with the largest number of captured individuals (45.08%), while *Heterotis niloticus* (2.66%) was the least represented species. There was no high fish diversity around the Lake Guidimouni. This result is different from the result reported by Ramsar [5] which noted the presence of 9 fish species. Indeed, *Heterobranchus bidorsalis* and *Hyperopisus bebeoccidentalis* have not been captured in the lake in recent years. This could be linked to rising water levels, which is one of the effects of climate change on the lake. The fish fauna is dominated by the Cichlidae family. This result was similar to that of Issiaka et al. (2018) [8] on Rouafi pond in the Konni district. The dominance of the Cichlidae family can be explained by the fact that species of

this family are tolerant of the lake environmental conditions. Trophic adaptation to contrasting environments is considered one of the main drivers of their evolution [9]. Also, Dieleman et al. [10] indicated that due to recurrent climate variabilities and change, *Oreochromis hunteri* and other cichlidae have adapted perfectly to the change in local habitat.

Table 1 List of the lake fish species

Order	Family	Species scientific name
Perciforms	Cichlidae	*Oreochromis niloticus (Linnaeus, 1759)*
		Tilapia zillii (Gervais, 1848)
	Latidae	*Lates niloticus (Linnaeus, 1762)*
Siluriforms	Clariidae	*Clarias gariepinus (Bürchell, 1822)*
	Bagridae	*Bagrus bajad (Forsskal, 1775)*
Lepidosireniforms	Protopteridae	*Protopterus annectens (Owen, 1839)*
Osteoglossiforms	Arapaimidae	*Heterotis niloticus (Cuvier, 1829)*

34 bird species belonging to 10 orders, 16 families and 24 genera were identified around the lake during the study period. The passeriforms order recorded seven families (38.88%) followed by the charadriiforms and coraciforms orders with two families each (11.11%). The other orders (pstittaciforms, apodiforms, ciconiforms, suliforms, gruiforms, anseriforms, pelecaniforms contained each a single family (5.55%) (Figure 5). This result was different with the findings of Yelakan et al. [11], Toudjani and Maman Nassirou [12] and Issiaka et al. [13] who reported the predominance of the ardeidae family in ciconiforms order. This was probaly due to the fact that ardeidae is a large family of migratory birds with a wide distribution depending on the seasons. However, seasonal variations are increasingly affected by climate change. This could explain the abundance of this family in the area of this study. However, the disappearance of the species *Burhinus senegalensus* was reported and linked to the effects of climate change by 62% of respondents. Indeed. climate change affects birds in many ways. According to Nature Canada [14], whatever the distribution or abundance of populations, their behavior, genetic composition, migration or breeding cycles, climate change has a significant impact on birds. According to Manon [15], because of climate change, thousands of migratory birds are spending less time in Africa or shortening their migration distances to spend the winter in southern Europe. Some have even become completely sedentary. With regard to families abundance, the most diverse was the ardeidae family with seven species (29.59%) followed by the anatidae (6 species) or 17.65%. The rallidae and scolopacidae families which recorded each three species (8.82%) were followed by Charadriidae and Corvidae with two species (5.88%) each, while the other families recorded only one species (2.94%) each.

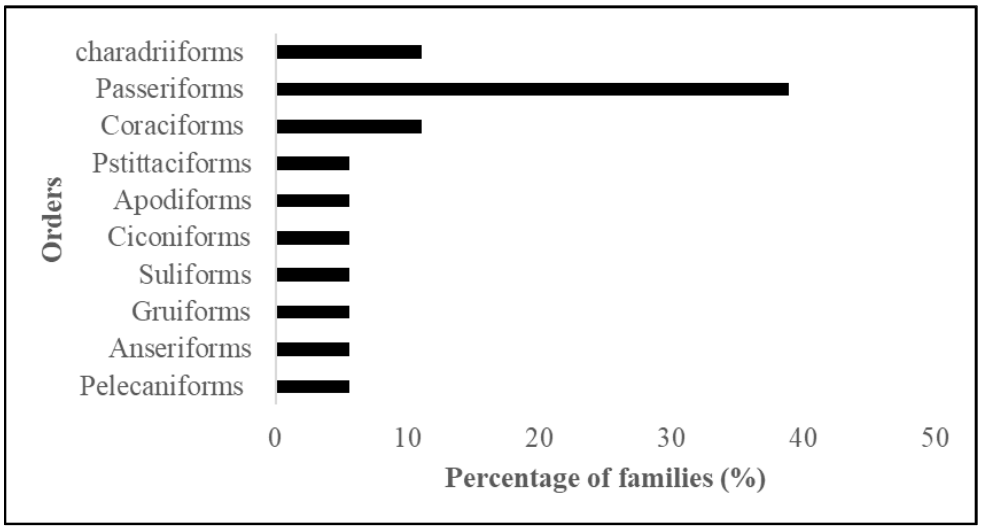

Figure 5 Distribution of bird's orders according to the percentage of families

3.3. Climate change impacts on Lake during the last 30 years according to respondents

The most of respondents (94%) reported increased rainfall in the last 30 years, while only 6% of respondents reported a reduction in rainfall in the same period (Figure 6).

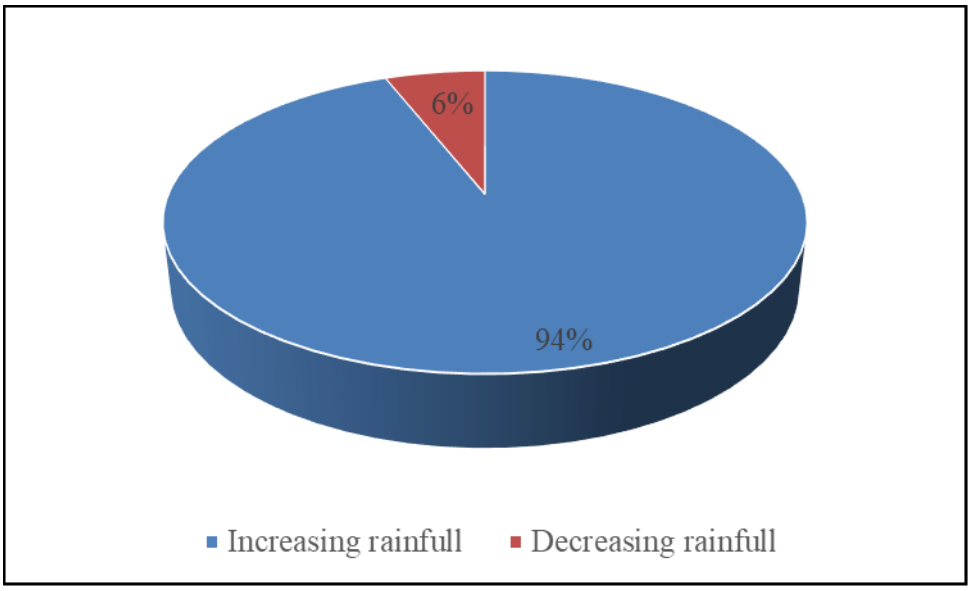

Figure 6 Variation in rainfall according to the respondents

The Figure 7 illustrated the occurrences of climate change impacts on rainfall, 35.8% of respondents noted that the effects of climate change were perceptible at the end of the rain season. For 16.7% of respondents the effects occur at the beginning of the season. For 18.3% the effects were observed all the rain season, while 12.5% of respondents noted that impacts of climate change were observed at the peak of season.

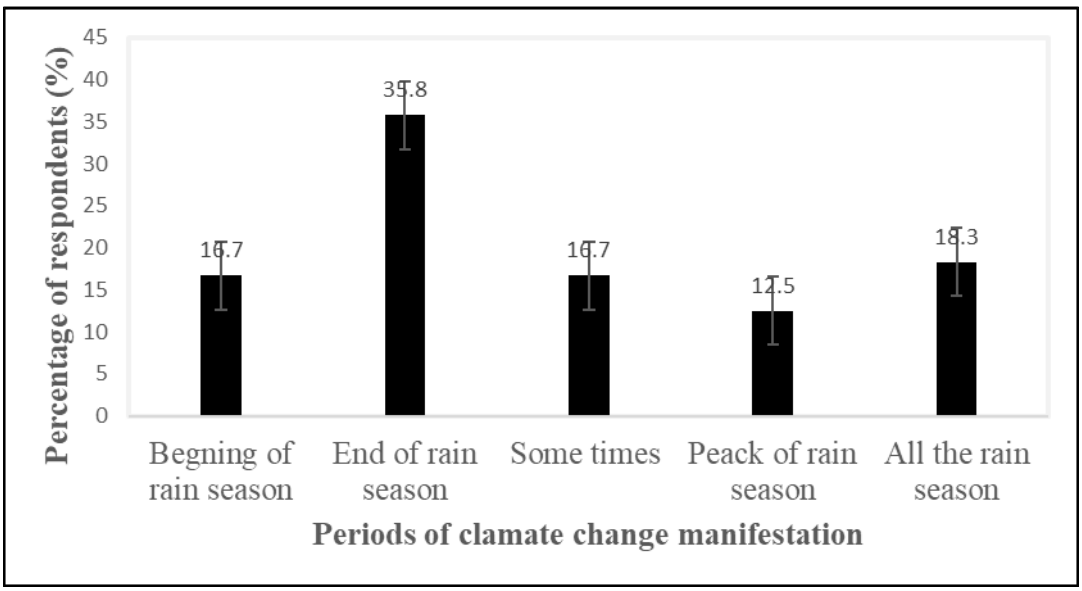

Figure 7 Periods of occurrence of climate change effects during the rainy season

According to 42% of respondents floods were the common climate change effects in the study area, while 32% and (26%) noted respectively increasing in water level (high water) and occurrence of invasive plants such as *Typha australis* (Figure 8). Indeed. according to INREA [16], the overall decline in dissolved oxygen in lakes directly impacts ecosystems, in particular the life of organisms, such as fish, and alters biogeochemical cycles, notably by increasing potential emissions of nutrients into the water and greenhouse gases such as methane into the atmosphere. Also, the lack of oxygen is a threat to the functions and services of aquatic ecosystems as well as to biodiversity [17]. The excessive

development of plants leads to the accumulation of a very large quantity of dead biomass in the decomposition drastically reduces the oxygen content of the waters fatal for many aquatic species. Thus, the reduction of the fish stock could be explained not only by the increase in the water level of the lake making artisanal fishing difficult, but also by the invasion of the lake by *Typha australis* which finds here the necessary conditions for its development preventing navigation throuth the waters of the lake.

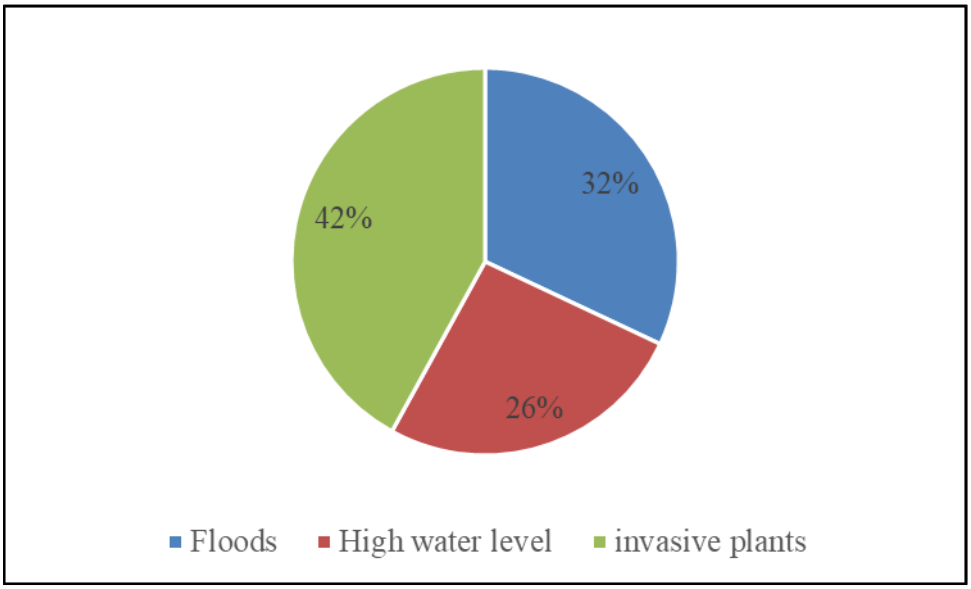

Figure 8 Impacts of climate change on the lake

The Figure 9 illustrated the situation of the lake 30 years ago. 45% of respondents stated that there were no invasive plants such as *Typha australis* in the lake. For 35% of respondents the lake was smaller and had low water level than actually, while 20% of respondents noted that the lake was consisted of two (2) small water bodies. Thus, the evolutive tendency showed an unfavorable evolution for the local populations.

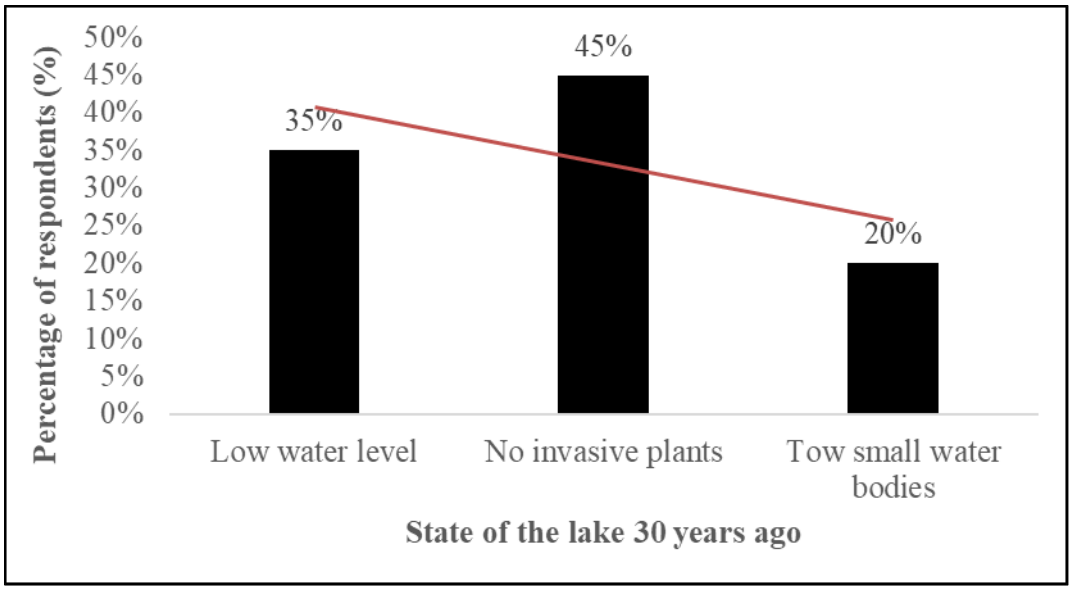

Figure 9 Situation of the lake 30 years ago

The Figure 10 showed population perceptions of the climate change impacts on fish and birds' fauna. In fact, 62% of respondents reported that climate change has a negative impact on fish and birds by leading to a decrease in the abundance of some species such as *Bagrus bajad* and *Heterotis niloticus* (fish) and *Burhinus senegalensus* (bird), while 38% of respondents believed that climate change has a positive impact such as the enlargement of the lake size.

According to data collected from the municipal environmental service, there has been a decrease of 320 tons in fish stocks between 2021 and 2022. This finding supported Badamassi et al.'s [18] assertion according to which the decline and/or disappearance of some species could be explained by their sensitivity to climate change. Also. Kabamba [19] reported the extinction of some fish species vulnerable to global warming and the modification of their habitats in Tshiala in the Democratic Republic of Congo.

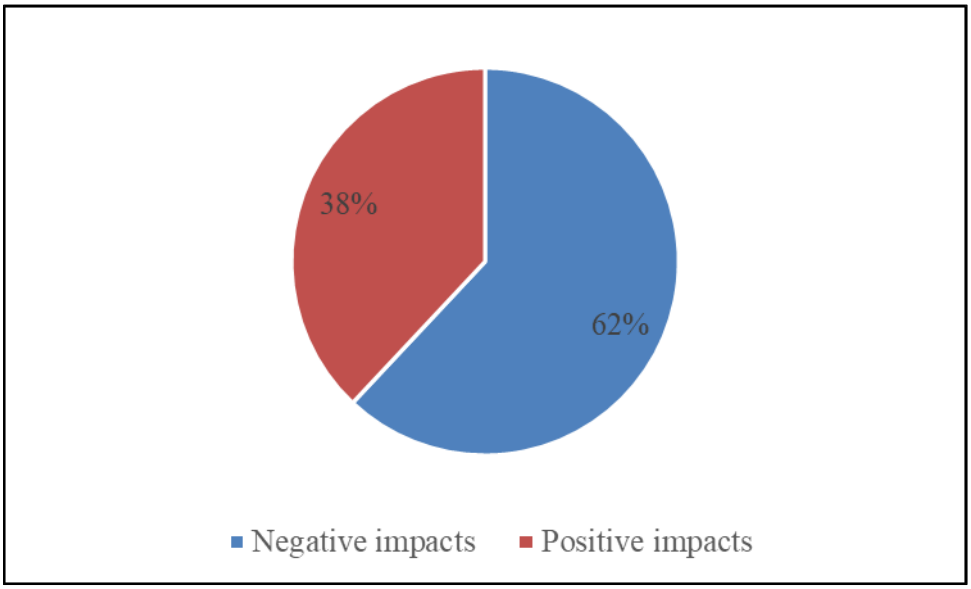

Figure 10 Effects of climate change on fish and bird fauna

4. Conclusion

The effects of climate change on natural resources in general and aquatic ecosystem particularly are severely impacting the daily lives of rural populations. The most difficult part is assessing them. This study, conducted around a wetland of international importance, could contributes to the assessment of these impacts on freshwater ecosystems generally and lentic ecosystems particularly. This study showed that water bird abundancies and fish stocks in the lake is declining over time, in parallel with the recurrence of extreme weather events. For sustainable management of the lake, continuous monitoring and strict enforcement of current regulations regarding various socioeconomic activities that exacerbate the adverse effects of climate variability and change around the body of water must be strengthened.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

Statement of ethical approval

Local Ethics Committee Approval was not needed because experimental animals were not used in this study.

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