

Fishing under Climate Change Conditions: Local Constraints at the Waterhole of Rouafi, Konni (Niger)

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Abstract: In Niger, the fishing sector supports the needs of communities for their income as well as to meet their nutritional needs for protein. The present work focused on fishing on the Rouafi waterhole, rural community of Bazaga, Konni department. The main objective of this work is to examine the evolution of fishery products in a climate change context. The methodology used in this study is based on the processing of meteorological data, data on the quantities of fish caught in the Rouafi waterhole, and the identification and mapping of the space occupied by cryptocoryne. The results show that climatic parameters (rainfall and maximum ambient temperature) do not directly influence the quantities of fish caught in the Rouafi waterhole. On the other hand, in parallel with the decrease in the quantities of fish caught, *Cryptocoryne spiralis*, an aquatic plant species, developed strongly.

Keywords: Rouafi Waterhole, Fish, Climate, *Cryptocoryne Spiralis*

Introduction

The major droughts of the 1970s and 1980s, soil erosion and high anthropogenic pressures have caused accelerated environmental degradation in the Sahel (Rishmawi & Prince, 2016). This degradation has caused not only the reduction and decline of the productive potential of the "natural resource capital", but also the disarticulation of the centuries-old systems of production and management of natural environments (Mahé and Paturel, 2009; Moussa Issaka, 2014; Karimou Barke et al., 2018). This is the case of wetlands, which are confronted, among other things, with invasive plant invasions (Amani and Barmo, 2010). Among the effects of this trend, from which communities are already suffering, are the decline of fisheries, water pollution, the proliferation of toxic algae and, above all, the erosion of biodiversity (Yousoufa, 2004; Walther, 2016).

In Niger, before the great droughts of the 1970s, fish catches were around 11,000 tonnes, of which 7,000 tonnes were caught in the Niger River and 4,000 tonnes in the various water bodies. In the following years, catches plummeted to their lowest level in 2009 with 1,469 tonnes, including 900 tonnes for the Niger River and 569 tonnes for the various water bodies (DPA, 2011). While, fishing brings together

nearly 50,000 people and generates a turnover of more than 40 billion CFA francs (MHE, 2012).

In Konni Department, fishing is practiced around some 17 ponds and reservoirs. All these ponds and reservoirs have benefited from fish stocking operations and fishermen's equipment, which are organized in cooperatives. The Rouafi pond (rural commune of Bazaga) is one of them. It has a permanent water regime and covers an area of more than 36 ha. The pond has been stocked three (3) times (1984; 1994 and 2014) but yields are constantly decreasing. It is in this context that this study, which concerns fishery products (fish) from the Rouafi pond, is being conducted.

The general objective is to examine the evolution of fishery products in the context of climate change. Specifically, the aim is to compare the evolution of the quantity of fish caught according to climatic parameters (rainfall and temperature); and to discuss the evolution of the quantity of fish caught according to *Cryptocoryne spiralis*.

Materials and Methods

Study area

The waterhole of Rouafi, is located in the village whose name it bears. Rouafi is in the rural commune



of Bazaga ($4^{\circ}59'4''$ - $5^{\circ}11'04''$ E and $13^{\circ}44'33''$ - $13^{\circ}56'00''$ N), located 15 km west of the capital of Konni department (in central-western Niger) (fig. 1). Its average depth is 1.5m in low water and exceeds 3m in high water (DDE/Konni, 2018). The hydrographic network of the waterhole of Rouafi is essentially composed of temporary watercourses that only

operate during the rainy season. The water that is collected in the waterhole of Rouafi comes essentially from runoff after rain. This runoff originates on the one hand from the immense chain of hills that surround the reservoir and on the other hand from a few watercourses, the main one being the Maggia (DDP/Konni, 2018).

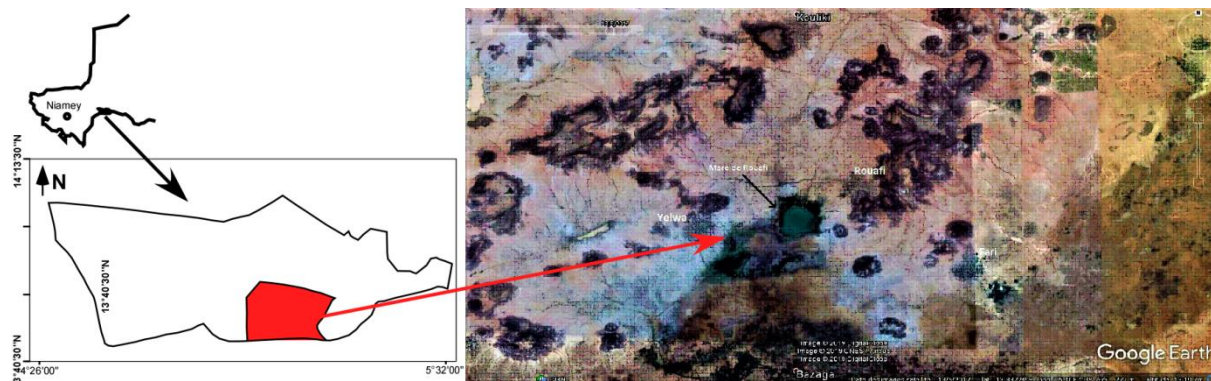


Figure 1: location of the study area

Material

Data on fish quantities

Data on the quantities (Kg) of fish caught were compiled from the fishing statistics table archives (catch sheets), stored at the Konni Environmental Department (DDE/Konni). These data are annual totals catch for the period 2007 - 2014 and monthly totals catch for the period 2015 to 2018.

Climatic data

Rainfall and temperature data are used to compare changes in the quantity of fish caught according to these two climatic parameters. Data from the Konni meteorological station were used and consist of annual rainfall totals and monthly temperatures. They cover the period 2007-2018. Also, NCEP-NCAR reanalysis data of temperatures covering the area of the waterhole of Rouafi were extracted at a monthly time step. These reanalysis data are more suitable for this region (Hassane, 2013). Data are produced by the National Center for Environmental Prediction (NCEP) in collaboration with the National Center for Atmospheric Research (NCAR) (Kistler et al., 2001). The dataset is calculated as a combination of observations and results based on the NCEP/NCAR operational global model. In addition, CRU.TS 2.1 precipitation field data (Mitchell and Jones 2005), covering the waterhole of Rouafi, are used (2007-2018).

Google Earth Image

Google Earth images covering the waterhole of Rouafi are from the month of November, which corresponds to the period when the waters of the pond are clearer. The images are from 2010 to 2017 that is to say 8 scenes.

Methods

Evolution of the quantities of fish caught

Simple statistical calculations (sum, mean, standard deviation) are used to characterize the annual and seasonal evolution of the quantities of fish caught on the waterhole of Rouafi. This evolution was compared with that of the meteorological-climatic parameters to investigate the possible relations of temperature or rainfall on fish caught quantities. The comparison was made using the Pearson correlation. The normalized values of this correlation provide a synthetic measure of the intensity of the relationship between two characteristics (Snedecor & Cochran, 1989).

Quantification of the surface occupied by *cryptocoryne spiralis* in the waterhole

On Google Earth images of the waterhole, some dark areas are visible. After identification, these areas correspond to the surface occupied by a *cryptocoryne spiralis*, an aquatic plant (Picture 1). These areas were delimited and their statistical variation were calculated on ArcGis software.

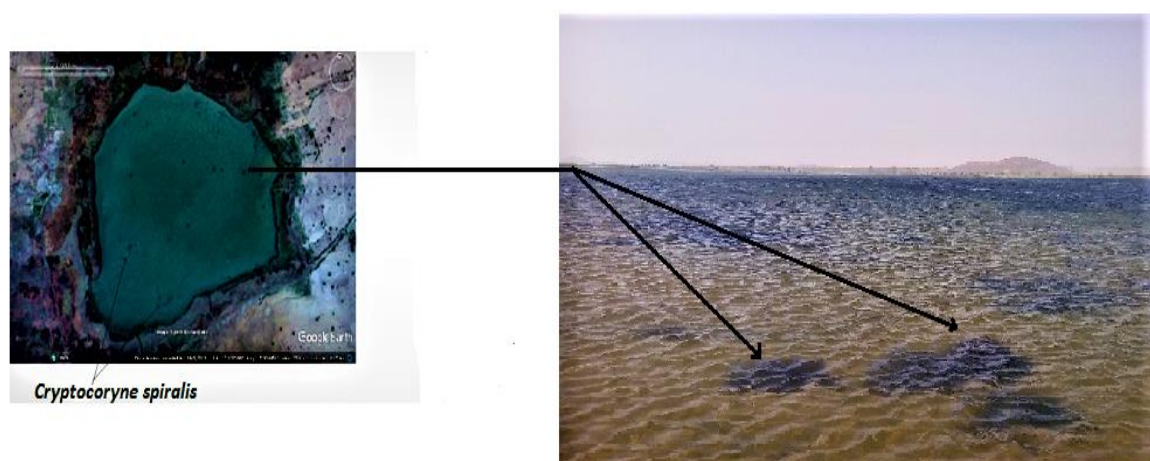


Figure 2: Identification of the *Cryptocoryne spiralis* plant in Rouafi waterhole.

Results and Discussion

Evolution of the quantities of fish caught between 2007 and 2018

The quantities of fish caught in the waterhole of Rouafi between 2007 and 2018 are marked by an average of 12.8 (+/- 5.8) t of fish were caught per year (Tab. 1). Between 2007 and 2013, the quantities exceeded 10 t/year before declining sharply in 2014. The lowest quantities of fish caught were observed in

2017 with only 3,967.5 Kg (Tab. 1). The largest quantities were caught in 2009 with 23,649.8 Kg of fish, nearly 8 times the quantities caught in 2017. The amount observed in 2009 seems exceptional since the last stocking dates back to 2014 so that the amounts of 2007 and 2008 are below those of 2009 (Tab. 1). Could this quantity be explained by the climatic particularities of this year?

Table 1: Annual quantities of fish caught between 2007 and 2018 in the waterhole of Rouafi

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
fish caught	14	21	23	17	12	14	10	6	10	9	3	8
Quantities (Kg)	004,7	264,0	649,8	955,1	260,5	149,0	989,0	604,0	563,0	855,0	967,5	250,0

Inter-annual evolution of fish production according to rainfall

The comparison of the annual changes in the quantities of fish caught during rainfall is made by taking into account a calendar shift of one year, which is similar to the fishing calendar. The approach consists in considering that the quantity of rainfall in year [n] would have an impact on the quantity of fish in year [n+1].

Linear trends in the quantity of fish caught in the waterhole of Rouafi and in the annual rainfall amounts recorded at the Konni station and that falling on the watershed of the waterhole indicate a decrease (Fig. 3). In detail, between 2007 and 2009, the

quantities of fish caught show a variation identical to that of cumulative annual rainfall. These same variations are observed between 2013-2014 and 2015-2016 (Fig. 3). These variations show that when the rains increase the amount of fish caught increases and vice versa. For the other years the variations are all not identical. From 2006 to 2017 the amount of fish caught shows a non-identical variation with the cumulative annual rainfall on the puddle watershed. The analysis of the relationship between the annual evolution of fish production as a function of rainfall shows low correlation coefficients: $r^2 = 0.002$ (quantity of fish/rainfall CRU-TS) and $r^2 = 0.06$ (quantity of fish/weather).

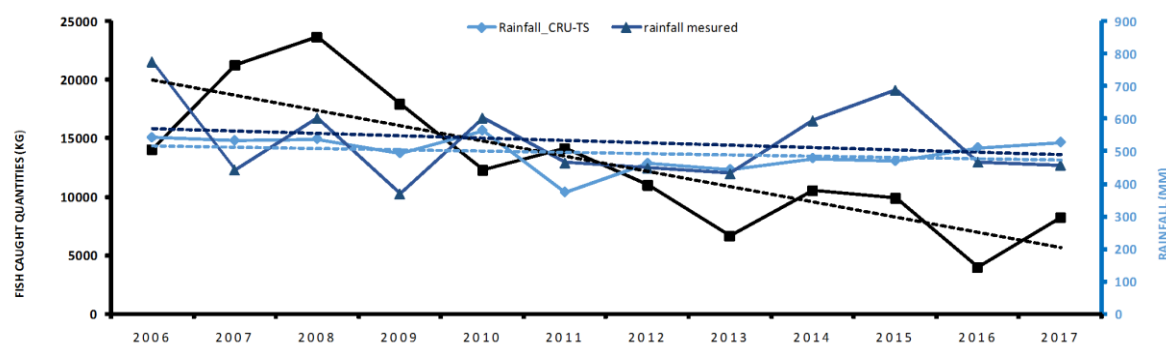


Figure 3: Evolution annual quantities of fish caught and cumulative rainfall between 2006 and 2017 in the waterhole of Rouafi.

Overall, these observations would indicate that the amount of rainfall does not determine the amount of fish caught. These results are different from those obtained by Bajot et al. (2012) in Burkina Faso, who showed that in small-scale reservoir fisheries, fish production depends on the hydrological regime: in good rainy years, production increases significantly, and vice versa. Although, in the waterhole of Rouafi, some of these observations would indicate some control of fish quantities by the amount of rainfall. In fact, these observed relationships are verified by the results of Lemoalle (2008), which showed that in the Sahelian region, the recent decrease in rainfall on large bodies of water directly impacts fishing yields. And, in general, these results are, in part, consistent with the results of Gownaris et al., 2016 which showed that catches of African inland fisheries in general, and dryland fisheries in particular, are more dependent on external climatic factors (including increased seasonal variability of surface water bodies).

The exceptional quantity of fish observed in 2009 cannot be explained by rainfall because the period 2009 is one of the deficit years in terms of cumulative rainfall recorded at the Konni meteorological station. This year is also a deficit year in the CRU.TS series (Fig.3).

Evolution of fish production versus temperature

The evolution of the annual quantity of fish caught in the waterhole of Rouafi was compared with that of the maximum ambient temperatures (monthly) of the Konni station and the NCEP/NCAR reanalysis. In order to comply with the fishing schedule, this comparison will focus on the season when fishing is not carried out. This season is considered as the renewal period of the fish stock in the pond. The season runs from September to February (Fig. 4).

Linear trends of the fish caught and of the monthly temperatures of the reanalysis indicate a decrease,

while those of the monthly temperatures recorded at the Konni station remained almost constant. In detail, from 2006 to 2017, the quantities of fish caught show non-identical variations with the monthly temperatures. The analysis of the relationship between the changes in the quantity of fish caught and monthly ambient temperatures (September-February) shows low correlation coefficients respectively ($r^2 = 0.21$; $r^2 = 0.03$; $r^2 = 0.16$; $r^2 = 0.001$; $r^2 = 0.1$; $r^2 = 0.04$) for reanalysis temperatures and ($r^2 = 0.18$; $r^2 = 0.17$; $r^2 = 0.008$; $r^2 = 0.01$; $r^2 = 0.03$; $r^2 = 0.06$) for temperatures recorded at the Konni weather station.

These observations show that ambient temperatures do not have a direct integral control on the quantity of fish caught in the waterhole of Rouafi. Results are different from those obtained by Parrel et al. (1986), Lovshin & Ibrahim, (1987) and Azaza et al (2010) who revealed that many factors can significantly affect fish production, but temperature is the most important factor.

It is then that the relation of the temperature taken at the scale of the Rouafi basin for the months of September and November ($r^2 = 0.21$ and $r^2 = 0.16$) and that of the temperature of the meteorological station Konni for the months of September and October ($r^2 = 0.18$ and $r^2 = 0.17$) conform well to the results of Etienne et al. (1994) who showed that variations in water temperature follow those of air temperature and that the latter, which is about the same as that of the body, directly affects the life and growth of the fish and controls its activity (Coche & Muir, 1995; Halvorsen & Svenning, 2000; Halwart & Gupta, 2010; Omasaki et al, Monthly ambient temperatures do not seem to explain the exceptional amount of fish caught in 2009, as for almost all the months considered (September-February) temperatures are decreasing during the period 2009.

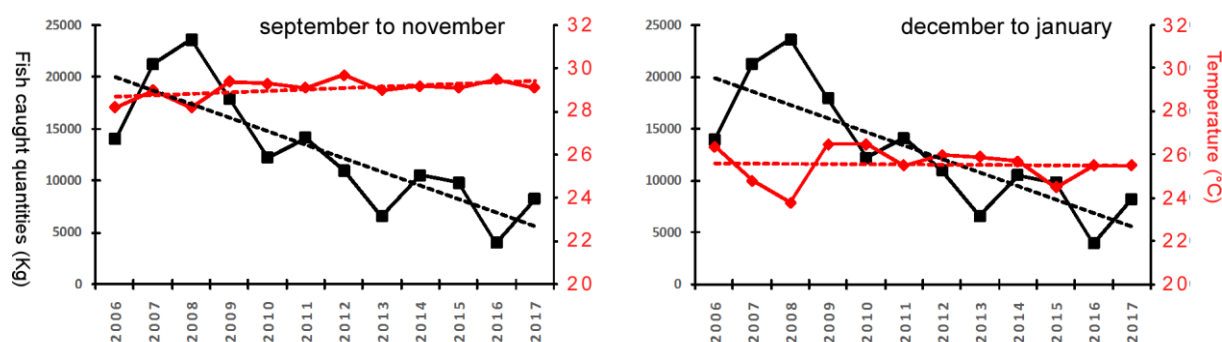


Figure 4: maximum ambient temperatures (monthly) and quantities of fish caught in the waterhole of Rouafi between 2006 and 2017

Fish production according to the expansion of *Cryptocoryne spiralis*

The quantity of fish caught shows a decreasing trend while the area occupied by *Cryptocoryne spiralis* in the waterhole of Rouafi shows an increasing trend (Fig.5). Although the annual variations do not show

proportional variations, this is the example of the 2010-2014 period. This trend has become more accentuated, despite the stocking in 2014, which resulted in a relative increase in the quantities of fish in 2015. Moreover, the analysis of the relationship indicates a good inverse correlation, $r^2 = -0.55$.

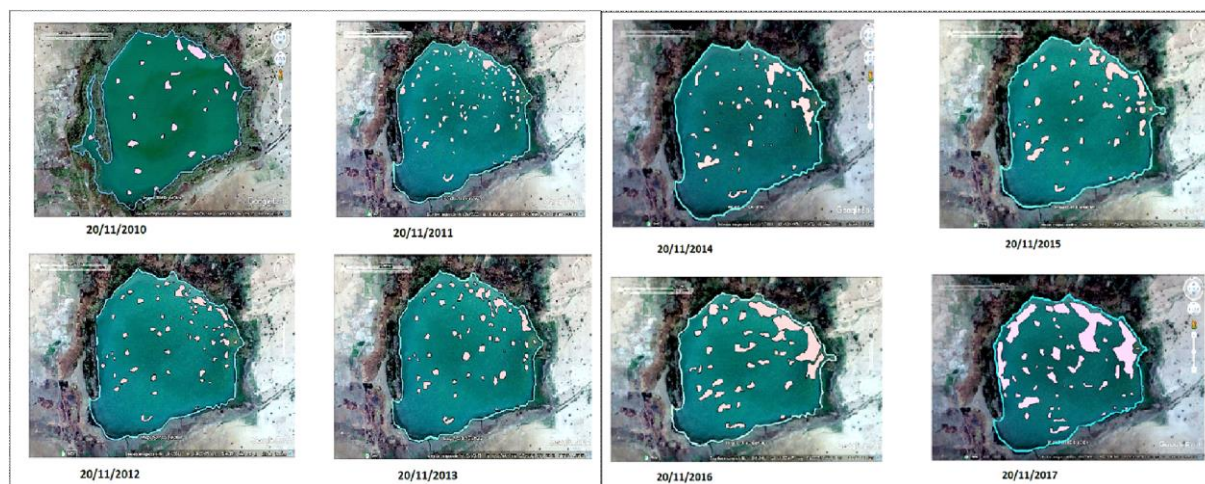


Figure 5: Images Google earth montrant l'espace occupée par la *Cryptocoryne spiralis* dans la mare de Rouafi entre 2010 et 2017 (Google earth).

The expansion of *Cryptocoryne spiralis* could explain the decrease in fish catch observed at the waterhole of Rouafi (Fig. 6). Indeed, the *Cryptocoryne spiralis* serves as a shelter for fish and prevents some tools (gillnet and sparrowhawk net) from reaching the bottom of the pond. This species is less described in the water bodies of Niger. Rather, it is the plant species *Eichornia crassipes* or water hyacinth that is

mainly described in the Niger River (Amani and Barmo, 2010; Mounkaila Ganda, 2015). This hyacinth causes an eutrophication of the environment that would explain the decrease in the fish population. (Amani and Barmo, 2010). *Cryptocoryne spiralis* could have the same effects on the fish population of the waterhole of Rouafi.

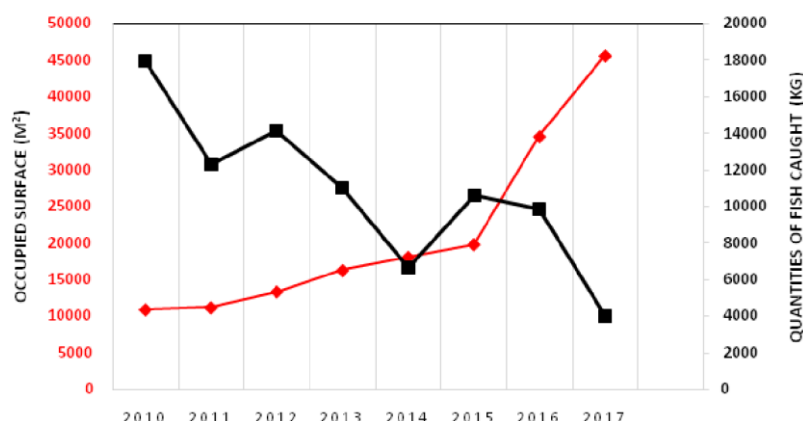


Figure 6: Expansion of *Cryptocoryne spiralis* and quantity of fish caught in the waterhole of Rouafi between 2010-2017.

Conclusion

This study conducted on the waterhole of Rouafi, rural commune of Bazaga (Konni Department) concerned fishery products (fish). The general objective was to examine the evolution of fishery products in a context of climate change. Between 2007 and 2018, an average of 12.8 (+/- 5.8) tons of fish are caught per year in the waterhole of Rouafi. Despite the stocking in 2014, the quantity of fish caught in 2015 is only 10.5 tons and remains in the downward trend in the quantities of fish caught. Trends in rainfall and maximum (ambient) temperatures are almost stable. Comparison of the variations in rainfall (availability of the water resource) and temperature with the quantities of fish caught does not show a direct relationship with the waterhole of Rouafi. On the other hand, the decreases in the quantity of fish caught coincide with the proliferation of the aquatic plant species, *Cryptocoryne spiralis*. The two trends show a better inverse correlation ($r^2 = -0.55$).

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